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September 22-24, 1988
Davis, California

Protection, Management, and Restoration for the 1990's

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The nearly 100 papers in these proceedings are aimed at a diverse audience of resource managers, environmental consultants, researchers, landowners, environmental activists, and a variety of user groups. Some of the papers explain how streams interact with the plants and animals at their margins and with the land that they occupy to accomplish a range of important functions, including protecting the banks from erosion, reducing the impacts of flooding, providing wildlife habitat, protecting instream habitat for fishes, producing forage for livestock, and enhancing human lives. Biological diversity in western lands is often directly related to these corridors, which also serve as major routes for migratory birds. Special attention is given to the several threatened and endangered species which need riparian habitats and to the response of riparian systems to such disturbances as fire, logging, landslides and diversion for power or water supply. A concluding section deals with measures being taken to preserve and restore riparian lands, particularly along large rivers and in the cities. Special attention is given in some of these papers to revegetation techniques.

Retrieval Terms: riparian habitat, riparian systems, biological diversity, revegetation, stream diversion, threatened and endangered species, range management.

Foreword

Authors of papers in these Proceedings provided manuscripts that were edited and returned to them with technical reviewers' comments. Authors were responsible for following up and acting on the reviewers' comments. Final manuscripts were processed electronically for publication by using the TeX computer program.

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Proceedings of the
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<u>*Contents*</u>

SESSION B: CENTRAL VALLEY RIPARIAN FORESTS

SESSION C: RANGELAND AND DESERT RIPARIAN SYSTEMS

SESSION F: WILDLIFE I—MANAGING FOR SELECTED SPECIES

SESSION G: WILDLIFE II—MANAGING WILDLIFE ASSOCIATIONS WITHIN RIPARIAN SYSTEMS

SESSION H: EFFECTS OF STREAM DIVERSIONS ON CALIFORNIA RIPARIAN SYSTEMS

SESSION I: IMPLEMENTING REVEGETATION PROJECTS

SESSION J: URBAN STREAMS

PREFACE

This volume presents the proceedings of the second large conference to be convened at the University of California, Davis, under the California Riparian Systems title. It is one of the many responses since the first expression of public concern in the mid-1970's over the catastrophic loss of these attractive and valuable streamside lands. By the time of the first big California riparian conference in 1981, the concern had already been picked up by the resource agencies, and they were represented in force at that meeting. But losses of riparian habitat have continued over the intervening years, even as we have learned the true value of these corridors in helping tame the forces at work within the rivers.

Central valley riparian forests have been reduced now to barely 1 percent of the original pre-Gold Rush acreage. In many cities and in some heavily grazed areas, the corridors scarcely exist at all. In the valleys these forests are casualties to agricultural and other economic development on the side that borders the uplands. On the side that faces the river they fall prey to limited-purpose water management programs, usually aimed at flood control and delivery of water.

The list of benefits from wise management of riparian lands is becoming familiar to people who attend these conferences. Though, as one resource manager put it, it takes a conference like this to remind us that the values are not just those related to the one resource that each of us happens to be concentrating on. The list of riparian values is not endless, but it is long and it includes these:

Protects banks from erosion.

Helps to reduce the impact of flooding.

Provides quality living conditions for fish and wildlife.

Creates corridors for their migration.

Harbors a number of endangered species.

Produces abundant fodder for cattle.

Produces timber and other wood products.

Provides recreation sites.

Contributes to the natural beauty of an area.

This conference was convened so that resource managers, researchers, agency administrators, users of the resources, and environmentalists could examine those values, provide an update on their status and management for all who are concerned with this complex of resources, and seek integration of the effort to protect and enhance them.

This second big conference had three emphases: (1) improving understanding of the ways that river, channel, bank and living things normally work together as systems in the riparian zone, (2) providing an appreciation for the part that riparian systems play in sustaining populations of several threatened species, and (3) reporting the results of experiments in restoring and revegetating riparian systems.

A number of participants have pointed out that this was not actually the second California riparian conference. It was the fourth. David Gaines, who later pioneered the conservationists' effort at Mono Lake, led the way by organizing an initial conference for about 70 participants in Chico in 1976. This was followed a year later by a similar conference in Davis, organized by Anne Sands. Entitled, "Riparian Forests in California: Their Ecology and Conservation," this memorable conference on the status of the Central Valley riparian forest drew 128 people. Offered in expanded form in 1981, the first "California Riparian Systems Conference" drew 711 people from an incredible array of interests and produced 1035 pages of proceedings–still in print, still in demand, and still heavily used. It is, in fact, occasionally used as a textbook.

The second California Riparian Systems Conference, which took place on September 22-24, 1988, demonstrated the continued growth of this concern, drawing nearly 900 participants. This was at a time when workshops, training sessions, and focused conferences on riparian habitats had become common. The smaller conferences appear to be serving the training and dissemination functions for a concern that is now well established. Often these smaller meetings have been aimed at specialists in limited fields, e.g., range management, forestry, hydropower or fisheries management. We perceived, therefore, that the big conference should be the place where ideas might be hatched and critiqued, controversies could be aired, and the work of integrating what many of us believe has become too scattered an effort would most definitely be undertaken.

The roster of speakers attests to the success the meeting had in drawing together diverse interests. In that list of more than 200 people, agencies loom largest. Surprisingly, consultants were almost as numerous. University contingents were surprisingly large, considering the fact that riparian concerns are largely peripheral to most academic imperatives. The citizens' organizations, resource-oriented private businesses and other user groups were less well represented in the speakers' list, though their presence was felt both in the discussions and in the support that some of them provided in financing the conference.

Another mark of the success of the conference is seen in the fact that few participants could agree on what was best about it. For some, a panel on progress in preserving riparian lands along the Sacramento River (which we were not able to reproduce here) was best. Others felt that a panel on integrating public and private interests came closest to meeting their needs. Others were especially satisfied with an evening discussion of ways to interest local communities in preserving stream environments (which also had to be omitted from these proceedings). There were many though who felt that the technical sessions offered the most.

It is for people who are likely to share this view that these proceedings are offered, for those are the parts of a conference that can best be reproduced in print. This has to be done, though, while recognizing the fact that the essence of a multifaceted conference like this is really in the spirit that it helps foster.

That spirit began with the people who first gave expression to the public concern for riparian lands through meetings like this. Some of the most significant of those people are no longer with us and it is to them that we dedicate this publication, hoping that it will help to continue the movement in a direction and at a pace that would have given them satisfaction.

Thus, we dedicate these proceedings to the memory of Richard E. (Rick) Warner, whose vision and devotion to the cause of riparian conservation live on in all of us, and to David Gaines, who started many of us on this journey, and to Mona Myatt, who caught that vision and helped see, through her company's contribution, that this effort could move ahead–even though she could not follow.

This conference was made possible by many people. The sponsors (contributors of $3,000 or more) and co-sponsors (lesser amounts or in-kind contributions) represent a wide range of support and include interests that have often been in conflict. This kind of breadth was seen also in the Advisory Committee, which numbered more than 40 (Appendix), and drew much enthusiastic participation, despite the potential for difference that existed among them.

Special thanks are due the Executive Group from that committee: John Menke, JoAnne Sorenson, Ann Riley, Ron Schultze, and Jim Nelson, who contributed much time and were almost never, in the press of their many other duties, heard to say "no" to a request for help. John Stanley, John Rieger, Roland Risser, Deborah Shaw-Warner, Phil Meyer, Steve Chainey and Earle Cummings, were not in the Executive Group but contributed almost as much—always willingly.

The staff of University Extension, with Lynn Read, Audrey Fowler, and Mike McCoy at the top of a long list, helped enormously in preparing for the conference, as did numerous individuals at the Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, in Berkeley, in preparing the Proceedings for publication. Thanks go to 30 people who responded to our need to pass the papers through technical review on schedule that left most of us gasping. Their pleasant and uncomplaining help is gratefully acknowledged.

These Proceedings were edited by Bert Schwarzschild and Roberta Burzynski of the Pacific Southwest Station (they also served as Proceedings Editorial Coordinators) and were electronically produced by the Computer Sciences Department of Texas A&M University, College Station, under the direction of Ban Childs.

Finally, special thanks go to my wife, Bonnie, who never once complained of my absence and near-total distraction during the months that led up to this conference.

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SESSION A: CHANNEL DYNAMICS AND RIPARIAN SYSTEMS

Geomorphologists have long been conscious of the need to reckon the bank stabilization effect of riparian vegetation into stream channel equations. Landmark studies were done some years ago by Stanley Schumm on the complex channels of the Murray River in Australia and by M. Gordon Wolman on some streams in the Eastern United States. By and large, though, the processes that control channel geomorphology and the development of riparian vegetation have received entirely separate attention in the years since then. An adequate understanding of the full interactive nature of the channel processes with riparian plant processes has been slow in coming, since a number of factors that are not normally considered in expressions of traditional channel dynamics have turned out to assume significant roles in streams with strong riparian borders. Streamflow dynamics, sediment transport, geology, channel morphology, channel pattern as well as plant form, plant succession and other purely biological processes are all part of the story.

In California these factors vary greatly with differing climate, geology and history of human activity. Clearly, the interaction between these two sets of processes changes also under differing patterns of channel alteration and use. An understanding of these changes is going to be essential to planning and design of programs for the protection and rehabilitation of riparian environments in the future.

In some of the papers the focus is on the role that riparian trees play in establishing channel boundaries (the Lisle, Barro *et al.*, and Trush *et al.* papers). Others draw contributions from interdisciplinary teams to link streamside conditions to ecological processes within the stream (the papers from the Oregon State University "stream team", Gregory *et al.* and Lamberti *et al.*) or to link human impacts to processes affecting the whole riparian corridor (Buer *et al.*). The Williams paper and the two Harvey papers deal with the deliberate design of river channels, with and without riparian elements.

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INFLUENCE OF VALLEY FLOOR LANDFORMS ON STREAM ECOSYSTEMS[1]

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Abstract: A hierarchical perspective of relationships between valley floor landforms, riparian plant communities, and aquatic ecosystems has been developed, based on studies of two fifth-order basins in the Cascade Mountains of Oregon. Retention of dissolved nitrogen and leaves were approximately 2-3 times greater in unconstrained reaches than in constrained reaches. Both valley floor landforms and riparian plant communities influenced the abundance of primary producers. Abundances of cutthroat and rainbow trout in unconstrained reaches were approximately twice those observed in constrained valley floors. Valley floors are one of the most physically dynamic components of the landscape, incorporating major agents of terrestrial disturbance and fluvial disturbance. These corridors are major routes for the flux of water, sediments, nutrients, and species. Because of their unique properties, valley floors play an important role in landscape ecology.

Riparian zones occur at interfaces — ecological interfaces between different ecosystems and conceptual interfaces between different scientific disciplines. The plethora of definitions and delineations of riparian zones are inconsistent, confusing, and often contradictory, reflecting the diversity of disciplines, perspectives, and objectives from which riparian zones have been studied. Most riparian studies have examined selected facets of riparian ecology, but few have developed integrated concepts of the physical, chemical, and biological properties of the interface between aquatic and terrestrial ecosystems. The lack of ecosystem perspectives of riparian areas severely limits our understanding and proper management of these unique components of the landscape.

The weakness of ecosystem perspectives in riparian research is evidenced in the term "riparian ecosystems," a term frequently encountered in riparian literature. Riparian zones are interfaces between terrestrial and aquatic ecosystems and exhibit gradients in community structure and ecological processes of these two major ecosystems. Considering riparian zones as distinct ecosystems obscures the patterns of process and structure that are the basis for the great diversity of biota and landforms in riparian areas.

Most definitions of riparian zones for land management or ecological research are based on a few selected hydrologic, topographic, edaphic, or vegetative attributes of riparian areas. Riparian zones have been investigated from the perspectives of erosion control by riparian vegetation, phreatophyte ecology, uptake of nutrients or contaminants from groundwater, chemistry of water entering lakes and rivers, shading of headwater streams, effects on aquatic invertebrates, migration routes for wildlife, habitat for water fowl, and fish habitat. All of these subjects are critical aspects of riparian ecology, but it is important to recognize the constraints of concepts or definitions of riparian zones developed for specific sets of objectives.

In recent decades, ecologists and land use managers have recognized the importance of the structure and functions of riparian zones for both aquatic and terrestrial ecosystems (Knight and Bottorf 1984, Meehan and others 1977, Swanson and others 1982). Meehan and others (1977) defined riparian vegetation as "any extra-aquatic vegetation that directly influences the stream environment". From an aquatic perspective, riparian zones are defined functionally as three-dimensional zones of direct interaction with aquatic ecosystems, extending outward from the channel to the limits of flooding and upward into the canopy of streamside vegetation (fig. 1). Examples of critical functions of riparian vegetation for stream ecosystems include shading, bank stabilization, uptake of nutrients, input of leaves and needles, retention of particulate organic matter during high flows, and contribution of large wood.

[1]Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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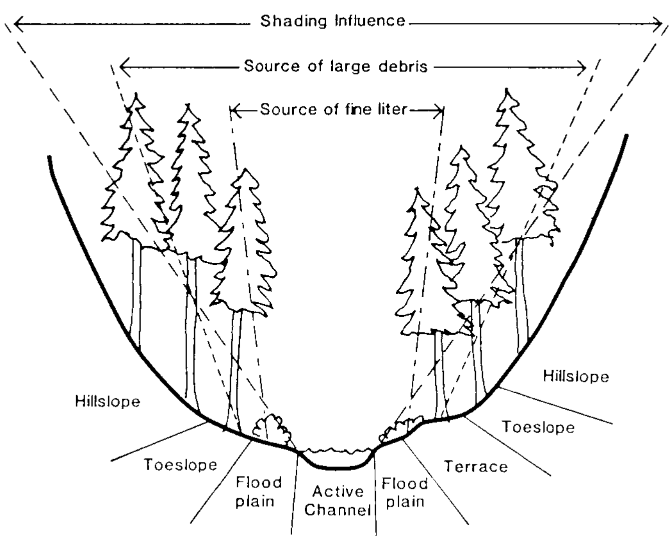

Figure 1– Riparian zone defined in terms of zones of influence of streamside vegetation on stream ecosystems (Meehan and others 1977).

Shading by streamside vegetation influences water temperature and aquatic primary production. Rooting of terrestrial vegetation within and adjacent to stream channels stabilizes banks and minimizes soil erosion. Living vegetation provides complex habitats for both aquatic and terrestrial wildlife. Leaves and needles provide essential food resources and habitat for aquatic insects. When floodplains are inundated, stems and roots of floodplain trees and shrubs comb organic matter out of transport and store it for subsequent processing on the floodplain or in the stream. Woody debris provides important structural elements that protect and stabilize stream banks, stores sediments that serve as habitat and spawning gravel, and traps organic matter that provides food for aquatic organisms. Dead woody material, both standing snags and wood on the forest floor, provides essential habitat for wildlife.

Most often management agencies adopt operational definitions of riparian zones that are based on hydric soils and unique terrestrial plant associations. If management agencies adopt perspectives of riparian zones that do not address critical ecosystem processes, the integrity of riparian resources cannot be insured. Integration of aquatic biological processes with physical templates of channel geomorphology and hydraulics has been a major challenge for stream ecologists in recent years. We present a hierarchical perspective of relationships between valley floor landforms, riparian plant communities, and aquatic ecosystems—an integrated ecosystem perspective of riparian zones.

Geomorphology of River Valleys

Flowing water interacts with the parent geology and inputs of organic and inorganic material from adjacent vegetation and hillslopes to form channels and floodplains within river valleys. Most geomorphic research has focused on lowland, floodplain rivers. In these alluvial systems, channel migration creates valley floor landforms and surfaces for development of riparian plant communities. The geomorphic dynamics of riparian zones in steep mountain landscapes involve both fluvial processes and mass movement events of adjacent hillslopes.

Valley floors contain both active channels and adjacent floodplains and terraces. Active channels are separated from adjacent hillslopes or floodplains by distinct topograhic breaks and commonly represent the lower extension of perennial terrestrial vegetation (Redman and Osterkamp 1982). *Floodplains* are relatively flat surfaces that are formed by fluvial deposition of sediments adjacent to active channels and are inundated during major floods. Several floodplain surfaces may occur within a valley floor; successively higher surfaces are flooded at less frequent intervals. In lowland valleys, floodplains are submerged much more frequently and for longer duration than floodplains in mountainous terrain. All floodplains and active channels are bordered by the lower flanks of adjacent *hillslopes*.

A *drainage network* extends from the headwaters to estuaries. *Sections* of a drainage network are differentiated by major topographic discontinuities, such as high gradient montane rivers, low gradient, lowland rivers in broad valleys, and broad coastal plains. Segments are continuous areas within a drainage formed by common large-scale geomorphic processes, and they have different potentials for development of active channels and floodplains.

A drainage segment is composed of *reach types*, delineated by the type and degree of local constraint imposed by the valley wall at the channel margin. The degree of local constraint controls the fluvial development of geomorphic surfaces. Constrained reaches (valley floor narrower than two active channel widths) occur where the valley floor is constricted by bedrock, landslides, alluvial fans, or other geologic features. Streams within constrained reaches are relatively straight, single channels with little lateral heterogeneity. River valleys in constrained reaches are narrow and include few floodplains. Consequently, riparian vegetation in these areas is similar in composition to adjacent hillslope plant communities.

Unconstrained reaches (valley floors wider than two active channel widths) are less constrained laterally and provide greater potential for floodplain development and active channel migration. Unconstrained reach types exhibit complex, braided channels and extensive floodplains, which support a diverse array of plant communities of different age. Riparian stands in these areas include many plant species adapted to frequent flooding.

Reach types are made up of sequences of *channel units*, representing different bed forming processes. Channel units in low gradient, sand and gravel bed streams are generally classified simply as pools and riffles (Leopold and others 1964). In high-gradient streams with coarser bed material, the distinction between high and low gradient units is conspicuous, but the steeper units may be divided into several additional types—rapids, cascades, falls. With the exception of abrupt falls, channel units are longer than one channel width and are distinguished on the basis of surface slope, degree of turbulence, and extent of supercritical flow.

Channel sub-units include hydraulic and geomorphic features shorter than the active channel width. Riffles, pools, rapids, and other features that are shorter than one channel width are categorized as sub-units. Backwaters, eddies, and side channels are also sub-units and play a distinctly different ecological role than sub-units along the main axis of the channel. Sub-unit features correspond to the habitat types employed in most aquatic ecological research. As flow increases and the active channel is completely inundated, channel units attain uniform surfaces and delineations between sub-units are obscured.

Riparian Vegetation

Riparian zones are extremely patchy, reflecting past fluvial disturbances from floods and non-fluvial disturbances of adjacent hillslopes. Fluvial processes are the dominant disturbance in riparian areas, but fire, wind, landslides, drought, freezing, disease, insects, and other natural agents of mortality common on upper slopes may influence riparian stands along valley floor. Furthermore, topoedaphic conditions of valley floors are extremely varied, ranging from continuously wet to extremely dry over short distances. Consequently, riparian plant communities are structurally and taxonomically diverse.

In conifer forests of the northwest, riparian plant communities exhibit greater diversity than plant communities of upper hillslopes. In riparian plant communities ranging from recent clearcuts to old-growth forests in excess of 500 years in Oregon, riparian communities contained approximately twice the species richness observed in upslope communities. Similar contrasts in species richness between hillslope and riparian areas were found in plant communities of the Sierra Nevada in California (table 1). Patterns of disturbance, particularly flooding, influence the spatial complexity of riparian plant communities, while environmental gradients, such as light, temperature, and moisture, determine the sharpness of transitions between riparian and hillslope plant communities.

Table 1 - Number of plant species per plot in riparian zones of the Cascade Mountains of Oregon and the Sierra Nevada of California (Art McKee, personal communication).

Location	Number of Plant Species Upland	Riparian
Cascade Mountains		
McKenzie River	19-32	51-107
Sierra Nevada		
Sequoia National Park	28-38	51-55

Patterns of disturbance in riparian zones differ from disturbances on upper hillslope in shape and areal extent. Flooding in river valleys creates narrow, linear disturbance patches. The resulting floodplain forest is composed of thin bands of early seral stages, predominantly deciduous. Longitudinally, patches of riparian plant communities commonly are short and alternate from one side of the channel to the other. Within a flood event, the total area disturbed may exceed tens to hundreds of square kilometers, though the width of the disturbance at any point may be only a few tens to hundreds of meters. On a basin scale, the total area disturbed in a given flood may equal or exceed that of common terrestrial disturbances such as fire, wind, and disease. However, individual patches within the disturbed area in floods are small, relative to the overall disturbance, and extremely numerous. The heterogeneity imposed by flooding in river valleys contributes to the biological diversity of riparian areas.

Aquatic Ecosystems

Physical processes within riparian zones influence the biological organization and rates of processes of stream ecosystems. Active channels and floodplains form the physical habitat for aquatic organisms. Large organic matter contributed by riparian vegetation serves as a dominant geomorphic element, particularly in headwater streams (Swanson and Lienkaemper 1978).

Riparian vegetation supplies organic matter in the form of leaves, needles, and wood to streams and floodplains. This terrestrial source of organic matter provides a major portion of the food base for stream ecosystems (Cummins 1974). Leaves of herbs, shrubs, and deciduous trees have higher food value for most aquatic invertebrates than the more refractory needles of conifers (Triska and others 1982). Diverse riparian plant communities in broad floodplain reaches potentially offer higher quality food than conifer-dominated riparian zones, but the input of litter from deciduous plants is restricted to a shorter time interval in autumn. Thus, mature conifer forests provide a more consistent but lower quality food supply to stream ecosystems (Gregory and others 1987).

The canopy of streamside forests potentially shades the stream channel, decreasing solar radiation available for aquatic primary production. In small, headwater streams, riparian canopies strongly limit primary production, and as streams widen downstream, the influence of riparian vegetation on primary production decreases as the canopy opens over the channel. In this sense, the presence of riparian vegetation reduces aquatic productivity through the algal food base. Removal of riparian vegetation by man also increases solar radiation reaching headwater streams and potentially increases primary production. In Lookout Creek in the McKenzie River drainage, percent cover of filamentous algae was 3-30 times greater in a reach flowing through young second-growth riparian stand than a reach flowing through a 450-year-old old-growth stand. The influence of riparian canopy cover on aquatic primary production is most pronounced in headwater streams and diminishes downstream as the opening over the stream increases with increasing channel width. As a result, the effects of riparian timber harvest on aquatic primary production is relatively greater in headwater streams and decreases downstream. Algal food resources for aquatic organisms are much less abundant in streams than terrestrial litter but much higher in quality as food for invertebrates.

Food resources, whether aquatic or terrestrial in origin, must be retained in the stream before being consumed by aquatic organisms. Valley landforms and adjacent riparian plant communities directly influence bed form and channel roughness, which determine retention of water and both dissolved and particulate inputs during both low flow and floods. In two fifth-order basins in the Cascade Mountains of Oregon, we measured the retention of leaves in constrained and unconstrained reach types (reported by Lamberti and others in these proceedings). Leaves in transport in unconstrained reaches with broad floodplains were retained 4-5 times more efficiently than leaves in constrained reaches. Large logs and smaller branches and twigs supplied by riparian vegetation form complex accumulations, which increase the retention efficiencies of stream reaches. In streams of the Cascade Mountains, an average leaf traveled more than 12 m in reaches influenced by debris dams; but an average leaf traveled less than 5 m in reaches influenced by debris accumulations and less than 1 m in reaches that were completely obstructed by debris dams (Speaker and others 1984).

Riparian zones modify the cycling of dissolved nutrients as they are transported from hillslopes, across floodplains, and down drainages. In coniferous and deciduous riparian zones of Oregon, microbial transformation of nitrogen were greater in riparian areas than in upper hillslopes (Mike McClellan, Oregon State University, unpublished data). Rates of denitrification were more than five times greater in floodplains than adjacent hillslopes (table 2), and rates of denitrification were higher in alder stands than in coniferous forests. Because of the rapid cycling of nitrogen in the riparian zone, elevated concentrations of nitrate were not observed in streams in alder stands, even though nitrogen fixation was observed.

Table 2 — Rates of denitrification in riparian zones and upslopes in a 40-year-old deciduous and a 450-year-old riparian forest (expressed as ng N/g dry weight of soil/hr with standard errors in parentheses).

		Geomorphic Surface		
Site	Soil Depth	Floodplain	Toeslope	Hillslope
Coniferous	0-15 cm	6.3 (2.2)	4.2 (4.2)	1.2 (1.2)
	0-30 cm	0.4 (0.3)	0.2 (0.1)	0
Deciduous	0-15 cm	15.0 (2.9)	8.2 (4.3)	3.0 (1.2)
	15-30 cm	11.3 (2.6)	1.4 (1.0)	1.2 (0.7)

Nutrient outputs from watersheds are not only modified within floodplain soils, but nutrients are rapidly taken up and transformed by stream communities as well. In streams of the McKenzie River drainage, we measured uptake of dissolved ammonium in constrained and unconstrained reaches. Dissolved nitrogen (ammonium) was approximately 2-3 times greater in unconstrained reaches than in constrained reaches (reported by Lamberti and others in these proceedings). Unconstrained valley floors are more complex environments both geomorphically and hydraulically and retain water and dissolved nutrients longer, increasing the potential for biological uptake. In addition, unconstrained reaches may support more abundant algal assemblages, increasing the biological demand for nutrients. Uptake of ammonium in reaches of Lookout Creek in young second-growth riparian forests was more than twice the uptake observed in reaches flowing through old-growth forests (reported by Lamberti and others in these proceedings), reflecting the influence of primary producers on nutrient cycling.

Higher trophic levels are also influenced by valley landforms. In the two study drainages in the McKenzie River in Oregon, abundances of cutthroat and rainbow trout in unconstrained reaches (120-200 individuals/100 m) were approximately twice those observed in constrained valley floors (60-80 individuals/100 m) (reported by Moore and Gregory in these proceedings).

Unconstrained stream reaches contain broad floodplains with numerous eddies, backwaters, and side channels. In addition to the main channel, these complex channel forms create a greater diversity of fish habitats and provide numerous lateral refuges during floods. In contrast, constrained reaches offer few refuges in which to escape the torrential flows of winter floods. Unconstrained reaches in our study streams also contained greater numbers of trout fry than constrained reaches. Salmonid fry rear in shallow, low velocity habitats along the edges of streams and in side channels and backwaters, particularly those associated with complex floodplains (reported by Moore and Gregory in these proceedings). Thus, the complexity of broad floodplains is beneficial for rearing of new year classes of fish and survival for fish of all age classes.

Conclusions

From an ecosystem perspective, riparian areas are created and maintained through extensive interaction between valley landforms, succession of terrestrial vegetation, and the structural and functional responses of aquatic ecosystems. Geomorphic processes create the structure of stream channels and floodplains, which serve as physical templates for successional development of riparian vegetation. The structure and function of stream ecosystems are strongly influenced by the habitat and food resources provided by channel structure and streamside vegetation.

Resource management agencies are faced with the pragmatic problem of identifying boundaries on landscapes without abrupt demarcation. Although effective riparian management requires establishment of such riparian management zones, all managers must constantly remind themselves that their riparian management zones usually include only a portion of the interface between terrestrial and aquatic ecosystems. Recognition of the trade-offs inherent in any riparian management system requires ecologically robust concepts of riparian areas. Management concepts and definitions of riparian areas that exclude the physical, chemical, and biological interactions within the interface between terrestrial and aquatic ecosystem cannot insure the ecological integrity of one of the most physically dynamic components of the landscape. The riparian areas along river valleys experience many of the disturbances of upslope forests (e.g., fire, disease, insect outbreak, wind) as well as the unique disturbance associated with floods. Riparian areas are also interfaces between terrestrial and aquatic ecosystems, encompassing overlapping gradients in the physical and biological properties of these distinctly different ecosystems. As a result, riparian areas are one of the most physically complex and biologically diverse components of the landscape. In addition, riparian areas are major routes for the flux of water, sediments, nutrients, and plant and animals within drainage networks. Because of their unique properties, riparian areas play important roles in landscape ecology and resource management.

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CHANNEL-DYNAMIC CONTROL ON THE ESTABLISHMENT OF RIPARIAN TREES AFTER LARGE FLOODS IN NORTHWESTERN CALIFORNIA[1]

Thomas E. Lisle[2]

Abstract: Large floods in northwestern California in the past two decades have mobilized extensive areas of valley floors, removed streamside trees, and widened channels. Channel cross sections were surveyed to illustrate an hypothesis on the linkage between sediment transport, colonization of channel margins by trees, and streambank recovery. Riparian trees, e.g., white alder (Alnus rhombifolia)*, colonize the water's edge at low flow to receive adequate moisture during the dry season. Such stands can endure annual high flows only after the flood-enhanced sediment load declines and the width of the annually mobile bed contracts to the low-flow width. Streambank formation along the low-flow margin can then proceed by deposition of fine sediment and organic debris.*

A series of large floods from 1950 to 1975 (Harden and others 1978) greatly altered riparian ecosystems in north coastal California from the Eel River basin northward. Channel aggradation as much as several meters, channel widening as much as 100 percent, and extensive destruction of trees by flood waters widened the zone of active bed sediments at the expense of riparian corridors along many streams (Hickey 1969; Kelsey 1980; Lisle 1981). Although most aggraded channels have degraded to stable bed elevations as excess sediment has been transported downstream, many remain widened (Lisle 1981). If probability prevails and such large floods do not recur, how will riparian stands and associated streambanks recover over the next few decades?

This paper presents a hypothesis on a relation between colonization of streamside trees and channel dynamics that may govern the recovery of riparian stands and reconstruction of streambanks. During large floods, extensive areas of streambeds and floodplains can be mobilized by high shear stresses and new inputs of sediment. Riparian species of willow and alder that have low tolerance to moisture stress tend to colonize the water's edge during summer low-flow periods. Because these trees also require a stable substrate, they can establish only after the zone of annually mobilized bed material contracts to a small fraction of the width mobilized by the last large flood. Once established, the trees can trap fine sediment and organic debris, add root strength to bed material, reduce local shear stress, and thereby induce formation of new streambanks. Widened channels thus may recover when new streambanks form inside flood-eroded banks at a spacing dictated by the zone of annually mobilized bed sediment.

Trees Along Mobile Bed Margins

Channel cross sections showing substrate and vegetation of three creeks affected by recent floods (1964, 1972, and 1975) in north coastal California illustrate colonization and growth of riparian trees along mobile bed margins. All examples were surveyed across reaches where bed and banks were composed of alluvium. The first example (Prairie Creek) presents the hypothesis in detail and illustrates bank formation along a channel transporting abundant fine sediment. The second (Hurdygurdy Creek) shows contrasts with a channel transporting little fines. The third (Willow Creek) details plant species occupying micro-habitats within the channel.

Prairie Creek

Prairie Creek, a tributary of Redwood Creek, Humboldt County, with a drainage area (DA) of 34 km^2 at the study reach, has a moderate sediment yield with abundant fines (Lisle, in press). The basin is heavily forested mostly with old-growth redwood. Summers are relatively cool and moist because the basin is only a few kilometers from the coast. Tertiary sands and gravels of the Gold Bluffs Formation (Moore and Silver 1968) underlying much of the basin supply readily mobile bed material. Flood flows usually cause modest changes in channel morphology, however, because human disturbance has been relatively light, the channel gradient is low (0.0032 in the study reach), and streambanks are strengthened by dense riparian vegetation. The mobile portion of the streambed–that which is entrained annually–is composed of sand and gravel with median grain diameter (D50) of 9.0 mm and is armored with pebbles and cobbles (D50=25.5 mm) (Lisle, in press).

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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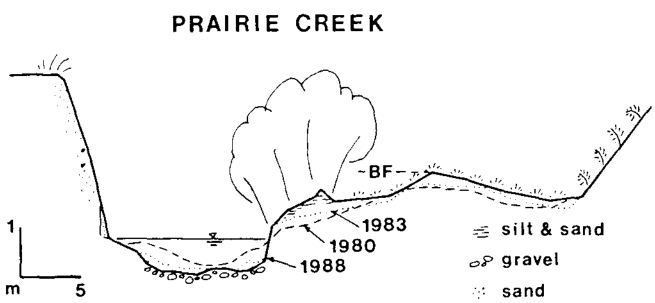

Figure 1 – Cross section of Prairie Creek, showing bed elevation changes from 1980 to 1988 and the distribution of riparian vegetation and substrate. Approximate bankfull elevation is indicated by BF.

A natural levee approximately 0.7 m high had accreted progressively on the inner right bank immediately adjacent to the mobile bed from 1980 to 1988 (fig. 1). The levee, which was composed of fine sand, silt, and organic debris, supported a narrow dense stand of red alder (*Alnus oregona*). The levee was highly irregular, due to locally thick deposits of newly laid fine sediment and local scour around large woody debris caught among the alders. The alders were rooted at about one-half of bankfull stage, and thus were probably flooded several times on average each year. Bankfull elevation in this cross section was poorly defined but, by extrapolation from adjacent reaches, corresponds approximately with the top of the bar.

In contrast to the levee, the adjacent bar surface was smooth and covered with low herbaceous vegetation. The bar accreted less than 0.3 m from 1980 to 1988. The bar surface in 1980 was composed of sand and pebbles and scant herbaceous vegetation; by June 1988, a denser mat of vegetation and organic matter had accumulated. This mat was probably more efficient at trapping fine sediment than the sparsely vegetated surface of 1980.

Repeated surveys of this cross section since 1980 suggest the following sequence of processes in forming the levee on the inner right bank. A major flood occurred in the Redwood Creek basin in 1975 (Harden and others 1978). Tree-ring dating of the largest trees on the levee indicate that trees within the channel were stripped by the flood but reestablished within a few years. The entire streambed was extensively reworked by the flood, or in other words, the bed apparently became mobile over its entire width (39 m).

Afterward, the mobile zone of the bed contracted to approximately its width at the time of study (10m), and alder were able to colonize the low-water's edge along the left margin of the bar. At this time the bar surface merged smoothly with the mobile bed, as indicated by the 1980 survey. During even modest stormflows, high friction generated by alders rooted low in the water created steep velocity gradients away from the main flow and promoted rapid deposition of fine sand, which is only intermittently suspended. Sand comprises as much as 55 percent of suspended sediment in Prairie Creek (Lisle in press). Sedimentation rates over the remainder of the bar were slower because of its smoothness and the depletion of coarse suspended fractions at the levee. As a result, the levee originated at a lower elevation but built faster than the bar, so that a level floodplain may be formed eventually. Channel incision since 1980 apparently helped to define a higher bank as the levee built (fig. 1). Root strength probably helped to stabilize these higher banks.

Hurdygurdy Creek

Hurdygurdy Creek (DA = 70 km^2 at the study reach), a major tributary of the South Fork Smith River, Del Norte County, is coarser and steeper than Prairie Creek and carries little fine sediment. In the study reach, the bed surface is mainly cobbles and boulders ($D50$ = 155 mm), and channel slope is 0.02. Moisture stress on riparian vegetation is greater than along Prairie Creek, because Hurdygurdy Creek is farther from the coast (20 km) and summers are hotter and drier. Sediment is pre-dominantly coarse bedload derived from metamorphic rocks of the Mesozoic Age. Unpublished data provided by Mike Furniss, Six Rivers National Forest, Eureka, California shows that the channel appears stable and cross sections surveyed since 1976 show little change.

White alders (*Alnus rhombifolia*) grew within the channel of Hurdygurdy Creek, but in contrast with trees in Prairie Creek, were not associated with bank formation (fig. 2). The alders were rooted near the low-flow water surface elevation, which was at less than one-half of bankfull stage. At this cross section, alders on the left portion of the channel ended abruptly at a certain point that was not related to elevation, but instead probably defined the left margin of the mobile bed. The bed to the right of the alders had an equal elevation and thus equal availability of moisture. This area was an active bar deposited against the larger, stabilized flood bar upon which the alders had established. The bed among the alders was clearly not mobile enough to cause removal of the trees. The alders grew among mossy boulders that had not moved apparently since the flood of 1964. Cores extracted from the largest trees indicated colonization of the bar was no later than 1966. The alders had trapped abundant large woody debris but little fine sediment.

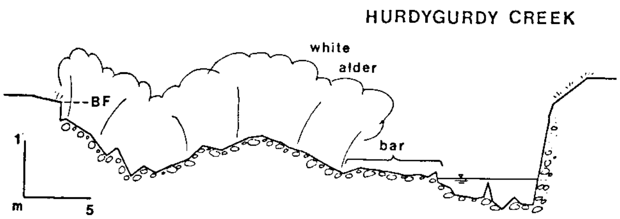

Figure 2 — Cross section of Hurdygurdy Creek surveyed in July 1986, showing growth pattern of riparian trees and substrate. BF indicates bankfull elevation.

Willow Creek

Willow Creek (DA = 110 km^2 at the study reach) is similar to Hurdygurdy Creek in climate and geology. The study site is 0.5 km upstream of the Highway 96 bridge and 1 km upstream of the junction of Willow Creek with the Trinity River in Humboldt County. Cartographic channel slope in the study reach is 0.019. The 1964 flood destroyed the stream gauge, which was located in the study reach, and deposited sediment on the prominent terrace (T2, fig. 3) 4-5 m above the existing streambed. Unrecorded large floods occurred probably in 1972 and 1975, as well; high rainfall and runoff were recorded in Redwood Creek, the adjacent basin to the west (Harden and others 1978).

Wet-site trees and herbs, including white alder, willow (*Salix hindsianai; S. lasiolepis*), black cottonwood (*Populus trichocarpa*), and sweet clover (*Melilotus albus*), grew in a narrow band (2-5 m wide) along the low-flow water's edge (Zones 1 and 2 in Section 1, Zone 1 in Section 2, fig. 3; table 1). Riparian alders and willows were established no higher than about 0.4 m above a stage typical of late summer, which is approximately 0.3 m below that during the survey. Bankfull was poorly defined, but corresponded roughly with the top of the bar in Section 1. Riparian trees were rooted at less than one-half of bankfull stage as defined. Cores extracted from the largest trees indicated colonization in 1973-1975. Herbaceous species growing on higher, drier sites (Zones 3 and 4) were typical of those that invade disturbed ground and have a wide range of moisture tolerances. The base of the drier zones was 0.2 m (Section 1) and 0.9 m (Section 2) above late summer stage.

As in Prairie Creek, riparian trees were rooted densely at the low-flow water's edge and appeared to stabilize alluvium sloping toward the channel thalweg. The trees thereby helped to define streambanks that were well below bankfull stage. As in Hurdygurdy Creek, however, little fine sediment deposited among the trees, which would lead to bank formation.

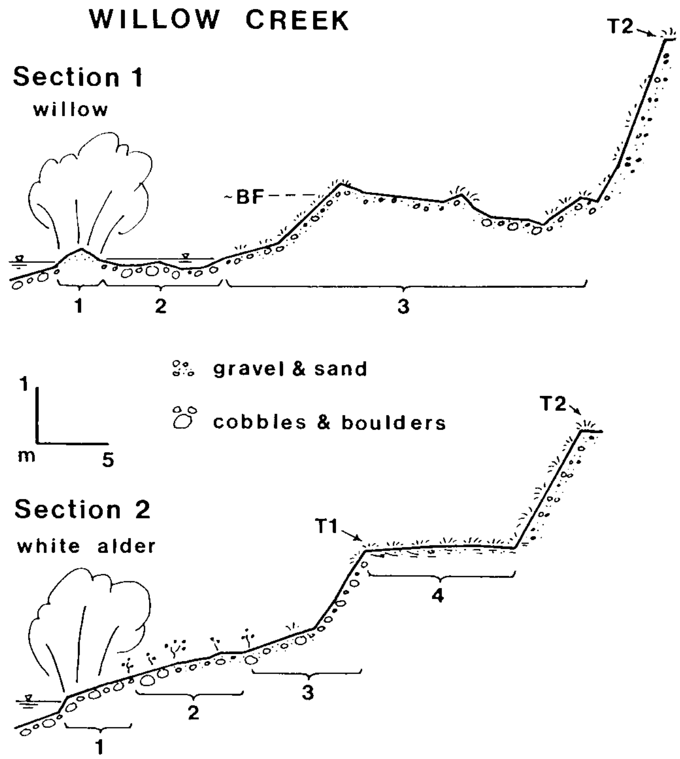

Figure 3 — Partial cross sections of Willow Creek surveyed in June, 1988, showing distribution of riparian vegetation and substrate. Numbered brackets show vegetation zones of table 1. BF indicates approximate bankfull elevation; T1 and T2 are alluvial terraces.

Table 1 – Species, relative abundance, and indicated habitat conditions of vegetation along zones of Sections 1 and 2 (fig. 3), Willow Creek.

	Species[1] and abundance[2]	Indicated habitat
Section 1:		
Zone 1	*Salix hindsiana*-A (sandbar willow), *Populus trichocarpa*-S (black cottonwood), *Mellilotus albus*-C (sweet clover)	High year-round moisture
Zone 2	*Salix hindsiana*-S, *Mellilotus albus*-S	High moisture
Zone 3	*Mellilotus albus, Silene gallica* (catchfly), *Bromus sp., Erodium cicutarium* (filaree), *Aira Caryophylla* (hair grass), *Kohlraushia velutina, Medicago polymorpha* (bur-clover), *Torilis arvensis, Vicia americana* (vetch), *Trifolum sp.*[3]	Recent or frequent disturbance; variable moisture requirements
Section 2:		
Zone 1	*Alnus rhombifolia-A* (white alder), *Rumus crispus*-S (curly dock), *Mellilotus albus*-C unknown grass-C	High moisture
Zone 2	*Mellilotus albus*-A, *Kohlrauschia velutina*-C, *Silene gallica*-S, *Lotus sp.*-S, *Lupinus sp.*-S	Disturbance
Zone 3	*Silene gallica, Bromus sp., Aira caryophyllea, Taraxacum officinale* (dandelion) *Cirsium sp., Trifolium sp., Lotus sp* [3]	Disturbance
Zone 4	*Bromus sp.* (and other grasses)-A, others:[3] *Lotus sp., Trifolium sp., Vicia americana, Cirsium sp., Salix lasiolepis (arroyo willow)*	Stabler substrate than Zone 3

[1] Scientific names follow Munz (1968).

[2] A-abundant, C-common, S-sparse

[3] All species approximately equal in abundance: sparse to common.

Discussion and Conclusions

One might expect flood-widened channels to become narrower by accreting material against eroded streambanks. Post-flood surveys of cross sections at gauging stations, however, have shown this not to be the case (Lisle 1981). Instead, observations of incipient bank formation and growth patterns of riparian trees suggest that recovered stream margins may become defined well within flood-eroded channels and below bankfull stage, and then accrete vertically.

The first step in this process is for sediment load to decrease to a level whereby the zone of annually mobile bed material contracts and becomes confined to a zone corresponding to summer flow margins. Riparian trees, especially white alder which require both a stable substrate and a shallow rooting depth to year-round moisture (Griffin and Critchfield 1976), can then establish along low-flow margins, even though they are frequently inundated during the wet season. With further growth, trees can significantly stabilize bank materials by adding root strength and reducing local shear stress through added roughness. In streams such as Prairie Creek that carry abundant fine sediment, trees may also promote deposition of suspended sediment, particularly sand and organic debris, and thereby cause banks to build vertically. In streams such as Hurdygurdy and Willow Creeks that are steeper and carry little fine sediment, banks may not readily form but instead become defined by channel incision between densely rooted riparian corridors.

This mechanism for the recovery of channels and riparian stands could apply to a variety of gravel-bed streams in Mediterranean climates. Observations of stages in colonization and growth of riparian trees and their substrate could indicate much about the condition and recent geomorphic history of the channel. The presence of narrowly spaced riparian corridors inside flood channels indicates that sediment load has waned considerably since the last flood, and that the channel has an extensive width to accommodate an increased load. The absence of trees within bankfull margins, on the other hand, may indicate that the entire width of the bed was mobilized recently and that an increased load may lead to further bank erosion or bed aggradation.

The hypothesis has not been tested. It suggests many opportunities, however, for fruitful collaborations between plant ecologists and fluvial geomorphologists seeking to understand channel recovery from floods.

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ALDER ESTABLISHMENT AND CHANNEL DYNAMICS IN A TRIBUTARY OF THE SOUTH FORK EEL RIVER, MENDOCINO COUNTY, CALIFORNIA[1]

William J. Trush, Edward C. Connor and Allen VV. Knight[2]

Abstract: Riparian communities established along Elder Creek, a tributary of the upper South Fork Eel River, are bounded by two frequencies of periodic flooding. The upper limit for the riparian zone occurs at bankfull stage. The lower riparian limit is associated with a more frequent stage height, called the active channel, having an exceedance probability of 11 percent on a daily average flow duration curve. Distinct tree communities occupy bankfull and active channel zones. Riparian densities (trees per meter of stream channel) along the active channel decreased with increasing channel gradient and curvature. Riparian densities at bankfull stage were not as sensitive to change in channel gradient and curvature.

Many alluvial streams have distinct banks that overflow only during periods of flood discharge. The flood discharge that just reaches the crest of the bank has been labeled bankfull discharge (Richards 1982; Wolman and Leopold 1957). The frequency of bankfull discharge for many alluvial channels ranges from 1.5 to 3.0 years (or greater) on an annual maximum flood series (for review, Williams 1978). On the tributaries of the upper South Fork Eel River, in Mendocino County, California, streambanks are composed of bedrock or coarse alluvium and do not exhibit the sharp break in channel cross section common in alluvial streams. Rather, bankfull stage height (water surface elevation above the streambed at bankfull discharge) often corresponds to the upper limit of sand deposition or to the upper border of large point bars (Trush, Connor and Knight 1988). A distinct break in channel cross section is apparent at a sub-bankfull stage, forming a smaller channel within the bankfull channel. Osterkamp and Hedman (1977) call this inner region the "active channel." They describe the active channel for Virginia rivers as:

> A short term geomorphic feature subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with the lower limit of permanent vegetation so that the two features, individually or in combination, define the active channel reference level. The section beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculptured by the normal process of water and sediment discharge.

Bankfull and active channels are discernable alluvial features on Elder Creek, a bedrock tributary to the South Fork Eel River. Elder Creek is the largest pristine Douglas-fir watershed in Northern California. The watershed is managed jointly by the Nature Conservancy and Bureau of Land Management, U.S. Department of the Interior, as the Northern California Coast Range Preserve. In the main channel, the lower limit for permanent woody vegetation ranges from the active channel crest up to bankfull stage, depending on location within the channel.

This paper examines the relationships between riparian tree populations and stream morphology in a pristine, bedrock channel. Specifically, the following hypotheses are examined:

1. Streambank species compositions are different at bankfull and active stages;
2. Riparian tree density at active channel stage decreases with increasing channel gradient and curvature;
3. Channel bend inflections support a disproportionately large percentage of the total riparian community;
4. Inside banks support higher riparian densities than the outside banks of channel bends.

Study Site

Elder Creek watershed (16 km^2) is located in the upper South Fork Eel River basin (fig. 1) on the western flank of Cahto Peak (1290 meters). In this region, landslides are a dominant geomorphic process in the highly fractured Franciscan sedimentary landscape (James 1983). More than 95 percent of the high annual rainfall (2030 mm) falls from November through April. Eighty five percent of the annual precipitation can occur as runoff (Rantz 1964). At 0.60 km from the mouth, the U.S. Geological Survey maintains a hydrologic benchmark station (Sta. No. 11475560), monitoring stream discharge and precipitation at 15-minute intervals.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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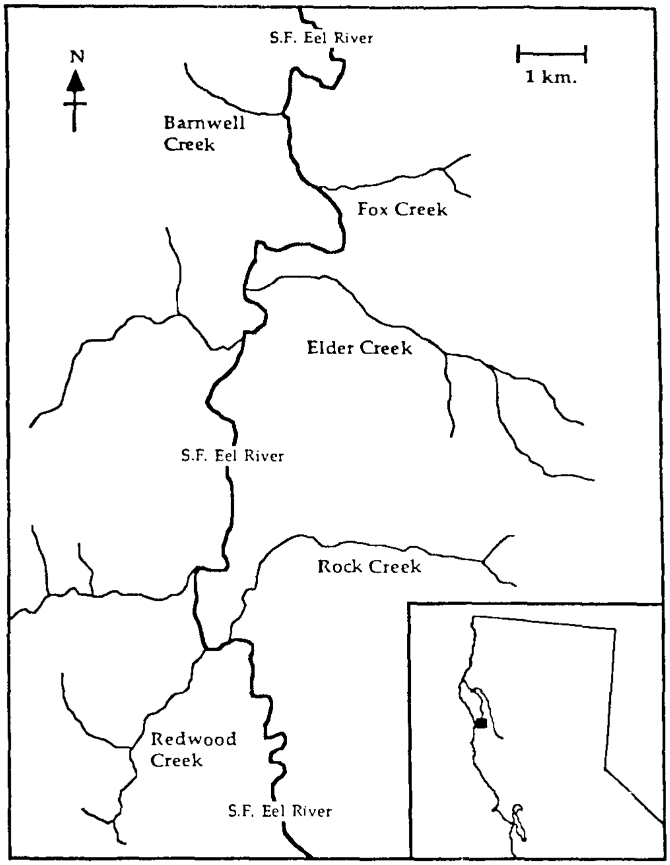

Figure 1— Location map of Elder Creek in the upper South Fork Eel watershed. The South Fork Eel River flows due north.

Upper watershed slopes are primarily a mix of *Ceanothus* spp., madrone *(Arbutus menziesii),* and manzanita *(Arctostaphylos* spp.). Middle and lower slopes are dominated by Douglas-fir *(Pseudotsuga menziesii),* tanoak *(Lithocarpus densiflorus),* and California bay laurel *(Umbellularia californica).* The riparian tree community is comprised of four major species. White alder *(Alnus rhombifolia),* Bigleaf maple *(Acer macrophyllum),* Pacific yew *(Taxus brevifolia),* and Oregon ash *(Fraxinus latifolia)* can be found in all channel locations. Higher on the channel bank, Douglas-fir and California bay laurel are common on terrace deposits. Unidentified mosses and sedges dominate the riparian understory.

Elder Creek is a coarse grained channel with particle sizes ranging from 50 to 150 cm in steep riffles and 5 to 10 cm in point bar deposits. Bedrock is exposed on the floor of all major pools and comprises 10 to 90 percent of the banks in typical channel reaches. In Rosgen's (1975) stream classification system Elder Creek would be a 'B1' stream type. Multiple terrace sets 3 to 15 m above the present channel indicate an extensive period of downcutting; significant floodplain formation is limited to very few, less confined channel reaches. Stream gradient for the entire main channel (5.1 km) averages 3.3 percent, though the channel gradient below a major knickpoint (2.3 km from the mouth) is 2.4 percent. The low sinuosity channel does exhibit depositional features typical of alluvial channels, though modified by bedrock outcrops and boulders. Coarse point bars are found at more acute channel bends associated with the larger pools. Pools and riffles have similar median particle size distributions ranging from 15 to 50 cm. Large woody debris has little impact on channel morphology in this pristine watershed.

Active and Bankfull Channels

Many of the criteria for identifying bankfull stage in alluvial channels (Williams 1978) apply to the active channel in Elder Creek. Kush, Connor and Knight (1988) developed the following criteria for identifying the active channel:

a. Base of alder trunks occur at active channel crest along straight channel reaches and at bend inflections; on acute channel bends, alders generally occur closer to bankfull stage;
b. Root wads of living sedges rarely above active stage unless there is seepage from the banks;
c. Tops of isolated gravel deposits in the lee of mid-channel boulders occurred at or below active stage;
d. Presence of decomposed shale clasts (i.e. highly fractured but shape maintained) uncommon below active stage;
e. Alluvial deposits at the downstream end of bedrock pools (the pools generally located at channel constrictions with no with no associated point bars) below active stage;
f. A distinct bench in the cross section above the active channel crest (berm) created by a matrix of gravel packed in interstices of large cobbles and boulders, as in Figure 2.
g. Mosses more abundant above active stage, but presence or absence of mosses on large cobbles and boulders not a reliable feature for active stage identification.

The best field evidence of the active channel is often along the edge of coarse point or lateral bars. A sharp break in the cross section of a lateral bar occurs at the crest of the active channel (fig. 2B). A bench of coarse particles packed in a matrix of sand and small gravel originates at the active channel crest and extends toward the bankfull stage. Osterkamp and Hupp (1984) call this bench the "channel shelf."

Using the Trush, Connor, and Knight (1988) criteria, active and bankfull stage heights were identified at 18 cross sections. Stream discharges at the surveyed active and bankfull stage heights were calculated from discharge rating curves specific for each cross section. Average active discharge for all cross sections was 1.97 cubic meters per second (cms)(std. dev.= 0.29); average bankfull discharge was 14.7 cms (std. dev.= 1.82). An active channel capacity of 1.97 cms has an exceedance probability of 0.11 on the average daily flow duration curve, i.e., on the average, active channel discharge is equalled or exceeded 40 days of the year. A bankfull channel capacity of 14.7 cms has a recurrence interval of 1.55 years using the Log Pearson III distribution and 1.65 years with the lognormal distribution (U.S. Water Resources Council 1981), i.e., bankfull discharge is approximately equalled or exceeded one day in an average water year.

Figure 2– Photographs of Elder Creek riparian zone on a lateral bar (A) and close-up of the active channel (B).

Methods

A detailed stream map was constructed for the lower 3.3 km of main channel in 1985 and 1986. A meter tape was set along the channel thalweg with compass bearings taken at each bend in the tape. Channel widths were measured with another tape placed perpendicular to the thalweg tape. Water surface slope was measured with an engineer's level during low summer flows. Features mapped included (1) variations in channel width at three stream discharges corresponding to bankfull, active, and mid-summer flows, (2) the channel thalweg (deepest location in a channel cross-section) at 2 m intervals, and (3) the dimension of all pools, riffles and alluvial bars. At map completion, measurement intensity averaged one set of channel width estimates for every 5 m of channel length. A map was drafted at a scale of 1:200.

The locations of all riparian trees (those trees at the bankfull stage or lower) greater than 2 cm in diameter (d.b.h.) were plotted on the channel map during 1986 and 1987. Trees with their root bases positioned at, or closer to, the active stage height were considered part of the active channel riparian population. Trees with root bases located at, or closer to, bankfull stage were assigned to a bankfull population. All trees were observed during an active and a bankfull discharge.

The stream channel was divided into homogeneous segments called planforms, utilizing the channel map. Riparian tree density (number of trees per meter of channel length) was calculated for each planform at active and bankfull stages. Criteria for determining the downstream extent of one planform and upstream edge of another planform included similarity in channel width, bank materials, curvature, and extent of depositional features. Cross-over of the channel thalweg from one bank to the opposite bank (i.e., at the inflection between two channel bends) provided an additional criterion for less confined planforms. Planform slope was calculated as the change in low flow water surface elevation over the thalweg length. Planform curvature was estimated as the change in thalweg direction. A straight line was drawn from the thalweg at the upstream edge of the planform to the thalweg at the apex of the bend. Another straight line was drawn from the thalweg's apex to the thalweg at the downstream edge of the planform. The change in direction, measured in degrees, from the upstream line to the downstream line was a simple measure of planform curvature. Using this procedure, the 3.3 km of channel was divided into 57 planforms, with slopes varying from 0.50 percent to 6.48 percent. Planform curvatures ranged from 1 to 110 degrees.

Results

Riparian populations at bankfull and active stages in the lower 3.3 km of the main channel of Elder Creek differed in species composition and relative abundance. A total of 581 trees were censused: 254 trees in the active population and 327 trees in the bankfull population. White alder and Oregon ash comprised 85.9 percent of the population at the active stage, while a more even mix of White alder, Oregon ash, Bigleaf maple, and Pacific yew comprised the bankfull population (fig. 3). Only a few individual alders and ash were noted above the riparian zone delineated by the bankfull stage. These individuals commonly were associated with springs or tributaries. The normally distributed size class distribution (size classes in d.b.h.) for the alder population and skewed size class distribution for ash (fig. 4) do not show abundant recruitment stocks of smaller individuals. Bigleaf maples were not limited to the riparian zone, but were common on steep slopes above bankfull stage. Pacific yew establishment ranged from the active channel berm up to terrace flats five meters above the bankfull stage. Size frequency distributions for maples and yews in Figure 4 only represent the riparian portion of their populations. Maple and yew recruitment also appeared low, particularly among yews with only two seedlings found along the channel.

Riparian tree densities (number of trees per meter of planform length) at the active channel stage exhibited a threshold to changes in planform slope and curvature. We labeled this a threshold because tree densities spanned a range of values for a given planform slope or curvature but were bounded by an upper limit (called the threshold density). For example, tree density for the active population exhibited a threshold response to planform gradient (fig. 5). At a gradient of 1 percent, riparian densities ranged from 0 to 0.36 trees per meter, but usually did not exceed 0.25 trees per meter. The planform with 0.36 trees per meter was a braided channel reach. The only other braided reach also appears as an outlier in Figure 5, with a density of 0.14 trees per meter at a planform slope of 5.3 percent. Riparian density threshold at a slope of 1 percent was approximately 0.25 to 0.30 trees per meter; higher densities for non-braided channel reaches with slopes near 1 percent were not found. Threshold density decreased as planform slope increased, e.g. at a planform slope of 3.5 percent the threshold density was approximately 0.12 trees per meter. Threshold riparian density at the active stage also decreased with increasing planform curvature (i.e., greater degrees of bend). Threshold densities decreased from 0.25 trees per meter at a curvature of 5 degrees to a slightly lower density of 0.20 trees per meter at a greater

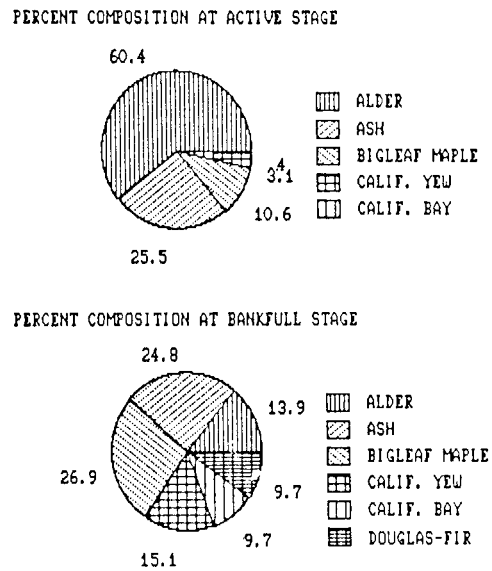

Figure 3– Relative species abundances of active and bankfull tree populations in the main channel of Elder Creek.

curvature of 50 degrees (fig. 5). The change in threshold density was greater above 50 degrees, decreasing to 0.05 trees per meter for a 100 degree planform curvature.

Changes in bankfull tree population density were not clearly related to planform slope and curvature. Threshold densities remained above 0.2 trees per meter over a wider range in planform slopes of 0.1 to 4.0 percent (fig. 6). A threshold density of approximately 0.20 trees per meter remained constant for planform curvatures ranging from 5 to 70 degrees (fig. 6).

The use of graphical techniques does not allow separation of the relative importance of slope and curvature in determining threshold tree densities. We are not aware of a reliable statistical technique for defining a threshold response. The upper limit for riparian densities (approximately 0.40 trees per meter) probably results from the need for a minimum canopy area per mature tree rather than fluvial interaction. There must be a limit to the degree of "packing" trees in a confined space. In many planforms, riparian densities at the active or the bankfull channel was zero. Shear bedrock surfaces provided little opportunity for seedling establishment in several of the stream canyon reaches.

The location at which a meandering channel changes direction (flowing from one meander into the next meander) is called a channel inflection point. At the inflection point, the thalweg is positioned near the center of the

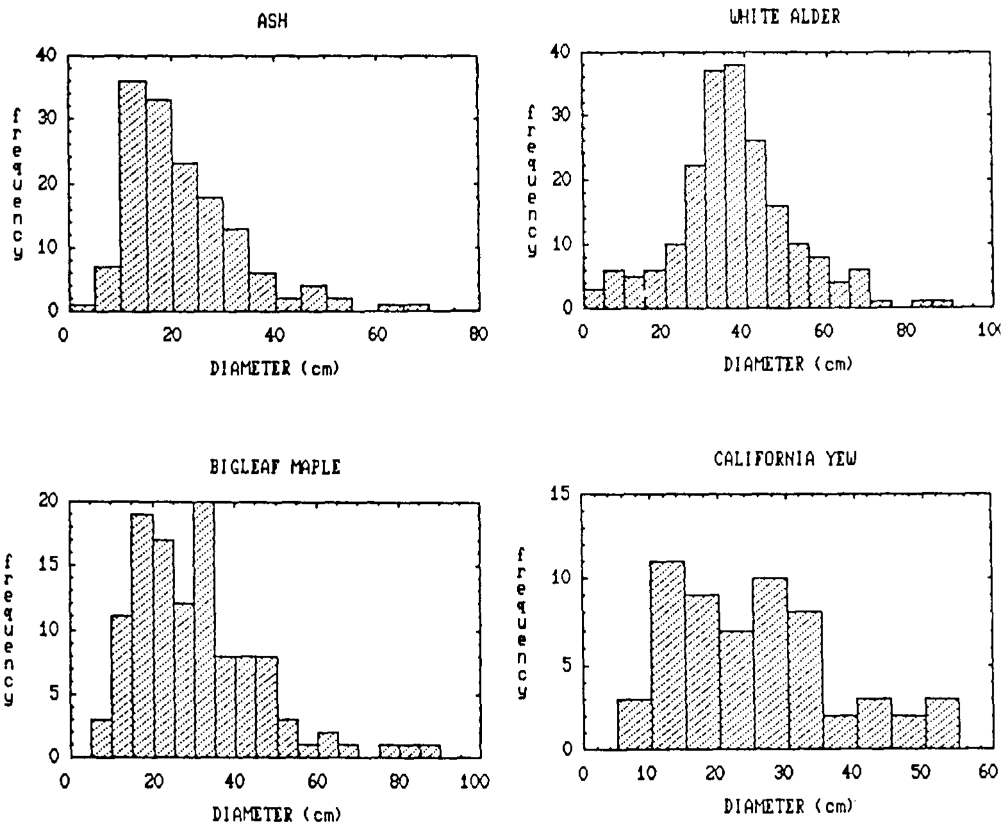

Figure 4— Size frequency (d.b.h.) distributions for the four most common riparian species in the main channel of Elder Creek.

channel. All riparian trees found at the inflection (a 5 to 8 meter channel segment on both sides of the channel) were censused from the channel map. The average riparian density at bend inflections was 0.35 trees per meter. Average densities for the active and the bankfull stage at bend inflections were similar, 0.15 trees per meter and 0.20 trees per meter, respectively. Average tree density (combined active and bankfull populations) for the entire channel was 0.18 trees per meter, indicating that planform inflections provided relatively better habitat conditions for survival than other locations in the channel's planform geometry.

Each tree was assigned to the inside or outside bank of its respective planform. In the active channel of Elder Creek, 121 trees occurred on the inside banks and 133 trees on the outside banks. In the bankfull channel, 185 trees were found on the inner and 142 trees on the outer banks. On the inner planform bank, the active riparian trees were less common than bankfull trees. On inner and outer banks of the active channel, riparian threshold density decreased with increasing planform curvature (fig. 7). Threshold riparian densities on the inner and outer banks of the bankfull channel did not exhibit as clear a response to planform curvature (fig. 8).

Discussion

Riparian species must be physiologically adapted to periodic inundation and physically adapted to survive the forces of large storm flows. Our initial hypotheses centered on the expectation that greater exposure to storm flows reduced survival. Active channel riparian populations, established lower in the channel, should be more exposed to each storm's force than bankfull populations. Alluvial channels can adjust to major storm flows by overtopping the banks, thus increasing channel width to partially accommodate the flow. Flow depth in the main channel slightly increases above bankfull discharge. In contrast, the confined channel of Elder Creek, with no banks to overtop, accommodates storm discharge by increasing flow depth and/or velocity. If shear stress can be roughly approximated as the product of depth and slope, the inability to adjust channel width creates continually increasing shear on the stream bed and banks with larger storm flows.

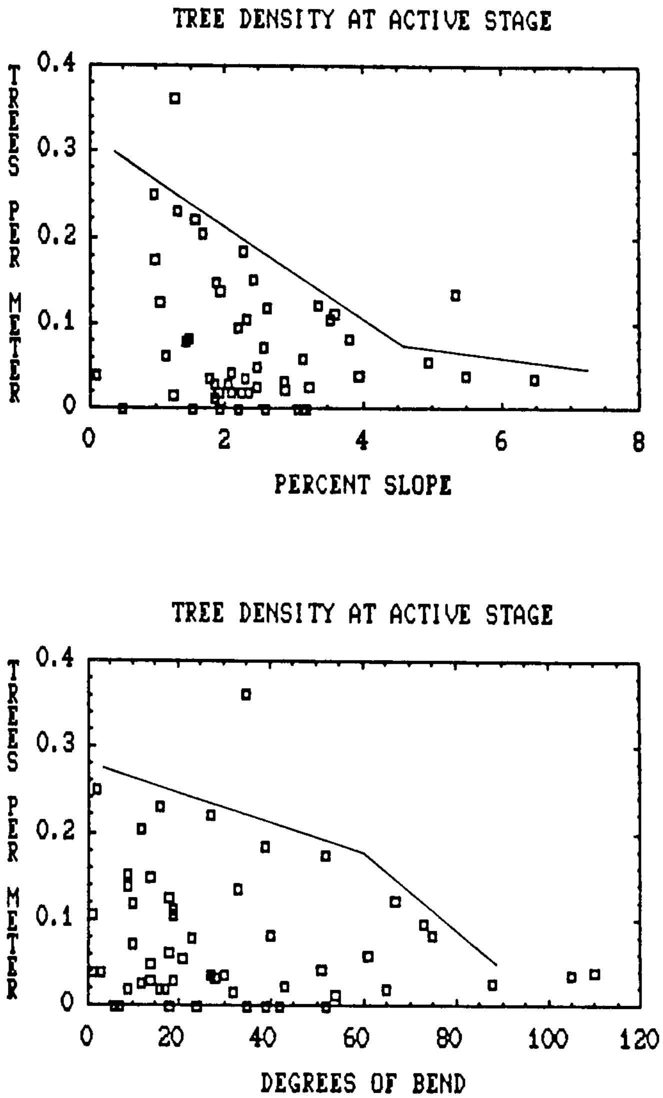

Figure 5— Relationship between the density (trees per meter of planform) of the active channel tree population and planform slope and curvature. The solid line indicates the threshold riparian density.

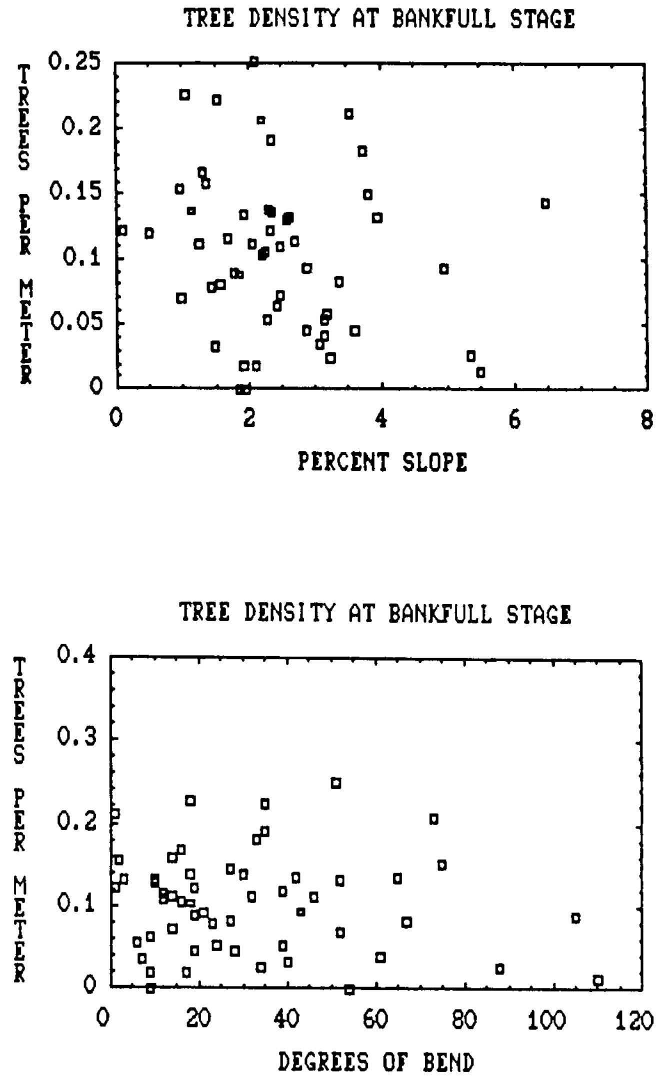

Figure 6— Relationship between the density (trees per meter of planform) of the bankfull channel tree population and planform slope and curvature.

As a starting point, we hypothesized that steeper channels were more difficult places to survive, particularly for individual trees established on the active channel berm. The active population did exhibit a decrease in threshold density with increasing planform slope (fig. 5), while threshold densities for the bankfull population exhibited no clear trend (fig. 6). The two braided planforms, plotting above the threshold density curve in Figure 5, had bankfull widths twice the average of nonbraided planforms. Potential for width adjustment at high flows could reduce storm impact and favor riparian establishment.

Lower planform curvatures were associated with higher riparian threshold densities, particularly for the active channel population. The most dense active populations of large alders occurred on short channel segments in planforms having slopes of 0.5 to 2.5 percent and low curvatures of 1 to 10 degrees; densities ranged from 0.25 to 0.40 trees per meter. Dense rows of alders occurred only on the active channel berm, often at planform inflections. The lowest active population densities were found on mobile point bars located on the inner bank of high curvature channel bends. On these bars, bedload movement occurred below bankfull discharge.

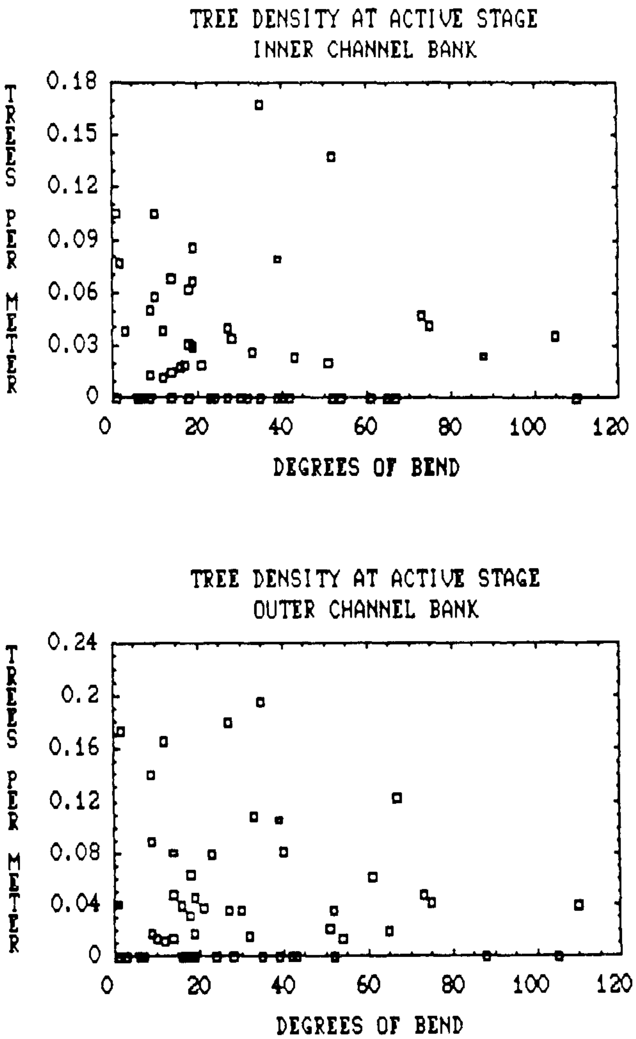

Figure 7— Tree densities (number of trees per meter of planform) on the inner and outer banks of the active channel in relation to planform curvature.

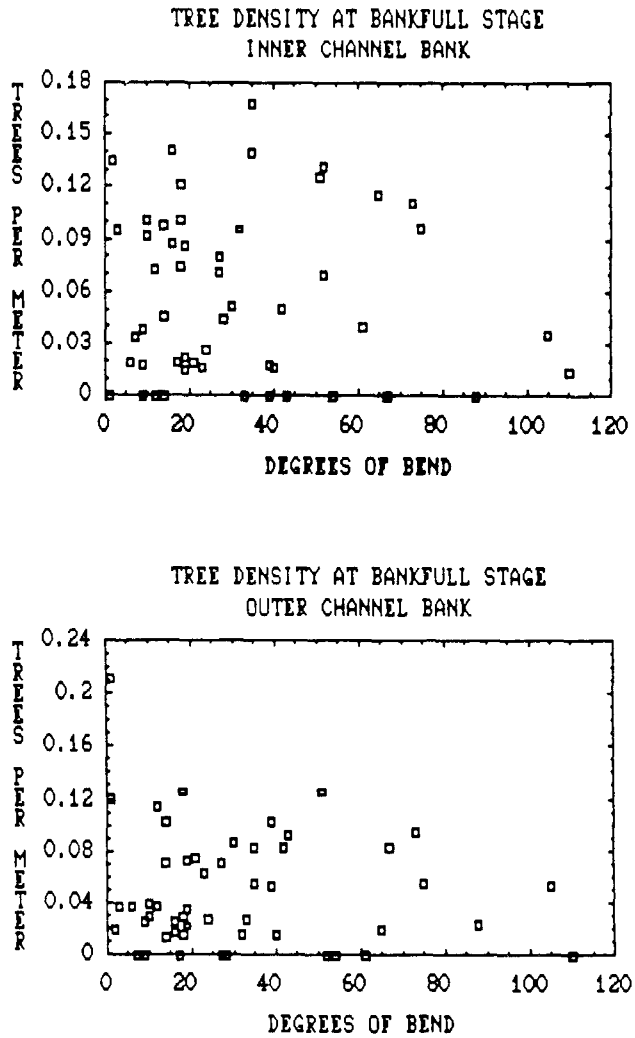

Figure 8— Tree densities (number of trees per meter of planform) on the inner and outer banks of the bankfull channel in relation to planform curvature.

We only can infer process by examining patterns or trends. We hypothesized that the outer bank was a more harsh environment for riparian establishment because (1) vertical water velocity profiles would undergo significant change moving away from the bank at storm flows, thus creating high shear stress and (2) floating debris would be directed against the outer bank causing stem damage and uprooting. Channel-wide bankfull riparian abundance was slightly higher for the inner banks (185 trees) than the outer banks (142 trees). In many planforms, the outer banks had numerous crevices among the boulders and bedrock that provided sheltered sites for riparian establishment. Outer banks were composed of relatively nonerodible bedrock or boulders; bank undercutting was rare. Undercutting of the outer bank may not have the "opportunity" to be an important factor affecting population densities on Elder Creek. Other stream types, with erodible banks, may have significant outer bank undercutting that greatly reduces survival to a large size for riparian species.

Low densities of active trees (fig. 7), compared to higher bankfull densities on the inner bend (fig. 8), indicate another process (particularly on high curvature planforms). Most bedload movement through a channel bend at high flows did not occur along the thalweg, i.e., along the outer bend. Most movement occurred across the point bar. Seedlings on point bars (i.e., the inner channel bank) would encounter significant scour during bedload movement, as a flood exceeds active stage and covers the bars. The upper extreme of the bar surface marks bankfull or near-bankfull stage. Trees at this location would not be as exposed to bedload scour. The lack of fluvial "sand-papering" on exposed roots of bankfull trees along the margin of point bars supports this hypothesis. Flood scarring of active channel trees appeared more frequent on the inner channel banks following a ten year storm in February, 1986.

Riparian establishment along the active channel exists in close equilibrium with channel dynamics. In adjacent Rock Creek (fig. 1), channel width from the active channel crest to bankfull has expanded due to aggradation from intense logging beginning in the late 1940's. The aggradation induced straightening of the active and the bankfull channel. Even-aged alder stands colonized the outside portion of the original channel bends. On the inner banks of low curvature planforms, young alders often extend from bankfull stage down to the active stage. Following major storms and subsequent lowering of the channel bed (decreasing supply of bedload as Rock Creek watershed successfully revegetates), another row of younger alders becomes established along a new, narrower active channel. Lines of alders, each a different age, document episodes of channel adjustment. Alder pattern could be used to assess the rate of channel recovery for aggraded streambeds.

Acknowledgements

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THE MIDDLE SACRAMENTO RIVER: HUMAN IMPACTS ON PHYSICAL AND ECOLOGICAL PROCESSES ALONG A MEANDERING RIVER[1]

Koll Buer, Dave Forwalter, Mike Kissel, and Bill Stohler[2]

Abstract: Native plant and wildlife communities along Northern California's middle Sacramento River (Red Bluff to Colusa) originally adapted to a changing pattern of erosion and deposition across a broad meander belt. The erosion-deposition process was in balance, with the river alternately building and eroding terraces. Human-induced changes to the Sacramento River, including bank protection, gravel mining, pollution, riparian vegetation removal, flow regulation, and flood control, have resulted in a number of physical and ecological effects. This study focuses on changes in bank erosion, bank composition, river length, depth, width, and sinuosity, and floodplain deposition (ongoing study, Sacramento River Bank Erosion Investigation, Department of Water Resources, Red Bluff, California.) *The Department of Water Resources, Northern District, is monitoring these changes using old survey maps, aerial photographs, and field surveys. Completed studies indicate that bank protection has significantly reduced a source of salmon spawning gravel from freshly eroded banks and will over time decrease the number of preferred spawning areas such as point bar riffles, chute cutoffs, multiple channel areas, and areas near islands. Bank protection also increases the tendency of the confined river to deepen and narrow, further reducing spawning habitat. Because of flood protection from dams and extensive bank protection along eroding banks, most of the rich high terrace soils and all but a few percent of the original riparian forest has been converted to agriculture and other uses. In addition, only 45 percent of the original streambank vegetation remains. Wildlife populations have declined markedly due to loss of riparian habitat and suppression of the natural successional processes that maintain the density and diversity of habitat within the riverine environment. Some species that are adapted to the dynamics of the erosional-depositional cycle are threatened with extinction or extirpation as key habitat elements are lost from the newly stabilized river system. Flood control has interrupted the natural equilibrium between erosion and deposition, resulting in reduction in bank erosion rates and in overbank sediment deposition. Solutions to these problems will require a comprehensive river management program that incorporates the natural processes of meandering and bank erosion.*

The Sacramento River is the largest and most important river system in California. The basin represents about 17 percent of California's land area, yet yields 35 percent of the water supply. It drains the north half of the Great Central Valley of California. The river is the State's most important salmon resource. Biologically, the riparian corridor between Red Bluff and Colusa is also one of the richest and most diverse that remains in California.

The Department of Water Resources (DWR), Northern District, has an ongoing study of geomorphic changes in this vital reach of the river (fig. 1). The Department began its bank erosion studies in 1977. For two years, four bank erosion sites were monitored. A report was published in 1979 outlining the results (DWR 1979b). Several of these sites were monitored until 1983.

A new monitoring program began in 1986. Nine new bank sites were surveyed in the 58-mile study reach. An additional six sites were surveyed in 1988. The scope was also expanded to include overbank deposition and bank composition. Ten floodplain cross-sections were surveyed to monitor sediment deposition and long-term changes. The study also considers long-range geomorphic changes caused by such human activities as dams, bank protection, and gravel mining. Geomorphic changes include channel narrowing and deepening; changes in riparian vegetation, channel length, width, sinuosity, and bank erosion, and sediment transport rates.

Historical Aspects

Before settlement of the Sacramento Valley, the Sacramento River was free flowing. Late summer flows were low, averaging 3,000 cubic feet per second (cfs), and in dry years dropping as low as 1,000 cfs. The river, however, would fluctuate widely in response to winter rains and spring snowmelt. Periodically, it would overflow its banks and flood large areas of the valley floor. These areas were covered by dense forests of riparian vegetation adapted to the periodic flooding.

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[1]Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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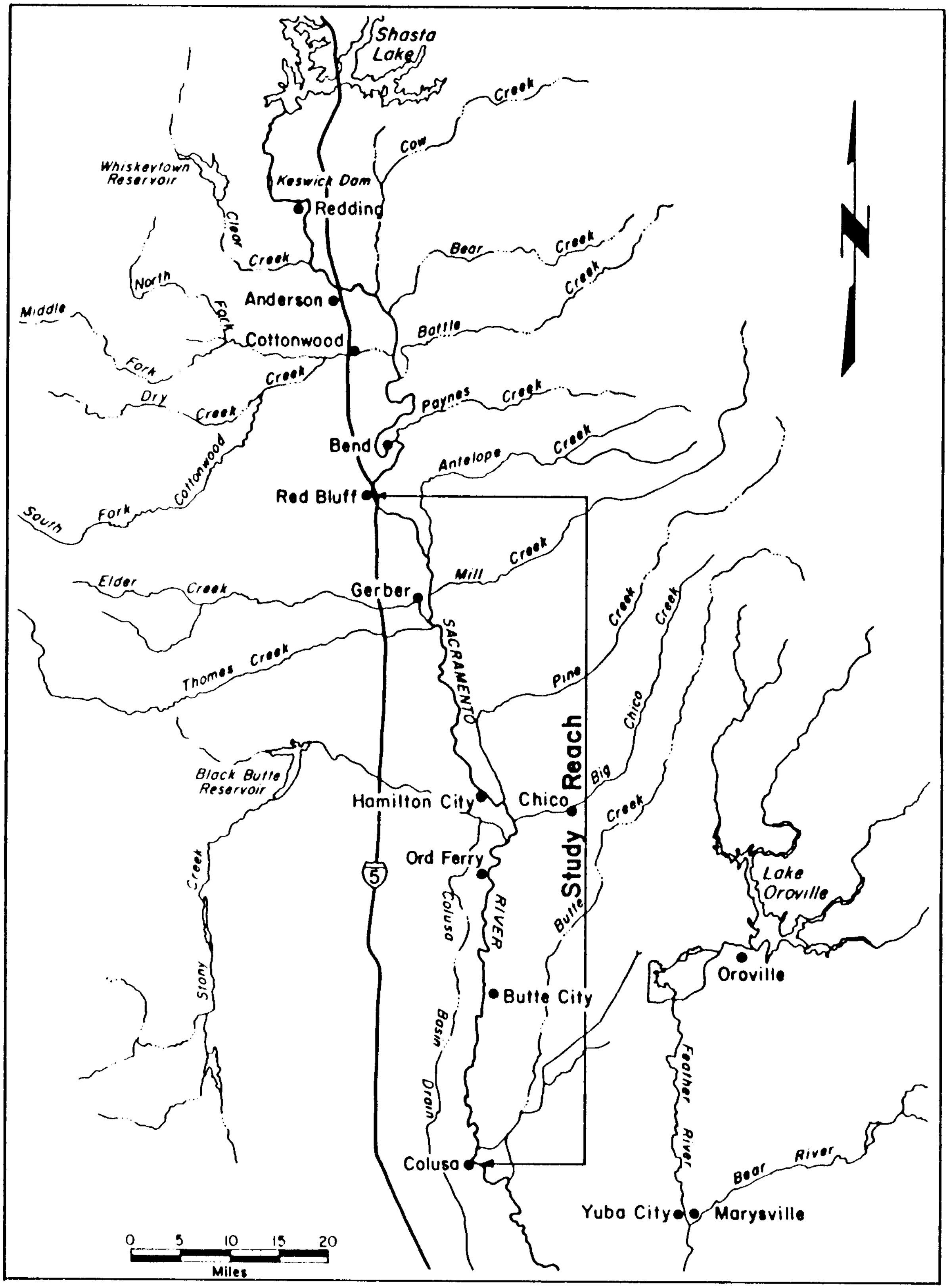

Figure 1— Sacramento River from Keswick Dam to Colusa

Below Red Bluff, bank erosion and lateral migration across the floodplain were natural processes. Large floods uprooted streamside vegetation, caused banks to recede and the river to meander. Sediment derived from tributaries and from bank erosion deposited in overbank areas where vegetation reduced water velocities.

Over a period of years, erosion and deposition were roughly in balance, so that the valley floor neither aggraded nor degraded. The riparian forests played a doubly important role here, first by reducing bank erosion and, second, by inducing deposition on the floodplain.

A large number of chinook salmon *(Oncorhynchus tshawytscha)* migrated up the Sacramento River each year to spawn. Although there were probably four runs then, as there are today, the two largest runs were thought to have occurred in the fall and spring. The other two runs, winter and late fall, are not as well documented historically, especially their numbers. Most of the spring- and winter-run salmon, as well as part of the fall and late-fall salmon, were thought to have spawned upstream from the present location of Shasta Dam. However, large numbers of spring- and fall-run salmon also spawned in many Sacramento tributaries.

Since about 1850, the study reach has undergone a number of hydrologic, geomorphic, and environmental changes, most of which have been detrimental to locally adapted species. These changes are caused by dams and diversions, bank protection, urbanization, stream gravel removal, hydraulic mining, agriculture, and logging. Many of these changes have had long-reaching effects, including alteration of river characteristics, such as depth, width, gradient, sinuosity, and bank erosion. This in turn has reduced riparian vegetation, water quality, hydrologic diversity, and fish and wildlife resources.

Urbanization, primarily in Redding, Anderson, Cottonwood, and Red Bluff, has caused additional problems in the study reach. Gravel extraction for highways, housing, and other projects averages more than 1.3 million cubic yards per year in Shasta County and 0.5 million in Tehama County, mostly from tributary streams. This, in conjunction with Shasta, Keswick, Whiskeytown, and other dams that prevent gravel recruitment from upstream reaches, has eliminated the spawning gravel available in downstream reaches.

Along with the rapid expansion of the mining industry, California agriculture also grew. First to be converted to agriculture were the fertile rimlands. Rimlands are next to the river, higher than the surrounding tule lands, and are less often flooded. Flood control had its inception in the low levees constructed on the rimlands by farmers protecting their crops.

Next to be developed were the tule, or swamp and overflow, lands. Through a series of legislative acts passed between 1855 and 1868, the State sold these lands to farmers who were obliged to reclaim them individually or through the formation of reclamation districts. Within a period of 3 years following the last act, practically all of such lands had passed into private ownership (Jones 1967). To date, as a consequence of just these two kinds of agricultural development, about 98 percent of the original riparian forest has been removed (DWR 1988).

Dams and unscreened or poorly screened diversions have severely depleted the river's fishery. Early dams and diversions built by miners and farmers obstructed miles of habitat without allowance for fish passage or mitigation measures. By the 1920s, at least 80 percent of the Central Valley spawning grounds had been cut off by obstructions, according to the U. S. Bureau of Reclamation (USBR 1972). Dams affect riparian areas mostly by the reduced incidence of flooding, bank erosion, and silt deposition required for the regeneration of riparian habitat. Flood control also encourages the development of riparian lands along the river.

More recently, major water development projects, such as Shasta and Keswick Dams and the Trinity River Diversion, have affected Sacramento River hydraulics. Shasta Dam stores 4.5 million acre-feet and, to a large extent, regulates flows from the Pit, McCloud, and upper Sacramento Rivers. Keswick Dam, 9 miles downstream from Shasta provides water regulation, stops salmon migration and acts as a fish-trapping facility.

The effect of Shasta Dam on the natural flow (DWR 1984) has been to:

1. Decrease the minimum discharge and increase the number of very low discharges. This occurs when the powerhouse is closed for repairs.

2. Increase the number of moderate discharges, particularly during the summer and fall irrigation season.

3. Reduce the number and the volume of high and very high flows.

Since December 1963, water has been diverted from the Trinity River Basin through the Clear Creek Tunnel and Judge Francis Carr Powerhouse to Whiskeytown Lake. The Spring Creek Tunnel then diverts Trinity water and most of Clear Creek water through another power plant into Keswick Lake. An average of about 1 million acre-feet of Trinity River water is now diverted into the Sacramento River Basin each year.

The effect of the Trinity River diversion on post-Shasta flows has been to increase average Sacramento River discharge by about 1,000 to 1,500 cubic feet per second throughout most of the year.

River Geomorphology and Ecology

Using such channel characteristics as gradient, geometry, underlying rock types, and gravel distribution, it is possible to divide the Sacramento River between Redding and Colusa into seven distinct reaches. These reaches were described in detail by the Department of Water Resources (1984; 1985) and are only briefly described here.

Typically, the river between Redding and Red Bluff (reaches 1 to 5) is a bedrock reach. The river is entrenched, in places, with some vertical banks 100 feet or more high.

Below Red Bluff, the Sacramento River is mostly an alluvial stream. Reach 6 is between Red Bluff and Chico Landing. It is sinuous and anabranching. Reach 6 has been divided into eight subreaches (6A to 6H) based on bank erosion, sinuosity, and meander belt width. Reaches 6A, 6C, 6E, and 6G are short, narrow, straight reaches with low sinuosity, low gradient, and only minor bank erosion. Between the short, stable reaches are longer, more sinuous, unstable reaches 6B, 6D, 6F, and 611.

Reach 7 is between Chico Landing and Colusa. Here the gradient is less; the river tends to be more sinuous with fewer islands. The most distinctive feature of this reach is the gradual downstream development of natural levees. This reach has been divided into five subreaches (7A to 7E), based on the criteria used for reach 6.

Bank Erosion

A river erodes both its banks and bed. Bed erosion leads to degradation and grading of the stream profile. In a bedrock stream, this process is generally slow, except during periods of geologically rapid rejuvenation and uplift. Bed erosion also occurs in alluvial streams, but the erosion is generally balanced by deposition over a period of years.

Bank erosion is generally of much more interest and concern to people. Bank erosion is dependent on channel shape, bed and bank material, and river hydraulic characteristics. Because of the generally stable banks of the Sacramento River between Keswick and Red Bluff, bank erosion is insignificant in most places. Between Red Bluff and Colusa, significant bank erosion occurs. Downstream of Colusa, flows and associated velocities are greatly reduced by overflow occurring upstream during flooding (both overbank flow and flow at the Moulton and Colusa overflow weirs). In addition, the flatter slopes of the channel bed downstream minimize the erosion potential.

In alluvial river systems, banks erode and sediments are deposited. Floodplains, islands, and side channels will undergo modification with time.

Bank erosion generally occurs on the outside of meander bends. Here, banks are susceptible to erosion because high-flow velocities impinge directly onto banks and turbulent motion along the channel thalweg undercuts the banks. Eroding banks may be either high-terrace or low terrace. High terrace banks normally have a deep soil profile containing mostly loamy sand and silt. Below the soil is a deposit of sand and gravel which usually originates as the point bars on the wide edges of river beds. A low-terrace bank consists mostly of a sand and gravel which was deposited as point bars with a thin soil profile on top.

The fish, wildlife, and riparian vegetation are adjusted to the cycle of erosion, deposition, and changing channel pattern in which the river swings slowly back and forth across a broad meander belt. The health and productivity of the system at any one point is dependent on the periodic rejuvenation associated with these changes.

Salmon prefer to spawn in fresh, uncompacted gravels that have recently moved. These spawning beds tend to occur in wide areas with multiple channels or chute cutoffs because of increased spawning flow velocity, reduced flood-flow velocity, shallower depths, and greater hydraulic diversity there. Gravel in the subsoil horizons of an eroding bank provides fresh gravel to spawning beds. Much of the sand and silt from the bank is redeposited in the riparian forests downstream. Abandoned channel oxbows and sloughs are ideal habitat for warmwater fish, such as largemouth bass and catfish.

Bank erosion is important for the recruitment of spawning gravel. It allows for the re-entrainment of gravel deposited on point bars. Between Red Bluff and Colusa, bank erosion is estimated to contribute about 85 percent of the total available spawning gravel (DWR 1984; 1985).

Bank erosion is also the driving force for riparian plant succession. On the outside of bends, high-terrace banks with a mature forest typically consisting of valley oak, box elder, and black walnut are eroded. On the opposite side is a point bar consisting of sand and gravel. Willows and cottonwoods become established here. The rapid invasion of riparian vegetation slows floodflow velocities and allows sand and silt to deposit. With time, riparian stages with a succession of different plant species occurs as the point bar becomes higher and farther away from the river.

Various birds and other wildlife use different riparian stages for feeding, nesting, and reproduction. The climax valley oak forests are relatively sterile compared to the younger riparian stages. Therefore, bank erosion and riparian rejuvenation are necessary to maintain a healthy and productive ecosystem.

Sediment deposition is inextricably linked to bank erosion. Without deposition, the channel would simply widen until it was so large that erosion would terminate. However, the coarser material eroded from the bank is deposited on point bars downstream. The point bars constrict the bend and enable erosion to continue.

DWR (1979) observed bank erosion over a 2-1/2-year period at six sites in the Red Bluff-to-Colusa Reach. This investigation has been expanded and is presently continuing. Bank erosion was divided into summer (low-flow) erosion and winter (high-flow) erosion. Only two of the six sites showed any erosion during the summer. Average bank recession between April and October 1977 was 11.4 and 2.2 feet, respectively.

In contrast, high flows were far more conducive to erosion. A major storm occurred in January 1978. Erosion was greatest during the period that included this storm, with erosion ranging from 30 to 50 feet of bank recession. During the storm itself, Woodson Bridge State Recreation Area below Thomes Creek lost over 40 feet in a single 24-hour period.

Beginning in 1986, nine new erosion sites were surveyed. Six more were added in 1988, for a total of fifteen sites. Figure 2 shows one of these. Each site is surveyed three to four times yearly. Successive bank lines are plotted and eroded bank area calculated.

Figure 3 shows the Sacramento River discharge and bank erosion between 1986 and 1988 at ten erosion sites. Note that no floodflows occurred during the 2 years and that the highest peak flow was about 65,000 cfs. At Ord Ferry, the flood stage, or bankfull discharge, is about 110,000 cfs and floodflow in March 1983 was about 160,000 cfs.

Six of the nine sites had essentially no erosion during the low-flow period. The Princeton site has eroded several thousand feet since 1978 and is the most erodible site on the river. It eroded an average of 4 feet during the low-flow period and an additional 30 feet during the two higher flow periods.

Another goal of the bank erosion study was to determine total bank erosion, gravel and silt produced from bank erosion, and bank recession rates. A total of 67 bank erosion sites were identified and evaluated by comparing 1976 and 1987 aerial photographs. Eroded areas were measured using a planimeter. Thirty of the sites were field surveyed. Longitudinal profiles were measured showing bank height, thickness of gravel, and thickness of silt. Gravel samples were sieved and analyzed. The additional 37 sites were identified as showing significant erosion, but were not sampled or measured in detail. Data from the surveyed sites were averaged by geomorphic reach and applied to the unsurveyed sites. Aerial photographs from 1976 and 1987 were compared and bank erosion areas measured using a planimeter. Table 1 is a summary of bank erosion data for the reach.

There are a number of interesting observations that can be made from this table. The average bank height from the bottom of thalweg to the top of the bank is about 25 feet, with 16 feet of gravel and 9 feet of silt. The average bank recession of an actively eroding bank is about 20 feet per year, ranging from a few feet to nearly 80 feet. The average length of an eroding bank is about 3,000 feet, for a total of about 197,000 linear feet. This represents 34 percent of the bank in the reach. Another 18 percent was eroding but has been protected with rock riprap.

Between 1976 and 1987, about 1,230 acres have been eroded. This has produced about 29 million cubic yards of sand and gravel and 20 million cubic yards of silt. Most of the gravel is redeposited on point bars immediately below the eroding bank. Some of the silts are deposited on the floodplain and some are washed downstream.

DWR (1979a,b), U. S. Corps of Engineers (USCE 1981), and the U. S. Geological Survey (USGS 1977) have compared pre- and post-Shasta erosion rates. All three investigations concluded that there has been a significant reduction of about 25 percent in bank erosion between the period 1896-1946 and 1946-1980. The differences in rates can be attributed in part to a reduction in the frequency and magnitude of peak flows resulting from regulation by Shasta Dam. Secondly, since bank erosion increases exponentially with discharge, any reduction in the occurrence of high flows will reduce the amount of bank erosion (DWR 1984; 1985).

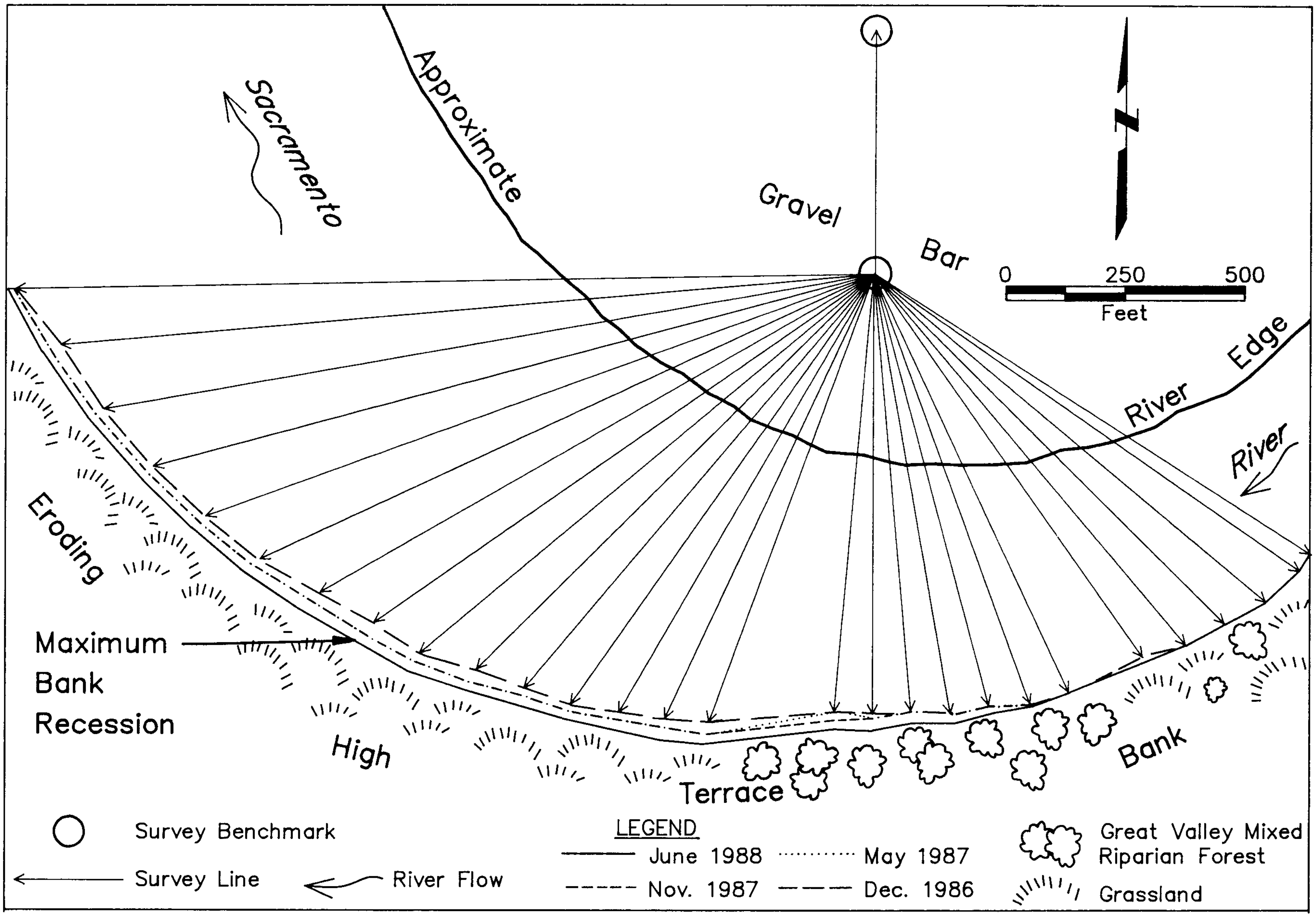

Figure 2— Golden State Island Surveyed Erosion Site December 9, 1986 through June 7, 1988

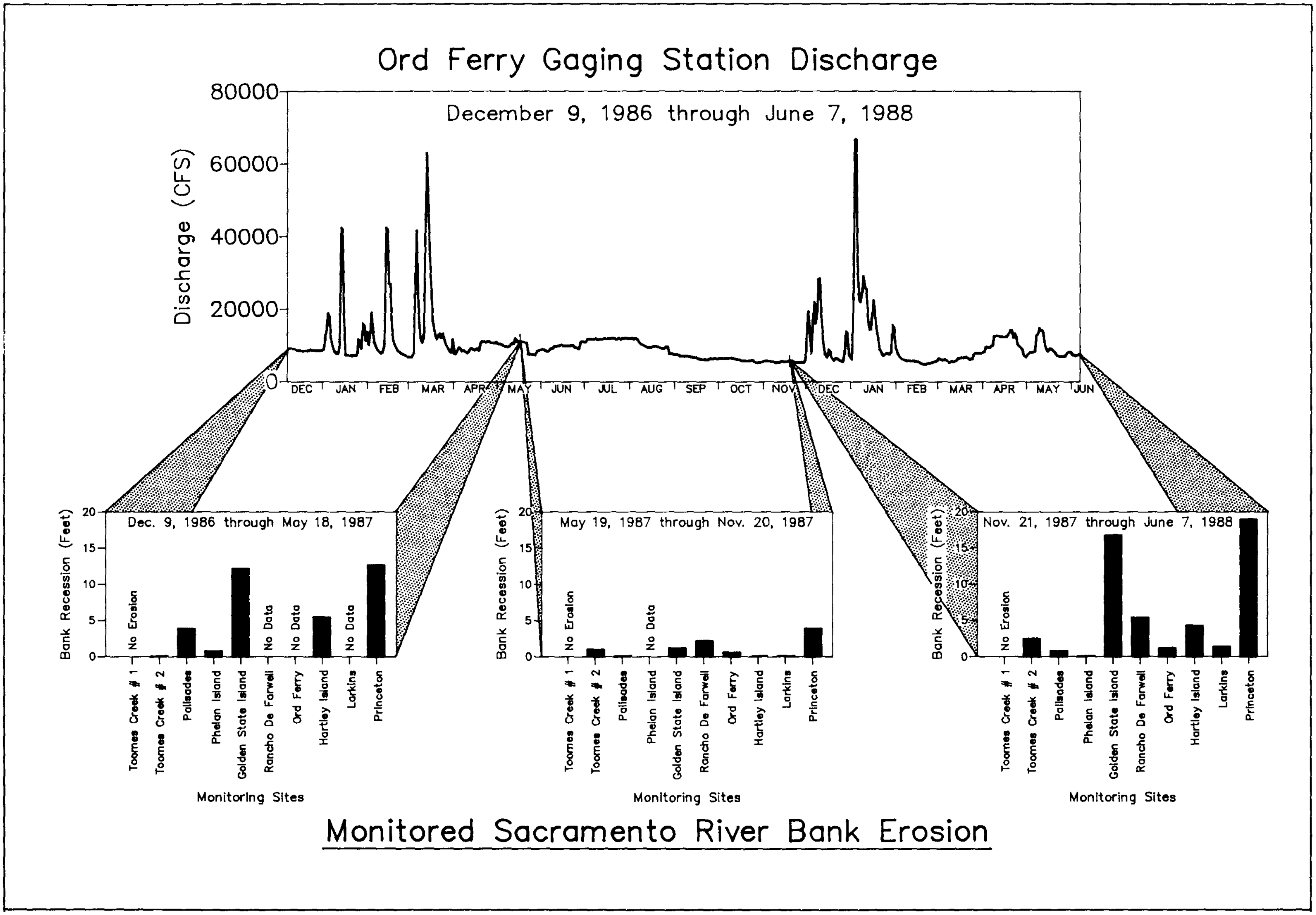

Figure 3– Sacramento River Discharge and Bank Erosion for Three Hydrologic Periods - December 9, 1986 through June 7, 1988

REACH	EROSION SITE	RIVER MILE	AVERAGE BANK HEIGHT (FEET)	AVERAGE GRAVEL THICKNESS (FEET)	ERODED BANK AREA (SQUARE FEET X 1,000)	TOTAL GRAVEL VOLUME ERODED (CUBIC YARDS X 1,000)	TOTAL FINE VOLUME ERODED (CUBIC YARDS X 1,000)	TOTAL BANK VOLUME ERODED (CUBIC YARDS X 1,000)	LENGTH OF ERODED BANK (FEET)	MAXIMUM BANK RECESSION FOR 11 YEARS (TOTAL FEET)	AVERAGE BANK RECESSION FOR 11 YEARS (TOTAL FEET)	AVERAGE BANK RECESSION PER YEAR (FEET)
6A	ERODING BANK	240.5	20.7*	14.2*	336	176.7**	80.9**	257.6**	3680	160	91.3	8.3
	SACT 1	239.9	21.1	13.7	236	119.7	64.7	184.4	1770	240	133.3	12.1
	ERODING BANK	239.5	20.7*	14.2*	141	74.2**	33.9**	108.1**	1960	160	71.9	6.5
	ERODING BANK	239.0	20.7*	14.2*	63	33.1**	15.2**	48.3**	1280	80	49.2	4.5
	ERODING BANK	239.0	20.7*	14.2*	32	16.8**	7.7**	24.5**	800	100	40.0	3.6
	SACT 2	238.5	20.3	14.7	742	404.0	153.9	557.9	3360	520	220.8	20.1
6B	ERODING BANK	237.0	19.9*	13.1*	3140	1519.6**	798.6**	2318.2**	5640	800	556.7	50.6
	SACT 3	236.5	15.4	12.0	485	215.6	61.1	276.6	3200	228	151.6	13.8
	ERODING BANK	236.0	19.9*	13.1*	96	46.5**	24.4**	70.9**	1090	135	88.1	8.0
	ERODING BANK	235.5	19.9*	13.1*	85	41.1**	21.6**	62.8**	1100	100	77.3	7.0
	SACT 4	235.0	23.3	13.2	1614	789.1	603.8	1392.8	4800	700	336.3	30.6
	ERODING BANK	234.0	19.9*	13.1*	665	321.8**	169.1**	491.0**	4520	240	147.1	13.4
	ERODING BANK	233.0	19.9*	13.1*	253	122.4**	64.3**	186.8**	1860	190	136.0	12.4
	SACT 5	232.9	21.1	14.0	468	242.7	123.1	365.7	3530	400	132.6	12.1
	ERODING BANK	232.0	19.9*	13.1*	96	46.5**	24.4**	70.9**	970	200	99.0	9.0
	ERODING BANK	231.5	19.9*	13.1*	371	179.5**	94.4**	273.9**	2220	320	167.1	15.2
	ERODING BANK	231.0	19.9*	13.1*	193	93.4**	49.1**	142.5**	1514	250	127.5	11.6
6C	SACT 6	228.9	33.9	16.9	144	90.1	90.7	180.8	2480	88	58.1	5.3
6D	ERODING BANK	227.5	27.2*	15.4*	786	447.3**	345.5**	792.8**	3840	460	204.7	18.6
	ERODING BANK	226.0	27.2*	15.4*	645	367.1**	283.5**	650.6**	3960	360	162.9	14.8
	SACT 7	225.5	30.7	14.8	44	24.1	25.9	50.0	1480	40	29.7	2.7
	SACT 8	224.4	20.8	19.9	131	96.6	4.4	100.9	2220	136	59.0	5.4
	SACT 9	223.3	26.8	14.2	264	138.8	123.2	262.0	3400	144	77.6	7.1
	ERODING BANK	223.0	27.2*	15.4*	605	344.3**	265.9**	610.2**	1980	560	305.6	27.8
	TOOMES 1 & 2	222.5	27.0	7.7	3118	889.2	2228.8	3118.0	5100	1080	611.4	55.6
	ERODING BANK	222.0	27.2*	15.4*	228	129.8**	100.2**	230.0**	1950	210	116.9	10.6
	SACT 28	221.3	24.4	20.5	407	309.0	58.8	367.8	2260	480	180.1	16.4
	ERODING BANK	221.0	27.2*	15.4*	257	146.3**	113.0**	259.2**	1900	260	135.3	12.3
	PALISADES	219.0	33.7	15.1	633	354.0	436.1	790.1	2880	440	219.8	20.0
6E	ERODING BANK	217.5	27.2*	16.2*	155	93.0**	63.1**	156.1**	1740	110	89.1	8.1
	ERODING BANK	216.0	27.2*	16.2*	1893	1135.8**	771.2**	1907.0**	8860	870	213.7	19.4
6F	SACT 12	213.1	19.0	6.4	1968	466.5	918.4	1384.9	2380	1280	826.9	75.2
	SACT 13	212.5	28.4	13.9	624	321.2	335.1	656.4	920	1280	678.3	61.7
	SACT 10	211.9	21.0	16.8	430	267.6	66.9	334.4	2350	312	183.0	16.6
	SACT 14	211.2	20.9	11.0	1469	599.5	538.6	1137.1	5100	620	288.0	26.2
	SACT 15	210.6	30.4	23.7	1161	1019.1	288.1	1307.2	3000	760	387.0	35.2
	SACT 16	210.4	23.9	13.6	1476	743.5	563.1	1306.5	4750	568	310.7	28.2
	ERODING BANK	209.0	27.1*	17.0*	547	343.8**	205.8**	549.6**	4620	240	118.4	10.8
	ERODING BANK	208.0	27.1*	17.0*	251	157.8**	94.5**	252.2**	1710	225	146.8	13.3
	SACT 17	207.2	40.2	35.0	41	53.1	7.9	61.0	620	120	66.1	6.0
	ERODING BANK	207.0	27.1*	17.0*	511	321.2**	192.3**	513.5**	2500	300	204.4	18.6
	ERODING BANK	206.0	27.1*	17.0*	401	252.0**	150.9**	402.9**	1850	330	216.8	19.7
	SACT 18	204.2	23.3	20.2	330	246.9	37.9	284.8	2660	220	124.1	11.3
	SACT 19	203.2	31.5	7.3	144	38.9	129.1	168.0	1700	140	84.7	7.7
	ERODING BANK	203.0	27.1*	17.0*	2333	1466.3**	877.9**	2344.2**	5220	1225	446.9	40.6
	ERODING BANK	202.0	27.1*	17.0*	610	383.4**	229.5**	612.9**	2500	375	244.0	22.2
	SACT 20	201.5	32.7	21.8	1235	997.1	498.6	1495.7	3230	600	382.4	34.8
	ERODING BANK	201.0	27.1*	17.0*	169	106.2**	63.6**	169.8**	1360	220	124.3	11.3
6G	ERODING BANK	199.0	26.5*	19.1*	245	173.3**	67.1**	240.5**	1900	215	128.9	11.7
6H	ERODING BANK	198.0	25.8*	21.2*	188	147.3**	32.4**	179.6**	2000	170	94.0	8.5
	ERODING BANK	196.0	25.8*	21.2*	1074	841.3**	185.0**	1026.3**	2580	695	416.3	37.8
	ERODING BANK	195.5	25.8*	21.2*	1110	869.5**	191.2**	1060.7**	2970	840	373.7	34.0
	ERODING BANK	195.5	25.8*	21.2*	1220	955.7**	210.1**	1165.8**	2560	680	476.6	43.3
	ERODING BANK	194.5	25.8*	21.2*	682	534.2**	117.5**	651.7**	2820	475	241.8	22.0
	SACT 21	194.0	23.3	21.9	294	238.5	15.2	253.7	2220	220	132.4	12.0
	ERODING BANK	193.5	25.8*	21.2*	285	223.3**	49.1**	272.3**	1800	220	158.3	14.4
	SACT 24	193.0	28.3	20.4	576	435.2	168.5	603.7	2820	320	204.3	18.6
7A	ERODING BANK	192.0	22.8*	12.1*	2321	1040.2**	918.1**	1958.2**	5810	520	399.5	36.3
	PHELAN	191.5	27.0	6.5	1955	470.6	1484.4	1955.0	4620	920	423.2	38.5
	GOLDEN STATE	190.0	26.0	6.0	1598	355.1	1183.7	1538.8	4080	652	391.7	35.6
	ERODING BANK	190.0	22.8*	12.1*	439	196.7**	173.6**	370.4**	3195	250	137.4	12.5
	SACT 23	189.0	47.9	43.7	102	165.1	15.9	181.0	1200	300	85.0	7.7
	SACT 25	187.7	21.9	13.6	1440	725.3	442.7	1168.0	3980	576	361.8	32.9
	ERODING BANK	187.0	22.8*	12.1*	1707	765.0**	675.2**	1440.2**	3400	1000	502.1	45.6
	ERODING BANK	187.0	22.8*	12.1*	2616	1172.4**	1034.8**	2207.1**	4200	1070	622.9	56.6
	SACT 26	186.5	21.4	21.0	2608	2028.4	38.6	2067.1	5800	1200	449.7	40.9
	R.D. FARWELL	185.5	17.6	13.4	1264	627.3	196.6	823.9	5140	500	245.9	22.4
	TOTAL		1678.4	1076.7	53750	28755.7	19698.0	48453.8	196909	29699	15768.0	1433.6
	AVERAGE		25.1	16.1	802	429.2	294.0	723.2	2939	443	235.3	21.4

* MEAN VALUES OF SURVEYED DATA BY GEOMORPHIC REACH
** GENERATED FROM MEAN VALUES OF SURVEYED DATA

Table 1. Sacramento River Erosion Site Parameters

Between Red Bluff and Chico Landing, 94,000 feet of riverbank has been riprapped and an additional 81,000 feet of riprap have been proposed. If this is developed, the total riprap in this reach would comprise 34 percent of the riverbank. In the Butte Basin reach (River Mile 176 to 194), 15 percent of the banks are protected and an additional 10 percent are planned (USCE 1988).

Bank protection, when effective, stops bank erosion and lateral migration. It prevents loss of valuable agricultural lands, transportation facilities, and structures.

Bank protection, particularly if it is along all the eroding banks of the river, will cause some long-range geomorphic changes. First, it will have a stabilizing effect on length and sinuosity. Second, it will prevent the re-entrainment through bank erosion of gravel deposited on point bars. This will have some long-range effects on the amount of available spawning gravel. Third, over a period of time, it will tend to narrow the channel, increase the depth of flow, and reduce the hydrologic diversity. Sloughs, tributary channels, and oxbow lakes will fill with sediment and no new ones will be created.

Changes in Length and Sinuosity

Analyses of channel length and sinuosity were done on eleven sets of maps and photographs dated between 1896 and 1987. These were tabulated and published in DWR (1985). No trends were apparent, however, in that some reaches are increasing in length and sinuosity and others are decreasing.

Changes in Depth and Width

The Department of Water Resources (1984) theorized that bank protection would cause the channel to narrow and deepen. When a channel is stabilized, it will no longer erode its banks but will erode its bed. Deposition will continue on the inside of the bend, causing the channel to narrow and deepen. Such a channel will have less hydraulic diversity and salmon spawning area.

As part of the bank erosion studies, sonar surveys were used to measure depths along eroding and riprapped banks. The surveys were done during the summer of 1987. River widths were measured from June 1987 aerial photographs.

Figure 4 shows the thalweg depths plotted with river mile. There were 37 riprapped banks and 28 eroding banks measured and plotted. The lines are 4-point running averages showing that the mean thalweg along riprapped banks average 6 feet deeper than comparable eroding banks.

A similar analysis was completed for river widths. Figure 5 shows that the average width at riprapped sites is about 90 feet less than at eroding sites. The difference in widths appears to remain fairly constant from Ord Ferry (River Mile 184.3) to River Mile 223; then the difference decreases until from River Mile 235 to Red Bluff, it is essentially nonexistent. This is a consequence of the more stable banks near Red Bluff.

The effects of Shasta Dam on river geomorphology are complex. In principle, Shasta Dam would tend to reduce width because of less frequent floodflows. However, this effect may be offset by factors that tend to increase channel width, such as riparian loss. Further study is necessary to adequately assess this complex issue.

Conclusions

Some of the conclusions of the study are that:

- Human activities causing adverse impacts include hydraulic gold mining, gravel mining, bank protection, flood control, and removal of riparian vegetation by agriculture.
- Changes in the hydrologic regime, primarily due to Shasta Dam, have reduced bank erosion rates and overbank deposition.
- Eroding banks consist predominantly of gravel, and the gravel is vital in replenishing salmon spawning areas.
- Floodplain deposition replaces silt lost by bank erosion. Our ongoing study will help to determine if the system is in balance.
- Bank erosion is necessary to maintain riparian succession, anadromous fish and wildlife habitat in the reach.
- Most of the bank erosion occurs during the winter. Summer erosion is significant in a few places along the river. Eroding sites differ considerably in bank erosion rates. The average rate is about 20 feet per year for the last 11 years. Between Red Bluff and Ords Ferry, this is about 110 acres per year or about 2 acres per year per mile. The high rate is most likely due to two large floods that occurred during this period.
- Bank protection will have several negative, long-range effects. Since over 85 percent of the gravel provided to the river comes from bank erosion, it will prevent the recruitment of gravel to salmon-spawning areas. It will cause the river to narrow and deepen. A survey of riprapped and eroded banks shows that riprapped banks are an average of 6 feet deeper at the thalweg. A similar survey of river width shows that the river at riprapped banks is an average of 90 feet narrower. Finally, it will affect the natural rejuvenation of riparian vegetation, reducing or eliminating the habitat for many species of birds and animals.

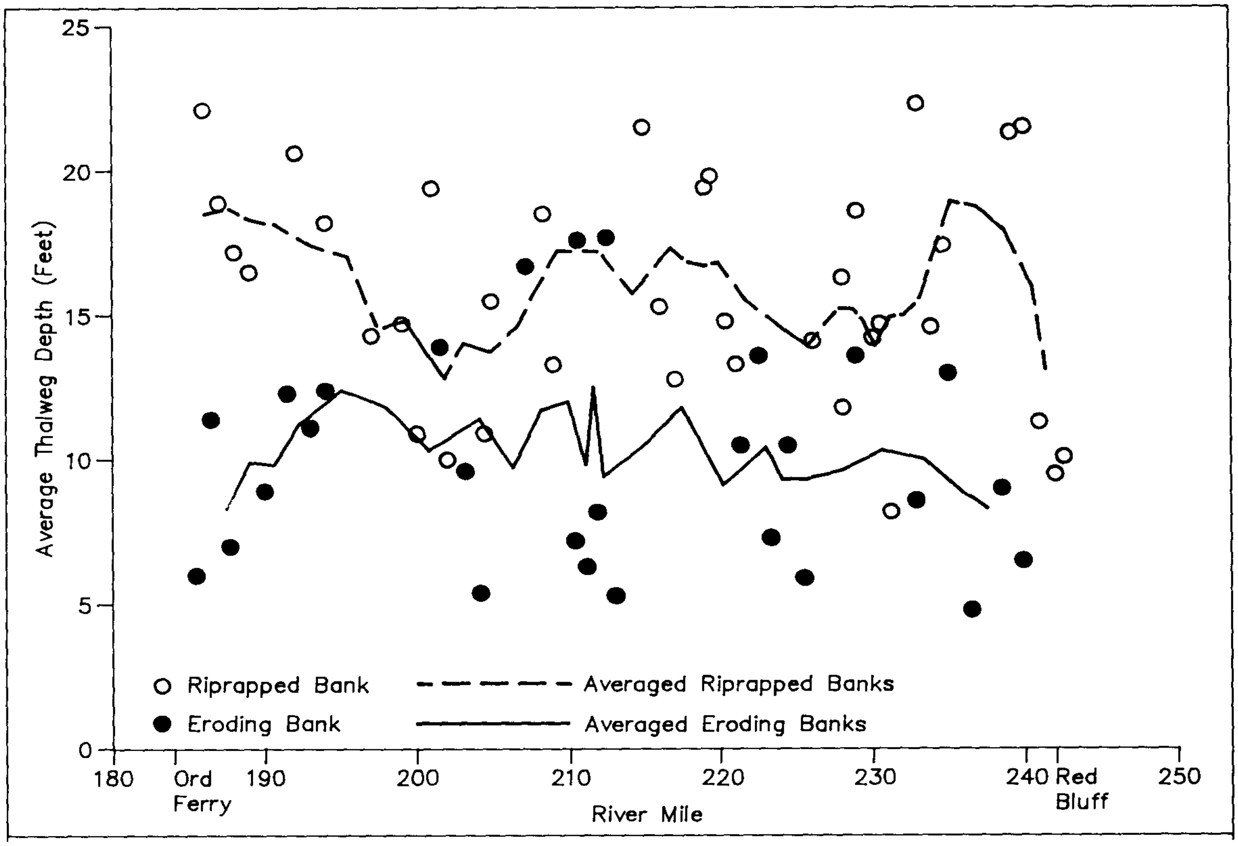

Figure 4– Thalweg Depths Next to Eroding and Riprapped Banks Sacramento River, Summer 1987

Recommendations

Recommendations of the study include development of a comprehensive management plan that will:

- Protect, enhance, and maintain the natural fish, wildlife, and riparian habitat along the Sacramento River. This includes regulation to protect erosion-dependent features such as salmon spawning areas, bank swallow nesting sites, oxbow lakes and offstream wet areas, riparian vegetation, and the attendant wildlife habitats.
- Continue monitoring programs of the Sacramento River geomorphology, including bank erosion, meandering, river depth and width, spawning gravel supply, and floodplain deposition.

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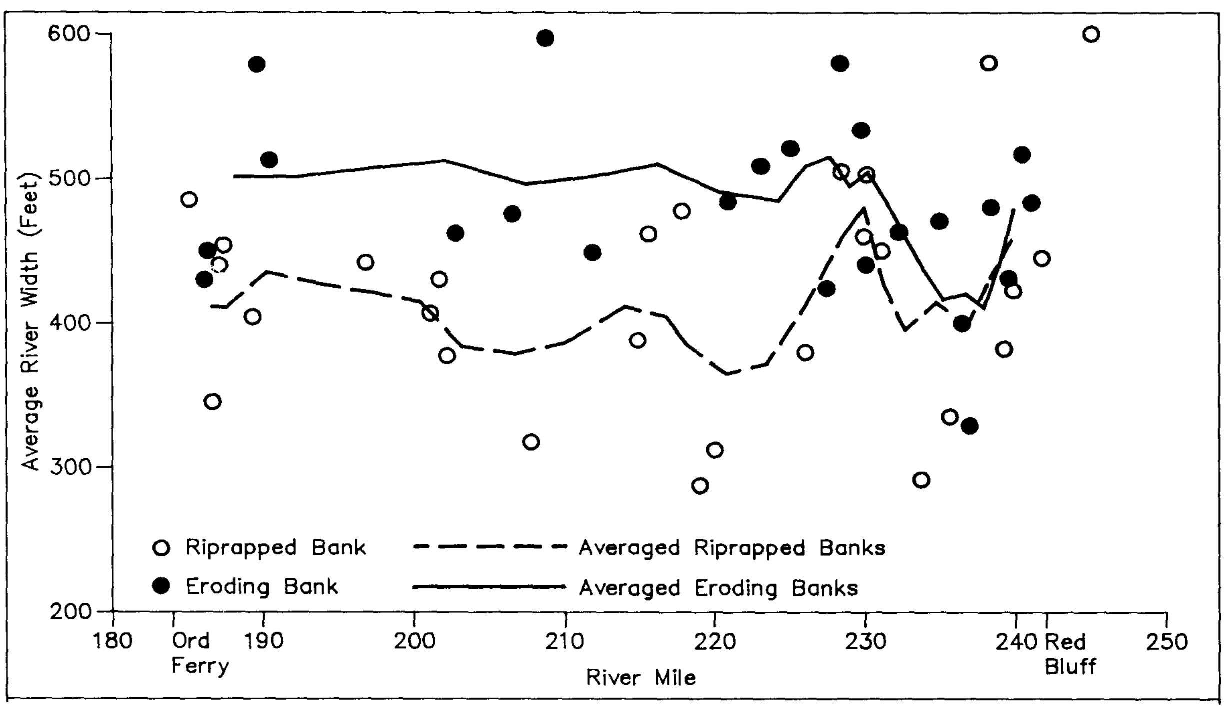

Figure 5-- River Widths Next to Eroding and Riprapped Banks Sacramento River, Summer 1987

INFLUENCE OF CHANNEL GEOMORPHOLOGY ON RETENTION OF DISSOLVED AND PARTICULATE MATTER IN A CASCADE MOUNTAIN STREAM[1]

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Abstract: Retention of particulate and dissolved nutrients in streams is a major determinant of food availability to stream biota. Retention of particulate matter (leaves) and dissolved nutrients (nitrogen) was studied experimentally during summer 1987 in four 300-500 m reaches of Lookout Creek, a fifth-order stream in the Cascade Mountains of Oregon. Constrained (narrow valley floor) and unconstrained (broad valley floor) reaches were selected within old-growth and second-growth riparian zones. Gingko leaves and ammonium were released into the channel and retention rates were measured. Retention of leaves and nutrients was 2-4 times higher in unconstrained reaches than in constrained reaches, in both old-growth and second-growth riparian zones. Retention was enhanced by increased geomorphic complexity of channels, diversity of riparian vegetation, presence of woody debris, and heterogeneity in stream hydraulics, sediments, and lateral habitats. Unconstrained reaches express these qualities and thus are critical areas for retention of particulate and dissolved nutrients in stream ecosystems.

Stream ecosystems face the fundamental challenge of retaining the dissolved and particulate nutrients delivered to them by their watersheds. Because the biota of many streams is dependent on input of nutrients from riparian zones (Vannote and others 1981), retention of these materials is essential to lotic food webs. Streams differ markedly from other ecosystems in that the unidirectional flow of water tends to transport nutrients to downstream reaches. As a consequence, mechanisms for retention of dissolved and particulate matter must be present within the stream reach before nutrients can be utilized effectively by the biota (Elwood and others 1983; Speaker and others 1984; Young and others 1978). The process of retention thus provides a critical linkage between nutrient input and biotic utilization in lotic ecosystems.

The premise of our research is that retention of dissolved and particulate matter is a function of valley floor landform, riparian vegetation, channel geomorphology, and stream hydraulics and substrate. Each of these factors can influence retention rates by modifying either the physical structure or the biological organization of stream ecosystems. In this paper, we focus on stream channel geomorphology as an important parameter regulating the retention of dissolved and particulate matter in streams. However, we also report on how the retention process is influenced by the interaction between channel geomorphology and other factors such as landform, riparian vegetation, and hydraulics. We used an experimental approach involving releases of leaves and nutrients into the channel to determine rates of retention in different geomorphic settings.

Study Area

Releases of leaves and nutrients were conducted in Lookout Creek, a fifth-order stream located within the H.J. Andrews Experimental Forest in the Cascade Mountains of Oregon, USA. We studied four discontinuous reaches in Lookout Creek (designated C, D, E, and G in this study), ranging from 336 - 547 m in length. Elevations of the study reaches ranged from 400-600 m, channel gradient was 2-3 percent, and summer baseflow discharge was 0.28-0.42 m^3/sec. Stream substrates were dominated by cobble and small boulders. Accumulations of large woody debris in the channel were significant features of some reaches.

The four reaches were classified on the basis of valley floor landform and riparian vegetation (Table 1). The valley floor is considered to be that portion of the valley that has been influenced by fluvial processes. Two categories of valley floors represented in this study were: constrained reaches, in which the valley floor was less than 3 times the width of the active stream channel, and unconstrained reaches, in which the valley floor was greater than 4 times the active stream channel width (Fig. 1). Based on these criteria, reaches C and E were constrained and reaches D and G were unconstrained.

Riparian vegetation was classified as old-growth conifer forest or second-growth mixed deciduous and conifer forest. Reaches C and D (one constrained and the other

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Table 1 – General characteristics of the four study reaches in Lookout Creek, Oregon.

	Reach			
Parameter	C	D	E	G
Valley Floor	Constrained	Unconstrained	Constrained	Unconstrained
Riparian Vegetation	Old-Growth	Old-Growth	2nd-Growth	2nd-Growth
Multiple Channels	Absent	Present	Absent	Present
Sediments	Shallow	Deep	Moderate	Deep
Canopy	Closed	Partly Open	Open	Partly Open
Lateral Stream Habitat	Limited	Abundant	Limited	Abundant
Woody Debris	Sparse	Abundant	None	Abundant
Dominant Channel Unit	Pool/Cascade	Riffle/Rapid	Rapid	Pool/Rapid

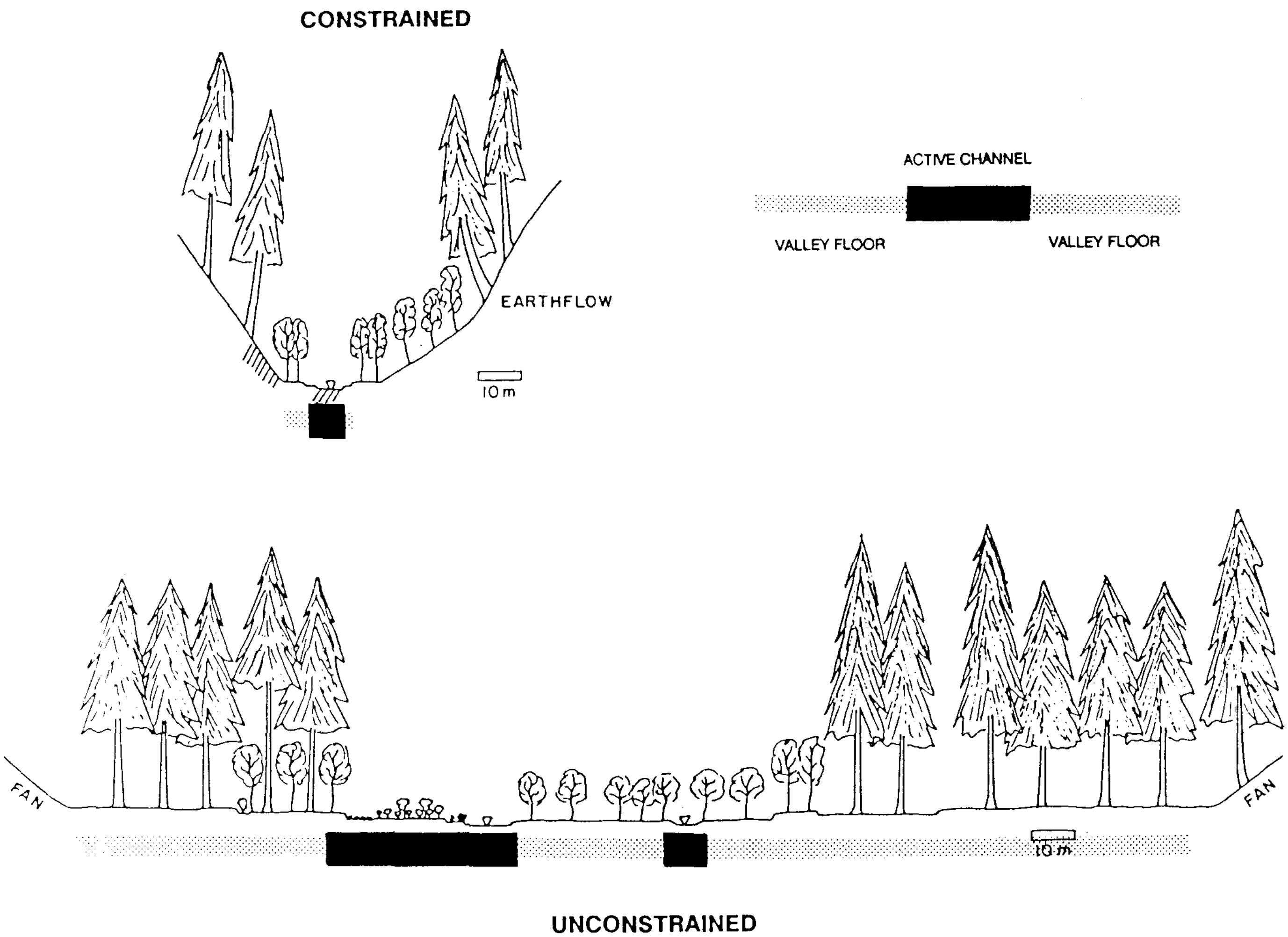

Figure 1— Schematic representation of constrained reach C and unconstrained reach D in Lookout Creek.

unconstrained) had old-growth riparian vegetation dominated by mature Douglas fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). The other two reaches E and G were in second-growth riparian zones dominated by young stands of red alder (*Alnus rubra*), big-leaf maple *(Ater macrophyllum),* and some conifers.

Mapping of valley floor landforms and channel geomorphology was conducted prior to this study (G. Grant and F. Swanson, unpub. data). The unconstrained reaches had two channels that spanned most of the reach length, whereas the constrained reaches consisted of a single channel. Specific reaches were divided into channel units, which were identifiable geomorphic components of the channel at least as long as the channel was wide. Channel units in this montane stream included cascades, rapids, riffles, and pools.

Materials And Methods

Retention can be thought of as the difference between the quantity of particles or dissolved nutrients in transport at a given point in the stream and the quantity still in transport at some point downstream, given no significant new inputs over that distance. This difference is best expressed in some standardized form because quantities of released particles or nutrients, length of stream examined, or duration of measurement will vary from experiment to experiment. Previous releases of leaves indicate that retention is represented well by a negative exponential model (Speaker and others 1984):

$$T_d = T_i e^{-kd}$$

where T_i is the total amount of released leaves or nutrients, T_d is the amount of leaves or nutrient in transport at some distance d downstream of the release point, and k is the instantaneous rate of removal from transport (instantaneous retention rate or retention coefficient). The average travel distance of a leaf or nutrient atom is the inverse of the retention coefficient, or $1/k$ (Newbold and others 1981).

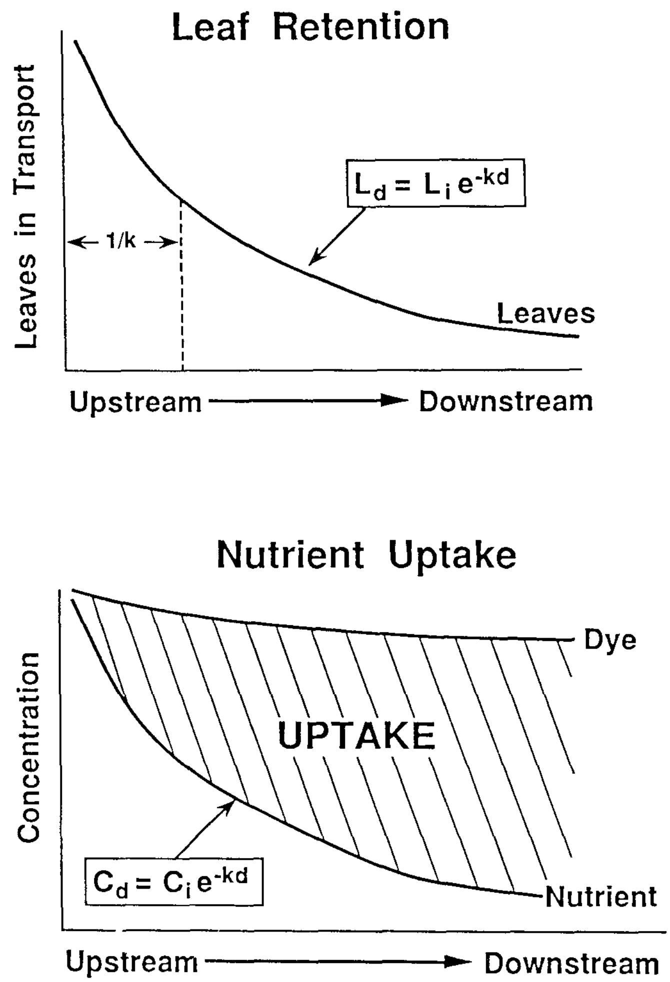

Figure 2 — Empirical models of leaf and nutrient retention in streams. A negative exponential model provided the best fit for observed retention of leaves and ammonium.

Leaf Retention

Ginkgo leaves (*Ginkgo biloba*) were released into the channel to measure particulate matter retention. Ginkgo leaves are about the same size as leaves of many riparian tree species, but gingko trees do not occur naturally in North American riparian zones. The leaves are bright yellow and thus easily distinguished from those of other riparian species. Ginkgo leaves were collected just after abscission, dried, and counted into 5000-leaf batches. Leaves were soaked in water for 12 hours prior to release to ensure neutral buoyancy in the stream. One batch of 5000 leaves was released at the top of each study reach. At 100 m downstream, a net was placed across the stream channel to capture any leaves that were not retained within that 100-m segment. All leaves caught by the net for 2 hr after the release were retrieved and counted. Leaf retention downstream of the release point conformed to a negative exponential model in most cases (Fig. 2).

Nutrient Retention

Because ambient nutrient levels throughout Lookout Creek typically are about 15 *u*g/L total inorganic nitrogen (TIN = NO_3-N + NO_2-N + NH_4-N) and 15 *u*g/L soluble reactive phosphorus (SRP = PO_4-P) for a N:P ratio of 1:1, production is usually limited by the availability of nitrogen. Ammonium nitrogen (as NH_4C1) was released into Lookout Creek to measure dissolved nutrient retention. NH_4Cl, the labile nutrient, was mixed in water with rhodamine-WT, a conservative dye tracer, to form a concentrated batch of nutrient and dye. This mixture was released at a constant rate into a turbulent area of the stream using a steady-head dripper system. Dye and nutrient usually mixed completely with stream water within 50 m of the release point. Sufficient ammonium was released to raise equilibrium TIN levels to between 50 and 70 *u*g/L (i.e., 3-5X above ambient) at the upstream end of the reach. When equilibrium was reached, two water samples were taken at the bottom of each channel unit within the reach. Dye concentration in one sample was measured on a Turner fluorometer. Ammonium concentration was determined in the other sample with a Technicon II autoanalyzer using the phenate method.

The conservative dye tracer provided a measurement of downstream dilution due to incoming tributaries, springs, seeps, and groundwater (Fig. 2). All nutrient measurements were adjusted for dilution using the correction NH_4-Nd . (Dye_i/Dye_d), where i is the concentration at the top of the reach and d is the concentration at some distance d downstream where the corresponding nutrient sample was taken. Dye releases also allowed measurement of discharge and hydraulic retention. All releases of leaves and nutrients were conducted at summer baseflow (0.3-0.4 m^3/sec) during August and September of 1987.

Results

Geomorphology and Hydraulics

The valley floor index, which is the ratio of the valley floor width to the active stream channel width, ranged from 1.3-2.8 in the constrained reaches C and E to >6.0 in the unconstrained reaches D and G (Table 2). Unconstrained reaches had 2-3 times the number of channel units as constrained reaches. This is due, in part, to the two parallel channels present in unconstrained reaches, which contributed units, wetted surface area, and total length to those reaches. For example, thalweg length was similar in the old-growth pair C and D and the second-growth pair E and G, but total length was two to three times higher in the unconstrained reach of each pair. Further, active channel area in unconstrained reach D was almost double that of constrained reach C. This a real difference was not as striking in the second-growth reaches E and G because constrained reach E was located on an alluvial fan, which resulted in a somewhat broader channel. However, downcutting through the fan still applied local constraint to reach E.

Discharge was 10-30 percent higher in unconstrained reaches than in constrained reaches, probably because of flow contributions from large stores of subsurface water in the deeper sediments of those reaches (Table 2). The time required for dye saturation of unconstrained reaches was about twice as great as for constrained reaches, indicating greater hydraulic residence time in the unconstrained reaches. In other words, unconstrained reaches retained water for a much longer time than did constrained reaches.

Table 2. - Geomorphic and hydraulic characteristics of the four study reaches in Lookout Creek, Oregon.

Parameter	Reach C	Reach D	Reach E	Reach G
Valley Floor Index[1]	1.3	6.9	2.8	[2]6.0
Thalweg Length (m)	410	547	349	336
Total Length[3] (m)	415	1198	391	663
Mean Width of Active Channel (m)	18.7	28.0	26.3	[2]30.0
Active Channel Area (m^2)	3948	7080	3005	3597
No. Channel Units	17	52	13	34
Discharge (m^3/sec)	0.31	0.40	0.28	0.31
Reach Saturation Time (h:m)	1:45	3:30	0:55	1:50

[1]Walley floor width (m) / Active channel width (m)
[2]Estimated
[3]Cumulative length of all channels

Table 3 - Leaf and nutrient (NH_4) retention in the four study reaches of Lookout Creek, Oregon. Length of experimental reach was 100 m for all leaf releases, and thalweg length for all nutrient releases.

Parameter	Reach C	Reach D	Reach E	Reach G
Leaf retention Coefficient k	0.008	0.031	0.008	0.045
Average Leaf Travel Distance (m)	132	33	125	22
NH_4 Retention Coefficient k	.0014	.0092	.0059	.0044
Average Ammonium Travel Distance (m)	732	109	171	229
Absolute Retention (*ug* NH_4-N•L^{-1}·$100m^{-1}$)	6.0	15.3	17.8	25.8

Leaf Retention

Leaf retention coefficients ranged from 0.008 in both constrained reaches to 0.031-0.045 in the unconstrained reaches (Table 3). The average travel distance of an individual leaf was 125-132 m in the constrained reaches compared to only 22-33 m in the unconstrained reaches. In constrained reaches, slightly over 50% of released leaves were retained in the 100-m reach whereas >95% of leaves were retained in the unconstrained reaches. The riparian setting (old-growth or second-growth) did not appear to influence rates of leaf retention, but rather valley constraint was the predominant factor.

Within specific reaches, high-velocity channel units with high roughness, such as rapids and cascades, retained more leaves than lower-velocity units with limited roughness, such as pools. Units with significant amounts of bedrock trapped few leaves. We observed that most retained leaves were trapped in interstitial areas between rocks, especially cobble and boulders. Substrates along stream margins trapped leaves more efficiently than similar substrates in mid-channel areas. Sticks and branches, where present, trapped leaves with high efficiency. Accumulations of woody debris, which occurred along stream margins in Lookout Creek, also trapped large quantities of leaves. Thus, in general, stream margins were more retentive than mid-channel areas, especially when these lateral habitats had roughness elements such as protruding rocks or woody debris.

Nutrient Retention

Ammonium retention coefficients ranged from 0.0014 in the old-growth constrained reach to 0.0092 in the old-growth unconstrained reach (Table 3). Retention coefficients were intermediate and similar in the second-growth reaches. Nutrient retention was very low in the constrained old-growth reach, where the average nitrogen atom traveled over 700 m before being retained; in absolute quantities, only 6 *u*g/L of NH_4-N (or 10.9 percent of that released) was retained over 100 m. In contrast, the average nitrogen atom traveled only 109 m in the unconstrained old-growth reach, and absolute uptake was over twice that of the constrained reach. Over 25 percent of the released ammonium was retained in 100 m.

In the second-growth reaches, nutrient retention was slightly higher in the unconstrained reach, where about 26 *u*g/L of released nitrogen was retained in 100 m. However, nutrient retention was quite high in the constrained reach as well (18 *u*g NH_4-N•L^{-1}.100 m), in particular when compared to the constrained reach in the old-growth. Over one-third of the released nutrient was retained in 100 m of the unconstrained reach, and about 25 percent was retained in the constrained reach.

Discussion

Geomorphic and Hydraulic Comparisons

The unconstrained reaches were characterized by broad valley floors bisected by two stream channels dominated by riffles, rapids, and some small pools. The relatively low gradient (2 percent) and reduced stream power of those reaches allowed accumulation of woody debris in the channel, which further increased channel complexity. Stream sediments were deep and heterogeneous. Lateral habitats were well developed and included secondary channels, backwaters, and isolated pools. Diversity of hydraulic environments was high, and water residence times were great due to considerable subsurface flow.

Riparian vegetation was diverse, and included herbaceous, shrub, deciduous, and coniferous species. Stratification of riparian vegetation was apparent, in that herbs and shrubs were located close to the active channel, whereas deciduous and coniferous trees grew at greater distances from the active channel. Because of this stratification, incident sunlight striking the channel was relatively high in unconstrained reaches, which resulted in substantial growths of benthic plants. For example, benthic algae and mosses covered 24-29 percent of the active channel in the unconstrained reaches.

Constrained reaches, by contrast, were characterized by a single channel with limited sinuosity and poor development of off-channel (lateral) habitat. In the Cascade Mountains, these gorge-like settings are often the result of either active hillslope processes such as earthflows, landslides, and deposition of alluvial fans or passive constraints such as bedrock outcrops that prevent lateral movement of the channel. Both mechanisms tend to funnel flow through a narrow slot on the valley flow. As a consequence, stream gradients are steeper (>3 percent), water depth is greater, and water velocity and stream power are higher than in unconstrained reaches. Due to scour at high flow, sediments tend to be shallow and woody debris accumulation is limited. In the old-growth constrained reach, vegetational diversity and stratification was low because conifers were perched close to the stream channel. Shading of the channel by hillslopes and nearby conifers limited benthic plant cover to only 10 percent of the channel. The second- growth constrained reach was somewhat unique in that it occurred on a broad but inactive alluvial fan. Although the channel was simple and linear, it was wide and its sediments were relatively deep. Light levels on the channel were high because of the absence of large conifers combined with low topographic shading. Accordingly, cover by benthic plants (46 pct.) was the highest of any reach.

Retention in Stream Ecosystems

Particulate and dissolved matter in transport provides a critical source of nutrients for a substantial portion of the aquatic biota. Particulate organic matter (POM) delivered from adjacent riparian zones into streams includes leaves, needles, seeds, twigs and woody debris. In the stream, this organic matter is decomposed by microheterotrophs such as bacteria and fungi or consumed by detritivorous invertebrates such as insects and snails (Cummins and others 1983). Often, a period of microbial conditioning is necessary before POM becomes palatable to invertebrate consumers (Anderson and Sedell 1979). Dissolved nutrients in streams include inorganic compounds such as nitrogen, often in the form of ionic ammonium (NH^+_4) and nitrate (NO^-_3), and phosphorus, as orthophosphate (PO_4^{-3}). These nutrients are utilized by stream plants such as benthic algae during photosynthesis, and by certain microheterotrophs such as bacteria during cellular metabolism (Triska and others 1983).

Particulate matter is retained in streams primarily by physical trapping. Channel roughness elements, such as coarse sediments and woody debris greatly enhance the retentive efficiencies of stream reaches (Speaker and others 1984). Leaves are trapped in the interstices of bed particles and within networks of woody debris accumulations. Along stream margins, low water velocities, shallow depths, and high roughness increase the potential for retention. Thus, complex lateral habitats will enhance leaf retention whereas simple (linear) stream margins will hinder retention.

Leaf releases in Lookout Creek indicated that unconstrained reaches were substantially more retentive of particulate matter than were constrained reaches. This retentive efficiency of unconstrained reaches was due to a number of factors, including (1) high roughness, (2) substantial development of lateral habitats (e.g., backwaters and side channels), (3) extensive wetted area, (4) low water velocities, (5) presence of woody debris along stream margins. These factors acted in concert to increase contact between leaves and streambed particles, and thereby enhance trapping of particulate matter. In contrast, constrained reaches were relatively unretentive of leaves. These reaches had lower roughness and wetted area, and thus there was reduced opportunity for contact between leaves and streambed. Poor development of lateral stream habitats in constrained reaches also limited leaf trapping along stream margins.

Dissolved Matter Retention

Dissolved nutrients can be retained in stream ecosystems by three different mechanisms: (1) uptake by primary producers, including benthic algae and mosses, (2) absorption or transformation by heterotrophic microorganisms, (3) chemical or physical sorption onto surfaces of inorganic substrates or detritus (adsorption). It is not clear which mechanism(s) was most important for nutrient retention in Lookout Creek. All three processes probably operated to some degree. Mechanism 1 was supported by our observation that retention was highest in reaches with the highest algal abundance, as in the constrained second-growth site. Microbial transformation (mechanism 2) also occurred because as ammonium declined in a downstream direction, nitrate increased slightly, indicating some microbial nitrification (conversion of ammonium to nitrate). Although we have no direct evidence for mechanism 3, as a cation ammonium is readily bound chemically and sorbed physically and thus some removal by this mechanism probably occurred. Regardless of whether the process was uptake, transformation, or sorption, retention serves to conserve nutrients in a specific reach. These nutrients may be used immediately as in the case of uptake or transformation, or stored for later use as in the case of adsorption.

High levels of nutrient retention in the unconstrained reaches are probably attributable to the geomorphic and hydraulic complexity of these reaches, which enhances opportunity for nutrient uptake and adsorption. In the old-growth, the unconstrained reach had 2.5 times the nutrient retention of the constrained reach. The unconstrained reach had more algae, higher hydraulic residence, greater water-sediment contact, and deeper sediments than the constrained reach. All of these factors could enhance mechanisms 1- 3 above and thus increase nutrient retention. The unconstrained second-growth reach also had substantial nutrient retention, probably because of high rates of algal uptake in this open reach. The alluvial fan that formed the streambed also may have provided the opportunity for ammonium adsorption during subsurface flow.

Summary

Retention of dissolved and particulate matter is of critical importance to the operation of stream ecosystems. Retention largely determines the availability of food resources to aquatic organisms. Long-term retention of detritus delivered from riparian zones, with its subsequent microbial colonization and consumption by detritivores, is critical to energy transfer in most streams. Retention of dissolved nutrients permits levels of primary production and microbial growth necessary to support grazing invertebrates. Higher consumers such as fish that rely on invertebrates for food are thus dependent on retention processes to supply food resources for their invertebrate prey.

Retention efficiency is intimately linked to riparian conditions and ultimately to valley floor landforms. Highly complex channels within broad valley floors display high retention, whereas simple channels within narrow valleys are less retentive. Channel geomorphology, including lateral habitat, bedform, and substrate characteristics, is a major determinant of rates of particulate and nutrient retention. Complex strata of riparian vegetation permit light gaps that encourage primary production and thus nutrient retention, while ensuring a steady source of detritus to the stream. Second-growth riparian zones may enhance nutrient retention due to algal uptake, but sacrifice particulate matter retention because of channel simplification. Retention is a complex interaction of valley floor geomorphology, riparian conditions, and in-stream biological demand that accentuates the intimate linkage between aquatic and terrestrial ecosystems.

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A NEW APPROACH TO FLOOD PROTECTION DESIGN AND RIPARIAN MANAGEMENT[1]

Philip B. Williams and Mitchell L. Swanson[2]

Abstract: Conventional engineering methods of flood control design focus narrowly on the efficient conveyance of water, with little regard for environmental resource planning and natural geomorphic processes. Consequently, flood control projects are often environmentally disastrous, expensive to maintain, and even inadequate to control floods. In addition, maintenance programs to improve flood conveyance and enhance levee stability, such as clearing riparian vegetation in channels and on levees, undergo little – if any – technical scrutiny. Such programs are often prescriptive in nature, rather than based on actual performance standards. A new approach to planning channel modifications for flood damage reduction is presented that is multi-objective and incorporates proper consideration of hydrologic, geomorphic, and biologic factors that influence stream hydraulics.

Extensive channelization of natural streams has occurred in the last 40 years in urbanizing areas. The purpose of these channelization projects, termed "channel improvements" by hydraulic engineers, was generally to maximize the area and value of developable land by reducing flood hazards. The conventional design methods used for flood control channels were developed mainly based on research carried out in the first half of this century (Brater and King, 1976; Chow 1959). The design methods were based on the application of hydraulics research on sediment-free fluid flow in relatively simple artificial pipe, flume, and weir configurations to modified natural streams. Parallel research in fluvial geomorphology on the behavior of natural streams in flood was not typically incorporated into design methods used by public works engineers.

The design methods used today are little different from those used forty years ago. However, with the advent of the computer and hydraulic programs such as HEC-2 (U.S. Army Corps of Engineers, 1982), the analysis of flood elevations and hydraulics is considerably quicker and easier.

The usual design standard for flood control projects is to protect surrounding areas against inundation in a 100-year flood or the Standard Project Flood (equivalent to about the once in 200- to 500-year flood). Most channelization projects have only been in existence for 2 or 3 decades, and so very few projects have actually experienced floods the size of the design flood. Nevertheless, there is now sufficient "operating" experience with artificial flood control channels in smaller floods to now be able to assess the adequacy of some of the conventional hydraulic engineering design criteria, and to propose a new approach to flood control design and riparian management.

Problems with Conventional Flood Control Design

Underestimation of Roughness of Lined Channels

Conventional flood control design methodology seeks to minimize the right-of-way required for flood control channels by increasing flow velocities, thereby allowing a narrower channel to be built that reduces flood elevations. This is done typically by lining the channel with smooth reinforced concrete. With a suitable slope in a uniform channel, the low roughness of the concrete can allow "super-critical flow" to develop very fast-moving shallow flow. When super-critical flow occurs, the channel cross-section and right-of-way can be significantly reduced. This has led to many channels of this type being built in California in the last two or three decades.

Coastal Northern California has experienced two large floods in the last three decades, in January 1982 and February 1986. The experience of the channelized Branciforte Creek (completed 1959) in Santa Cruz County in 1982, and Corte Madera Creek (completed 1970) in Marin County in 1982 and 1986, shows that these super-critical flow channels do not perform as designed and can overtop their banks at flows considerably smaller than their design flood.

Figure 1 shows the channelized Corte Madera Creek overtopping in the 1982 flood when in-channel flows were approximately 4,500 cfs, equivalent to about the 15-year flood. The design flood at this location was 7,800 cfs, with 2 feet of freeboard, equivalent to about the 200-year flood.

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Figure 1— Corte Madera Creek during the January 4, 1982 flood overtopping its banks just upstream of a bridge near the College of Marin. Turbulence in foreground is water hitting the bridge face. The rectangular concrete channel is about 2 feet below water surface during a 15-year recurrence flood of 4,500 cfs. The channel was designed to contain a 200-year flood of 7,800 cfs with 2 feet of freeboard. Similar flooding occurred in February of 1986. (Photo: Philip Williams)

On Branciforte Creek during the 1982 flood, the channel filled to the top of its capacity at a peak discharge of 6,650 cfs. This channel was designed to contain a Standard Project Flood of 8,500 cfs with 2 feet of freeboard.

The primary reason for the failure of these channels in medium-sized floods was that the actual effective roughness of the channel during the flood was considerably larger than that calculated by conventional design methods.

Immediately after the 1982 flood, it was possible to identify the flood profile on Corte Madera Creek by flood marks in the chain-like fence along the channel shown in Figure 1.

The best fit analysis using HEC-2 indicates that the actual Manning's roughness at the time of the flood peak was approximately 0.030 instead of the 0.014 assumed in the design for smooth concrete channel (Vandivere and Williams 1983). The higher roughness meant that flow was "sub-critical" rather than super-critical as designed, and consequently flood elevations were approximately 6 feet higher than predicted for the design flood, even though flows were considerably lower.

The primary reason for the increased roughness was the bed load sediment conveyed through the channel. After the flood, boulders up to 12 inches in diameter were observed in a sediment delta formed at the downstream end of the channel. Without considering the effect upon roughness of bed forms, gravel and boulders of this magnitude would be sufficient to cause the increase in roughness that was observed by increasing energy losses at the bed of the channel. A number of researchers in fluvial geomorphology (e.g., Limerinos 1970) have demonstrated the relation between bed load size and channel roughness in natural streams. For a Manning's roughness of 0.030, the d84 value would be 2.6 inches (d84 = 84 percent of particles in the sample are smaller than 2.6 inches).

In retrospect, the increase in roughness observed in the concrete channel is not surprising. Wherever flood flows are large, large amounts of sediment are mobilized and are conveyed downstream by natural watercourses. This bed material cannot be prevented from entering the concrete channel section, and all of it is conveyed throughout the channel length without the opportunity for deposition in any section. Nevertheless, concrete channels of this type continue to be designed and constructed based on "clear water" analysis, ignoring the direct effects of sediment on the hydraulics.

In natural streams, super-critical flow rarely occurs in long reaches due to the size of bed material mobilized (Jarrett 1984).

Failure to Account for Channel Bed Erosion and Deposition

Clear-water analysis design procedures currently in use do not take into account the significant changes in channel morphology that occur during the course of a flood. Reassertion of meandering in an artificially straightened channel can cause levee failure. However, the most significant effects on flood levels are changes in the channel bed.

Hydrologic design criteria for artificial channels assume high antecedent rainfall prior to the design flood event. In California and in many other locations, this creates the conditions for large numbers of debris avalanches and mudflows (National Research Council and U.S. Geological Survey 1984). Large amounts of sediment and debris are introduced into tributary streams and can cause significant aggradation (filling with sediment) of the bed, particularly where the floodplain has been developed, eliminating the natural sediment storage area. This can raise flood elevations and cause flood paths to be substantially different than those predicted.

Further downstream, the channel bed can degrade during the course of a flood, lowering flood elevations below those predicted by clear water analysis. An example of the failure to consider the erosion and deposition of sediment in a river channel is the case of the San Lorenzo River Channelization Project in Santa Cruz completed in 1958. The defect in the original hydraulic design, which assumed that the river channel could be maintained at down to about 8 feet below sea level at its mouth, has been documented by Griggs (1984). By 1982, the channel bed had typically silted up about 6 feet. According to clear-water analysis, the flood control project could only protect against the 30-year flood. In January 1982, the flood flow of 30,000 cfs was approximately the 30-year flood, but the flood was contained within the levees. Approximately 4-6 feet of scour had occurred at the downstream end during the time of the flood peak, greatly increasing the capacity of the channel.

Current design criteria do not recognize the benefit of keeping a natural sand bed in a channel in reducing flood levels. This leads to construction of flood control projects such as the Los Angeles River flood control channel which have concreted the channel bed, preventing scour in a large flood.

Failure to Account for Debris

Clear-water design of channels generally ignores or underestimates the role of floating debris in increasing flood elevations. In California and in many other areas, large floods can carry large amounts of debris such as uprooted vegetation and trees, fences, and parts of structures. On smaller streams, this, combined with sediment, invariably impedes or completely blocks the hydraulic efficiency of small- to medium-sized culverts. Further downstream on the main channels, bridges and culverts can be partially obstructed, causing significant increases in flood elevations upstream. On some creeks during large floods, the water surface profile is actually a staircase of obstructed culverts and backwater ponds.

The rise in water surface elevation due to backwater from an obstructed bridge can greatly exceed the reduction in water surface elevation due to stream channelization. Figure 2 shows an extreme case – a bridge across Soquel Creek in Santa Cruz County obstructed by debris during the 1982 flood (9,700 cfs, or about a 16-year flood event) (Thompson 1982). Flood elevations were increased at least 10 feet upstream and directed the main flood flow out of the channel.

Underestimation of Maintenance Requirements

The engineering perception that the design of flood control projects is mainly a question of selecting the appropriate channel geometry, has led to an emphasis on initial construction of a flood control project. This in turn has led to neglect of consideration of how flows, sediment, and vegetation interact in determining flood-elevations in modified streams. Very little analysis has been carried out of realistic maintenance requirements. Instead, assumptions are made concerning stream geometry and channel roughness, and these are imposed as maintenance requirements on the channel, whether or not they are cost-effective.

Typically, in trapezoidal earth-lined flood control channels, a design Manning's roughness of about 0.03 to 0.04 is used. According to a somewhat subjective interpretation of roughness values for low-gradient natural streams, the design engineer may determine that no woody vegetation can be allowed in the channel bed and banks, and any that grows there must be regularly removed as part of a prescriptive maintenance procedure. Wide trapezoidal channel beds exposed to the sun are ideal nurseries for riparian vegetation such as willows and cattails, and costs of removal can be high. Frequently, local flood control districts have insufficient money for maintenance and economize by carrying out prescriptive maintenance every few years instead of every year. This can result in the vegetation being managed at a state at which it offers greatest resistance to flows – short dense brushy vegetation in the channel bed. Figure 3 illustrates how roughness changes with the age of riparian vegetation.

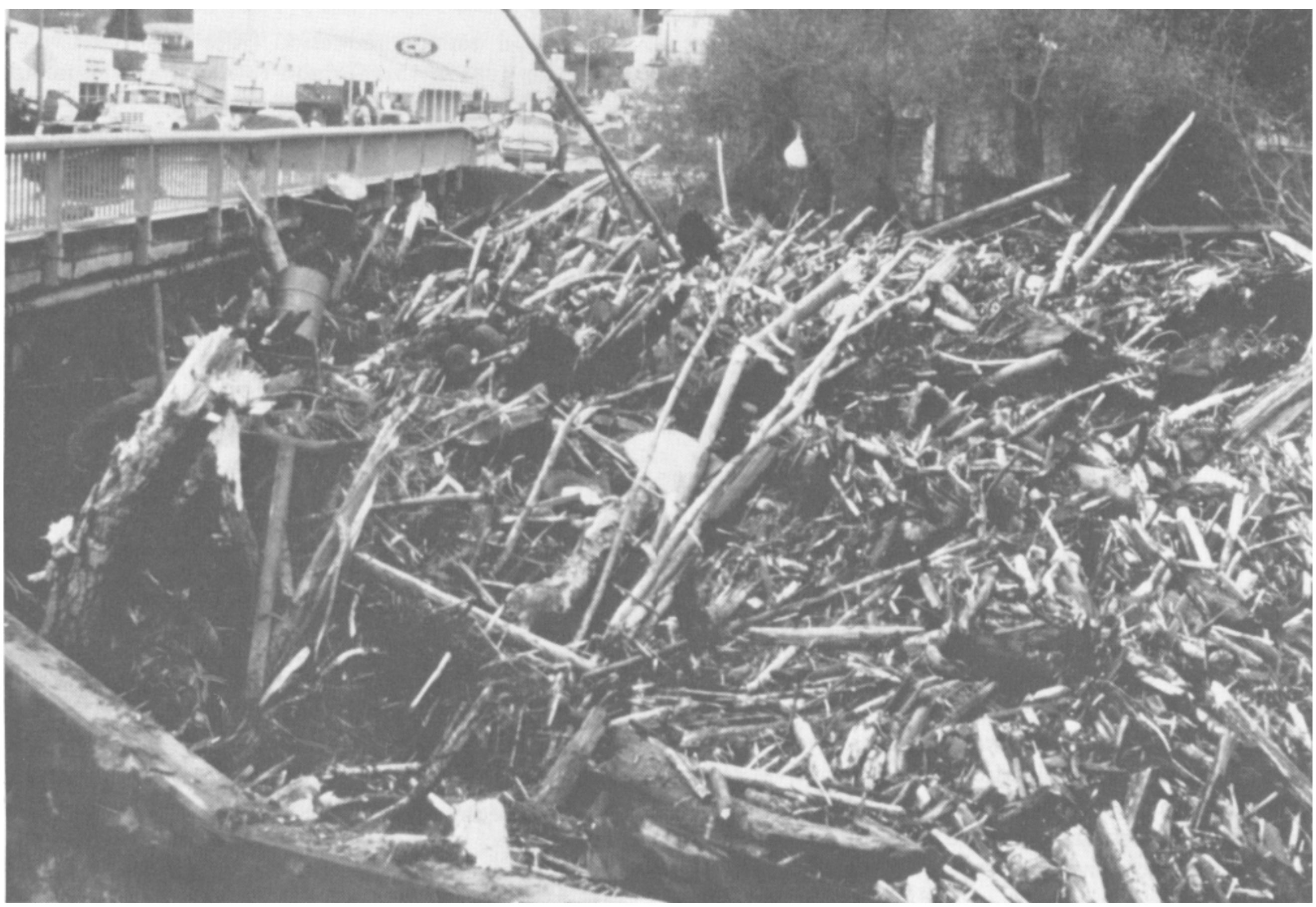

Figure 2—A debris jam of Soquel Creek at the upstream side of the Soquel Drive Bridge after the January 4-5, 1982 flood. This jam (27,000 yd') diverted most of the flood discharge (estimated at 9,700 cfs and about 15-year recurrence) through town (visible in upper left background). Flow depths of up to 6 feet exceeded predicted 100-year elevations. (Photo: Gary B. Griggs)

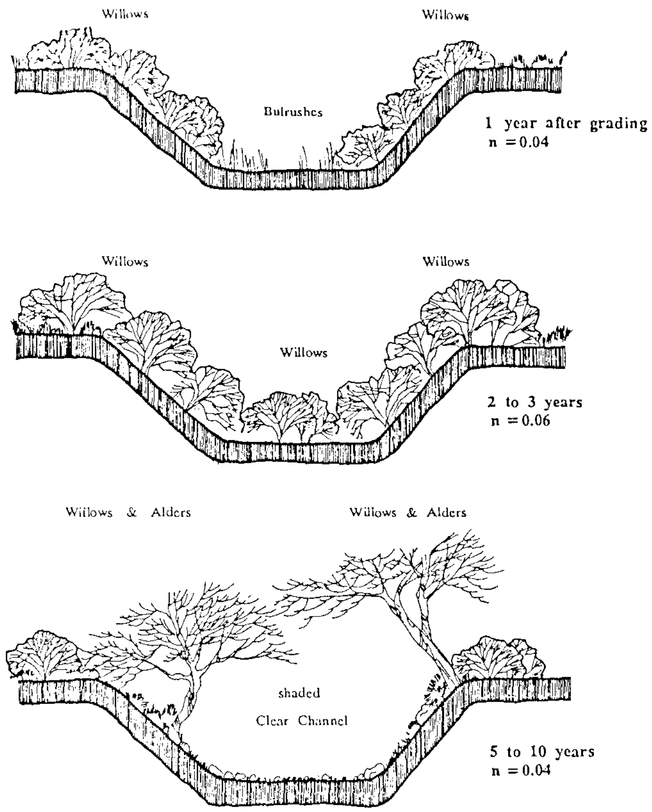

Figure 3 — Conceptual diagram of change in channel roughness with age of riparian vegetation.

Other maintenance costs that are frequently underestimated are sediment, debris, and garbage removal and repair of channel bank erosion.

The lack of effective maintenance can often negate the reductions in flood elevation initially achieved by channelizing the stream.

Current Design Methods Overestimate Channelization Benefits

Failure to recognize the design problems described earlier tends to result in an exaggerated expectation of benefits of stream channelization over alternatives that preserve a more natural creek corridor. Recognition of realistic roughnesses and the role of sediment and debris would tend to reduce the supposed benefits of lined channels in favor of preserving flood plains and providing adequate bridge crossings. Recognition of natural scouring during floods would call into question the rationale for lined channel beds. Adequate consideration of maintenance requirements would recognize the hydraulic benefits of more natural riparian vegetation and channel morphology over geometric cross-sections.

A New Approach to Flood Control Design

With an experience of the last few decades, we suggest a design process that will lead to greater long-term reduction in flood damages while allowing the enhancement of riparian corridors. The following are the key elements of this process:

1. Utilize an integrated planning process: This requires an understanding that stream modification will affect more than flood levels. All the significant hydrologic, geomorphic, ecologic, and economic factors have to be considered, rather than approach the design as a plumbing problem. This generally requires involvement of a range of skills beyond traditional hydraulics engineering.
2. Clearly Identify Design Objectives: Stream modifications are rarely single-purpose projects. They typically can include the following:
   - Flood damage reduction (it is important to state this goal in this fashion rather than the nebulous and impossible "control" of floods);
   - Protecting or restoring riparian ecosystems;
   - Providing recreational access;
   - Enhance property values along creek corridor.
3. Understand the physical system: This means developing an understanding of the natural hydrology and geomorphology of the particular watershed and then identifying past, and possible future, human-caused influences on these physical processes. Such an understanding provides the setting in which to establish specific design criteria for a particular reach.
4. Carry out an integrated design: An integrated design would consider not only the direct effects of stream modification on flood elevation but also all the significant processes that affect flood elevations and are affected by the channel modification. Typically, these would include:
   - Downstream effects on hydrology and stream morphology;
   - Effect of future changes in watershed on hydrology and sediment delivery;
   - Relationship between riparian vegetation management and channel hydraulics;
   - Effect on seasonal streamflows;
   - Effect on groundwater levels and recharge;
   - Effect on fisheries;
   - Effect of changes in flow velocities on bank erosion, downcutting, and upstream drainage system;

- Planning for the consequences of failure of any part of the flood management system, e.g., levee failure or culvert obstruction;

- Designing to minimize long-term maintenance requirements, taking into account the evolution of the stream corridor.

5. Develop maintenance program based on performance standards: The methods used presently for flood control channel maintenance are generally prescriptive in nature. Typically, there is a maintenance program at a set time interval to strip vegetation and regrade channels whether or not it is actually required. Such maintenance practices are not only environmentally destructive but can be expensive and not particularly effective.

A performance standard-based maintenance program would establish maximum design floodwater surface elevations. Periodic monitoring of the stream channel, including cross-section surveys and inspection of potential obstructions and channel roughnesses would be required. The results of this monitoring would be used in standard hydraulic programs such as HEC-2 to determine in what portions of the channel sediment removal or vegetation thinning may be required. This approach could significantly reduce the frequency, extent, and environmental disruption of channel maintenance. It would tend to allow riparian vegetation to reach maturity, thereby shading the channel and reducing roughness (see Figure 3). It would also allow the channel the opportunity to flush out some of its accumulated sediments in small-sized floods.

An Example of Integrated Design — Wildcat Creek

The Wildcat Creek flood control project in North Richmond, California, is an example of the application of many of the aspects of the integrated design approach described above. This project was originally proposed more than 20 years ago as a concrete channel, then as a single-purpose trapezoidal earth channel. Concern by local citizens and environmentalists led to the adoption of a multi-purpose design by the Army Corps of Engineers and Contra Costa County Flood Control District. The key elements of this adopted design, referred to as the "consensus plan," are shown in Figure 4 and are contrasted with the earlier trapezoidal plan. This project, which is intended to reduce flood damages in the adjacent community, restore the riparian corridor, and provide public recreational access, is now under construction.

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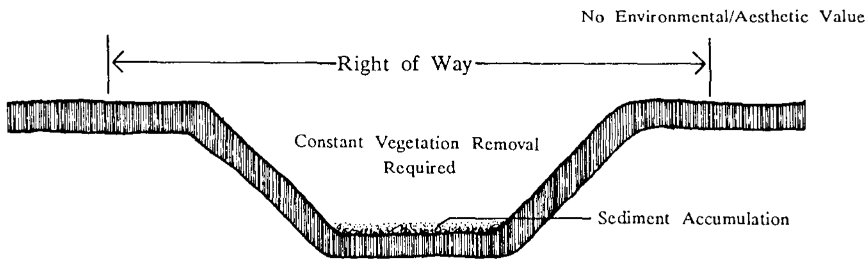
A) Single Purpose Trapezoidal Channel (Rejected)



B) Multipurpose 'Consensus Plan' (Implemented)

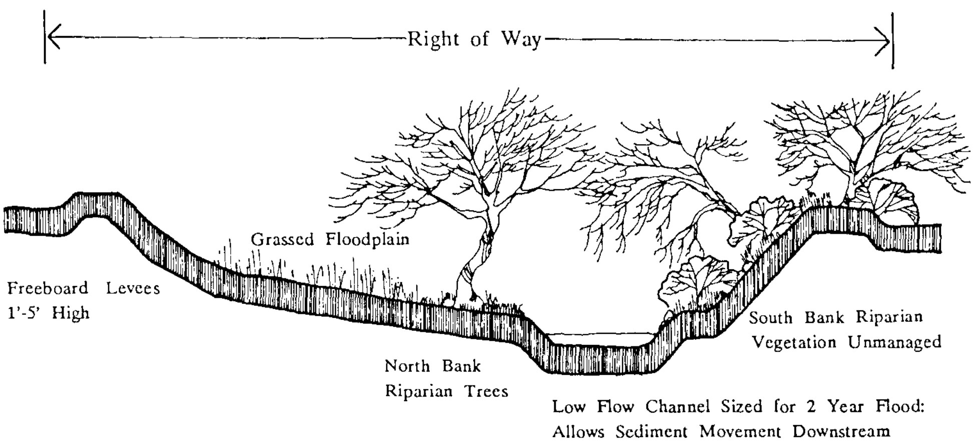


Figure 4— Conceptual designs for Wildcat Creek Flood Control Project.

EFFECTS OF BANK REVETMENT ON SACRAMENTO RIVER, CALIFORNIA[1]

Michael D. Harvey and Chester C. Watson[2]

Abstract: Twelve low radius of curvature bends, half of which were rivetted, were studied in the Butte Basin reach of Sacramento River, California, to determine whether bank revetment deleteriously affected salmonid habitat. At low discharge (128.6 cubic meters/s) it was demonstrated that revetment does not cause channel narrowing or deepening, nor does it prevent re-entrainment of gravels on point bars. Point bar sediments in rivetted bends are not coarser than those in non-rivetted bends. Point bar morphology is stage-dependent, and therefore, point bars are both sources and sinks for spawning-size gravel which can mitigate against reduced gravel recruitment due to bank revetment.

Approximately 20 percent of the total bank length (both banks) in the Butte Basin reach of Sacramento River has been rivetted to prevent bank erosion and meander migration that have threatened flood-control levees and flood-relief structures. Revetment in this paper refers to the bank protection method of sloping back an eroding bank (2H:1V) and covering it with rock. A number of concerns have been expressed about the possible effects of bank revetment on the morphologic characteristics of the bends on the river, which in turn may have adverse effects on the salmonid fishery (CA Department of Fish and Game (DFG) 1983; CA Department of Water Resources (DWR) 1984). Approximately 57 percent of the total spawning area in the river is associated with meander bends (fig. 1), and meander bends are also important juvenile rearing areas (DWR 1984). Chinook salmon select spawning areas with a narrow range of physical conditions. Spawning conditions appear to be optimum when the gravel size in the substrate is between 25 and 152 millimeters, flow depth is greater than 0.25 meters, and flow velocity is between 0.2 and 1.5 meters/s (Diebel and Michny 1986). Rearing area: are generally shallow and have low velocity (DFG 1983). Preferred salmon spawning areas are at pool-riffle interchanges (fig. 1) in a bend (Reiser and Bjornn 1979).

Bank erosion rates and the rates of lateral migration of the channel are highest on Sacramento River when the bend radius of curvature to width ratio (Rc/W) is 2.5, and they are both lower when Rc/W is greater or lesser than 2.5 (Nansen and Hickin 1986; Harvey 1988). Measured lateral migration rates range from 37 to 10 meters/year (Harvey 1989). Bends are generally rivetted when Rc/W is between 2.3 and 3.8 because the rates of bank erosion are high. The principal concerns on Sacramento River are that revetment will: (1) cause the river to deepen and narrow, (2) cause a coarsening of sediments on the point bars, (3) prevent re-entrainment of gravels deposited on the point bars, and (4) prevent gravel recruitment from the eroding banks. The objective of this investigation was to determine whether revetment of low radius of curvature bends in the Butte Basin reach was adversely affecting the salmonid habitat by modifying the morphologic characteristics of the bends.

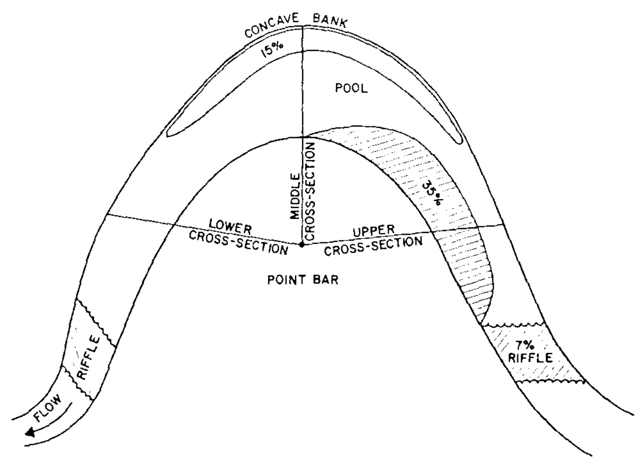


Figure 1— Schematic diagram of a meander bend that shows the locations of surveyed cross sections. The cross-hatched areas are preferred salmon spawning areas and the percentages indicate the importance of these with respect to all spawning areas along the Middle Sacramento River (DWR 1984).

Few studies have been conducted to determine the effects of bank revetment on river morphology. Friedkin (1945) in a laboratory study of a model stream with sand bed and sand banks observed that revetment caused thalweg deepening and vertical accretion of the point bars in bends with a wide range of radii of curvature, but channel narrowing occurred only in bends with a

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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high radius of curvature. The concerns expressed about the effects of revetment (DFG 1983; DWR 1984) appear to be based on the results of this study. Following revetment of a low radius of curvature bend on Red River, Arkansas, water-surface width increased, flow depth decreased and cross-section area did not change. Therefore, revetment did not cause channel narrowing or deepening (Water Engineering and Technology, Inc. 1987). Fall River, Colorado, is a very sinuous, sand and gravel transporting meandering stream with banks that are root reinforced. The extreme resistance of the bank materials is analogous to the effects of bank revetment. Point bars on Fall River are dynamic, stage-dependent geomorphic features even when the concave bank does not retreat (Anthony and Harvey 1987a, 1987b; Harvey and others 1987).

Sacramento River Field Study

Data Collection

Under low-flow conditions (128.6 cubic meters/s) twelve bends in the Butte Basin reach were investigated. Half of the bends were revetted and half were not. The radii of curvature of both sets of bends ranged from 381 to 572 meters. Harvey (1989) demonstrated that the morphology and dynamics of bends on Sacramento River could be related to the radius of curvature of the bends. At each bend three cross sections were surveyed to a common datum with a boat-mounted fathometer and an EDM-theodolite (fig. 1). The cross sections were located consistently at: (1) the upstream limb of the bend (upper), (2) the bend apex (middle), and (3) the downstream limb of the bend (lower). In the non-revetted bends the toe sediments of the concave bank which were primarily composed of point bar sands and gravels (non-cohesive) or abandoned-channel fills (cohesive) were recorded at each cross section. Wolman counts (Wolman 1954) of the lower point bar sediments were made at the head of each point bar to determine the size distribution of the sediments because the sediments at this location are the coarsest on the point bar (Bluck 1971). From the cross-section surveys the following data were obtained: (1) water-surface width, (2) maximum flow depth, (3) average flow depth, and (4) cross-section area below the water surface. Average flow velocities were calculated from the continuity equation (Q - A.V). The survey data was also used to determine the water-surface slope through the bend. Grain-size distribution parameters were obtained from the Wolman counts.

Data Analysis

Mean and standard deviations for each of the variables for the revetted and non-revetted bends were determined and the means were tested for statistically significant differences with a t-Test (90% probability level). The results of the t-Tests of the means for all the revetted (18) and non-revetted (18) cross sections (table 1) indicate that: (1) water-surface width in revetted bends is less than that of non-revetted bends, (2) there is no difference in maximum depth, (3) average depth is less in revetted bends, and (4) cross-section area is less in revetted bends. When the non-revetted cross sections were subdivided on the basis of the cohesiveness of the concave bank toe sediments and were compared to the revetted cross sections, the statistical analyses indicate that: (1) there is no difference in water-surface width, (2) the maximum depth is associated with cohesive sediments, (3) average depth is less in revetted bends, and (4) cross-section area is less in revetted bends. These results indicate that the effect of revetment on water-surface width is equivocal, but revetment does cause a reduction in average flow depth and cross-section area. The deepest (maximum depth) flows were associated with the occurrence of cohesive sediments in the toe of the concave bank.

Table 1 — Comparison of cross section variables at revetted and non-revetted bends of Sacramento River. Discharge was 128.6 cms.

Type of Bend	Water Surface Width (m)	Max. Depth (m)	Average Depth (m)	Cross Section Area (m^2)
revetted	106.7+20.5	3.7+1.5	1.6+0.8	166.3+69.7
(No. Obs.)	18	18	18	18
Non-revetted	119.5+20.8	4.2+1.6	2.3+0.7	263.4+55.0
(No. Obs.)	[1]18	[2]18	[1]18	[1]18
Non-CohesiveToe	118.6+17.7	3.7+0.9	2.1+0.5	246.1+46.1
(No. Obs.)	[2]13	[2]13	[1]13	[1]13
Cohesive Toe	121.6+29.7	5.7+2.1	2.7+1.0	308.2+178.9
(No. Obs.)	[2]5	[1]5	[1]5	[1]5

[1] Significantly different from revetted value at 90% probability level.
[2] Not significantly different from revetted value at 90% probability level.

The revetted and non-revetted cross sections were compared on the basis of their locations within a bend: upper, middle, lower (table 2). The results of the statistical tests indicate that: (1) revetment has no effect on water-surface width, nor maximum flow depth, at any of the locations within a bend, (2) revetment causes a reduction in average flow depth in the upper and middle cross sections, but has no effect on the lower cross section within a bend, and (3) revetment causes a reduction in cross-section area in the upper and middle cross sections, but it has no effect on the lower cross section within a bend. The results indicate that the effects of revetment are limited to the upper and middle parts of a bend, and the principal effect is a reduction of average flow depth.

Water-surface slopes and grain-size parameters for the revetted and non-revetted bends were compared statistically (table 3). The results indicate that revetment has no effect on water-surface slope or on the grain-size distributions of the point bar sediments.

Table 2 — Comparison of cross section variables at different locations in revetted and non-revetted bends of Sacramento River. Discharge was 128.6 cms.

Cross Section	Water Surface Width (m)	Maximum Depth (m)	Average Depth (m)	Cross Section Area (m[2])
Upper:				
revetted	110.6+27.7	3.0 + 1.3	1.3+0.6	136.3+47.5
Non-revetted	127.7+24.7	3.9 + 0.4	2.2+0.3	271.0+12.7
(No. Obs.)	[2]6	[2]6	[1]6	[1]6
Middle:				
revetted	109.1+19.0	3.4 + 0.9	1.6+0.7	164.1+69.4
Non-revetted	112.5+20.0	4.3 + 1.3	2.3+0.5	256.2+32.4
(No. Obs.)	[2]6	[2]6	[1]6	[1]6
Lower:				
revetted	99.7+19.0	4.8 + 1.6	2.1+1.1	198.4+84.5
Non-revetted	117.8+17.5	4.5 + 2.5	2.4+1.2	262.7+94.5
(No. Obs.)	[2]6	[2]6	[2]6	[2]6

[1] Significantly different at 90% probability level.
[2]Not significantly different at 90% probability level.

Table 3 — Comparison of water-surface slopes and grain-size variables at revetted and non-revetted bends of Sacramento River. Discharge was 128.6 cms.

Type of Bend	Water Surface Slope (m/m)	d_{50} (mm)	d_{95} (mm)	[1]d_s (mm)
revetted	0.00013+0.000083	15.1+6.9	38.6+12.7	2.1 + 0.3
(No. Obs.)	[2]6	[2]6	[2]6	[2]5
Non-revetted	0.000101 +0.000091	12.4+4.7	42.5+14.0	2.1 + 0.4
(No. Obs.)	6	6	6	5

[1]d_s is geometric standard deviation
[2]Not significantly different at 90% probability level.

Discussion

This investigation of the effects of revetment on salmonid habitat, which was conducted under low-flow conditions, when the alleged effects of revetment are considered to be most deleterious (DFG 1983), has addressed some of the principal concerns about the effects of revetment on river morphology. Revetment does not cause an increase in channel depth, but in fact appears to cause a reduction in average flow depth in the upper and middle parts of a bend, which may increase the area of rearing habitat in a bend (DFG 1983). The reduction in average flow depth is not sufficient to reduce flow depths below those required for spawning (0.25 meters: Diebel and Michny 1986). The effects of revetment on water-surface width are equivocal because the statistical analyses have produced conflicting results (tables 1 and 2). Revetment does not induce a coarsening of the point bar sediments (table 3), nor does it appear to affect water-surface slope (Friedkin 1945). However, because of continuity, a reduction in cross-section area at a constant discharge must result in higher average velocity in revetted bends. When all of the cross sections (36) were considered, the mean flow velocity + 1 standard deviation of the revetted and non-revetted bends were 0.97 + 0.35 and 0.57 + 0.15 meters/s, respectively. The results of a *t*—Test indicate that the means were different statistically. There was no statistically significant difference between the mean velocities in revetted and non-revetted bends at the lower cross section. However, the mean velocity (0.97 + 0.30 m/s) of the revetted middle cross sections was significantly different from that of the middle non-revetted cross sections (0.56 + 0.08 m/s). This was true also for the upper cross sections (1.16 + 0.39 m/s *vs.* 0.52 + 0.02 m/s). Therefore, revetment appears to cause an increase in the average flow velocity in the middle and upper parts of the bend. However, the increased velocities are well within the limits of 0.2 to 1.5 meters/s required for spawning (Diebel and Michny 1986).

The effects of revetment on gravel re-entrainment from point bars could not be addressed directly in this investigation. However, data from the Butte Basin reach of Sacramento River are available, (Gundlach and Murray 1983), where monumented cross sections were resurveyed at different discharges (fig. 2). The repeat surveys demonstrate that point bar morphology is stage-dependent, and that vertical accretion occurs during higher discharges. This accords with the observations of Anthony and Harvey (1987a, 1987b) and Harvey and others (1987).

There is no doubt that revetment of a bend prevents recruitment of gravel from the floodplain at that location. Vanoni (1987) concluded that 85 percent of spawning-size gravels are derived from bank and bar erosion, and therefore, revetment will reduce gravel availability. However, to some extent the reduced availability from bank erosion sources is mitigated by the fact that point bars are both sinks for and sources of gravel because they accrete vertically during higher flows and are eroded during recessional flows (Anthony and Harvey 1987a, 1987b; Harvey and others 1987) provided that there is an upstream source of gravels.

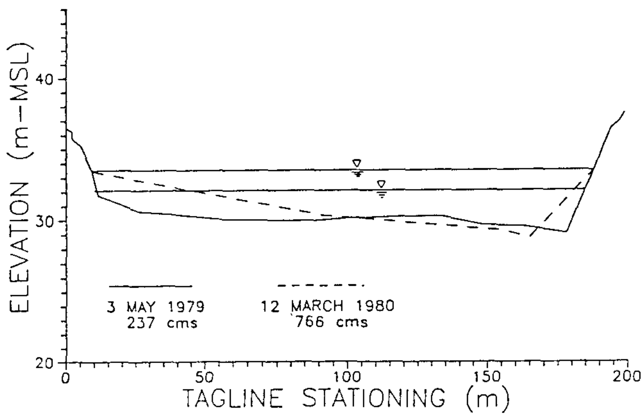

Figure 2 Cross section adjustments with change in discharge in a revetted bend. Data from Gundlach and Murray (1983).

Conclusions

Revetment of individual bends in the Butte Basin reach of Sacramento River does not effect salmonid habitat adversely. Revetment does not cause channel narrowing or deepening, nor does it prevent re-entrainment of point bar gravels or cause coarsening of the point bar sediments. Gravel recruitment from point bars mitigates to some extent the elimination of the banks as gravel sources provided that there is an upstream source of gravels.

Acknowledgments

We thank Ed Sing of the Sacramento District, Corps of Engineers for his assistance, and Z.B. Begin, Geological Survey of Israel, S.A. Schumm, Colorado State University, and two anonymous reviewers for their constructive reviews. The study was funded by Contract No. DACW05-87-C-0094, U.S. Army Corps of Engineers.

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POST-FIRE INTERACTIONS BETWEEN RIPARIAN VEGETATION AND CHANNEL MORPHOLOGY AND THE IMPLICATIONS FOR STREAM CHANNEL REHABILITATION CHOICES [1]

Susan C. Barro, Peter M. Wohlgemuth and Allan G. Campbell [2]

A heat wave in southern California during the summer of 1985 set the stage for a record fire year. One of the largest fires began on July 1, 1985 when an arsonist ignited a blaze in the Wheeler Gorge area of the Los Padres National Forest in Ventura County, California. Of the 118,000 acres (47,790 ha) burned in the Wheeler Fire, over 60 percent was scorched by high intensity fires, resulting in severe watershed damage and the production of hydrophobic soils. ore than 30 miles (50 km) of stream channel were also damaged in the fire. The size and intensity of the blaze, as well as its proximity to the pictur-esque town of Ojai, caused managers great concern over the possibility of mudslides and flooding during the first post-fire winter. Plans for emergency rehabilitation, which included reseeding and channel clearing, were implemented immediately.

To investigate post-fire interactions between riparian vegetation and channel morphology, we selected a 100 m section of burned riparian zone situated in a 1.5 mi^2 (4 km^2) portion of the upper Santa Ynez River drainage basin (34°29'N, 119°26'W)(Figure 1). The sampling scheme involved repeated channel surveys and tree inventories from fall 1985 through winter 1988. Located along a boulder-bed reach about 2.8 mi (4.5 km) upstream of Jameson Lake, a water supply reservoir serving the city of Montecito, the vegetation is typical of a South Coast Riparian Forest: *Alnus rhombifolia* (white alder) is the dominant species, but *Platanus racemosa* (sycamore), *Populus* fremontii(cottonwood), and *Quercus agrifolia* (coast live oak) are also common.

The intensity of the fire through the riparian area is indicated by the damage to trees and the understory. The understory species—which included *Ribes, Rosa*, and *Toxicodendron*—were completely removed by the fire and only bare ash remained. Over 90 percent of the alders in the studied reach were killed by fire (Figure 2). Many of the oaks, sycamores and cottonwoods were top-killed but were vigorously sprouting from the base. Although there appeared to be no correlation between tree diameter and mortality, we speculate that bark thickness may affect differential mortality.

Fire, in addition to removing vegetation, causes changes in soil characteristics which lead to accelerated erosion on hillside slopes. In fall 1985, the first rainstorms after the fire flushed hillslope debris into the channels, clogging them with sediment. High winds occurring in December 1985 toppled many dead branches and some whole trees into the channel. Subsequent storms organized the downed trees into loosely structured dams of organic debris occurring on average every 10-15 m. These logjams affected the sediment dynamics of subsequent flows, as accumulated sediments were flushed downstream and trapped behind these barriers. The amount of sediment stored behind these structures was quite varied and ranged from one tenth to five cubic meters. Logjams were not noticeable immediately after the burn; rather pre-fire channel configuration was determined by the position of large boulders.

Post-fire riparian vegetation/channel interactions can be dictated by management practices. The USDA Forest Service Burned Area Rehabilitation Handbook (FSH 2509.13) suggests that the best management practice balances downstream value protection with the environmental implications of the treatment. To protect life and property, treatments generally involve channel clearing, necessarily at the expense of the riparian environment. Because trees in the riparian zone (both living and dead) act as stabilizing elements in streambed configuration, their removal will provoke adjustments in channel morphology. In addition, removal of obstructions increases flow velocity; which may scour the channel bed, increase the sediment load, degrade the water quality, export nutrients out of the system, and cause deterioration of the biotic habitat.

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[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California

[2] Botanist, Hydrologist, and Hydrologist, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Riverside, California

Channel clearing is often undertaken even when life and property are not at risk. If downstream values include water supply or flood control reservoirs (as along the Santa Ynez River), a more appropriate course of action may be to leave the burned riparian zone intact. While more sensitive to debris flows produced by catastrophic storms, during more moderate events, obstructions will dissipate some of the flow energy, and the increased sediment storage capacity will buffer the sedimentation impacts downstream. Logjams will create a stepped channel gradient, resulting in a slower routing of nutrients, increased water quality, and greater habitat diversity. Although logjams constitute an additional channel configuration parameter, ascertaining the influence of specific obstructions on channel morphology was beyond the scope of this study.

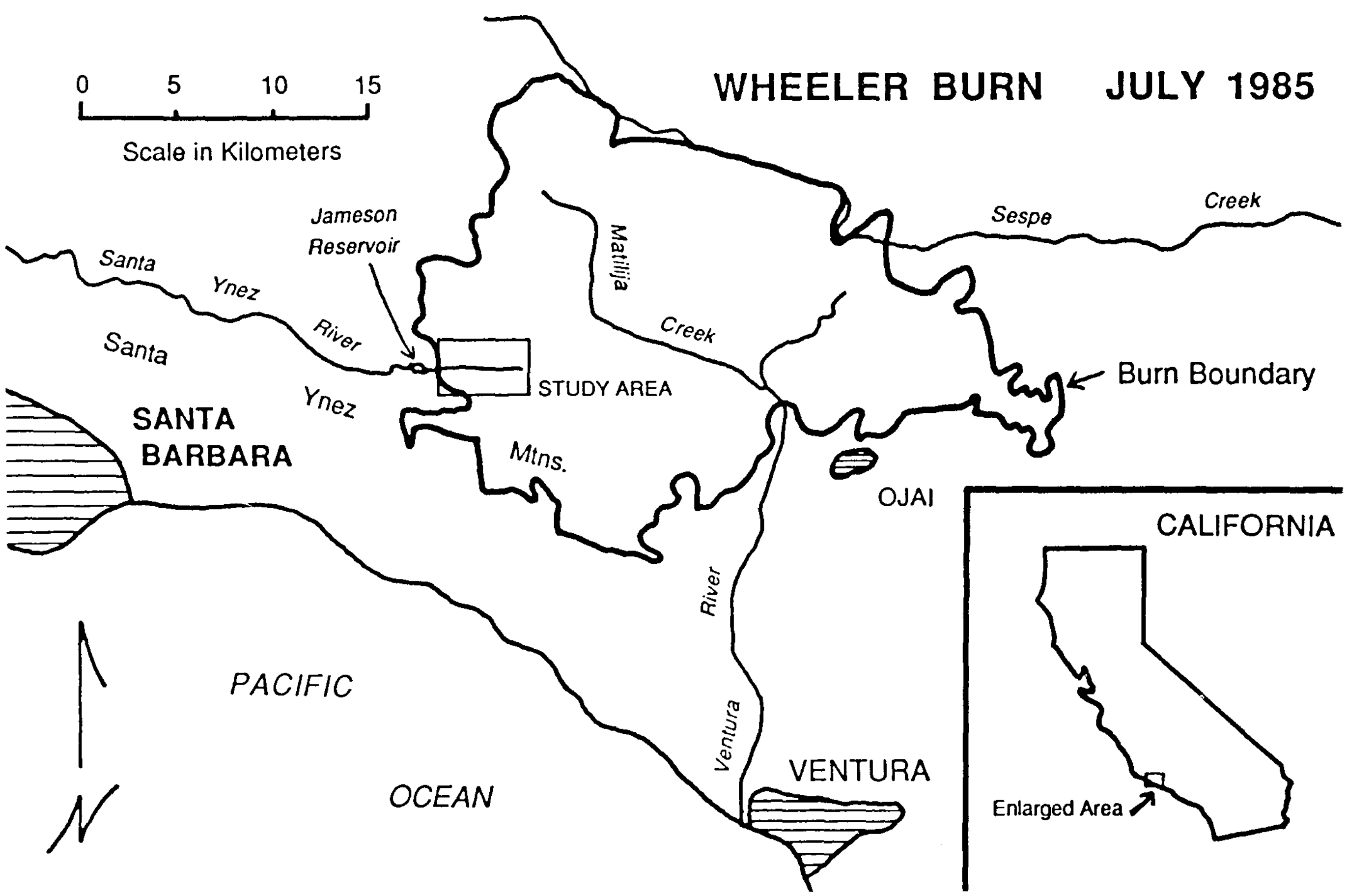

Figure 1—Location map of the study area on the upper portion of the Santa Ynez River

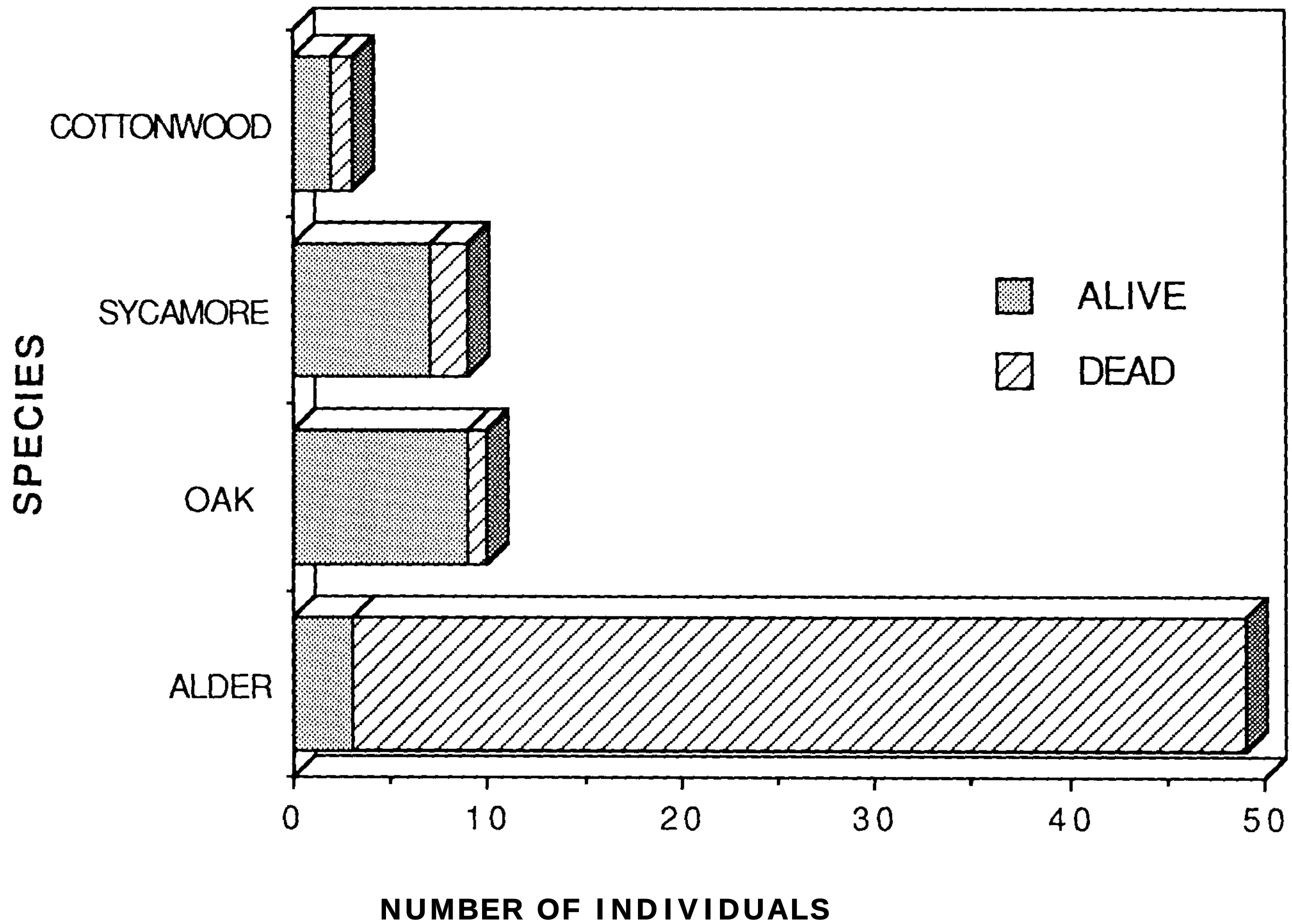

Figure 2—Tree species frequency and degree of mortality within the study area

MEANDERBELT DYNAMICS OF THE SACRAMENTO RIVER, CALIFORNIA[1]

Michael D. Harvey[2]

Abstract: A 160km-long reach of Sacramento River was studied with the objective of predicting future changes in channel planform and their effects on water-surface elevations. Planform data were used to develop regression relationships between bend radius of curvature (Rc) and both short-term (5 years) and long term (90 years) lateral migration rates (MR) and migration distances (MD). A dimensionless cutoff index (Rc/MD) was developed to predict bend cutoff occurrence. Cutoffs occur when the cutoff index value is between 1.7 and 3.7. Channel planform controls water-surface elevations and bend cutoffs can reduce upstream water-surface elevations by up to 1 meter over a wide range of discharges.

In order to obtain an understanding of the meander dynamics of the Sacramento River, which is a coarse-grained meandering river located in the Great Valley of California, a geomorphic study of a 160km-long reach of the river from Colusa to Red Bluff was undertaken in 1987 (fig. 1). The reach of river between Glenn and Chico Landing (Butte Basin), which is located at the upstream end of the flood-control levees, is of major importance to flood control in the lower Sacramento Valley. The objectives of this study were to see if: (1) an understanding of meander dynamics could be used to predict the rates and locations of within-channel erosion and deposition due to changes in river planform, and (2) the planform of the river has significant effects on overbank flooding and sedimentation.

Point-bar development and concave bank erosion have been the principal concerns of those studying the dynamics of meandering rivers. Figure 2 is a schematic diagram of a reach of a meandering river that defines the terms that are used in this discussion of the dynamics of the Sacramento River. Erosion along the concave bank occurs because of convective acceleration in downstream flow (Henderson 1966), and because of intensification of cross-stream flow. Both are caused by flow convergence which implies that the shape of a meander bend significantly affects bank erosion (Nanson and Hickin 1983). As the radius of curvature of the bend decreases, the channel cross section in the pool zone is constricted laterally because of vertical growth of the point bar (Knighton 1984; Carson 1986). Therefore, lateral migration of the channel and concave bank erosion are dependent on the flow characteristics and the shape of the bend.

The rate of bank retreat is dependent on the resistance to erosion of the concave bank materials (Nanson and Hickin 1986), the duration and magnitude of the flows (Odgaard 1987), the radius of curvature of the bend (Nanson and Hickin 1983, 1986; Odgaard 1987), and the capacity of the flows to transport bed- material sediment (Neill 1984; Nanson and Hickin 1986). Channel migration is a discontinuous process because it is dependent on the occurrence of flood flows (Brice 1977;

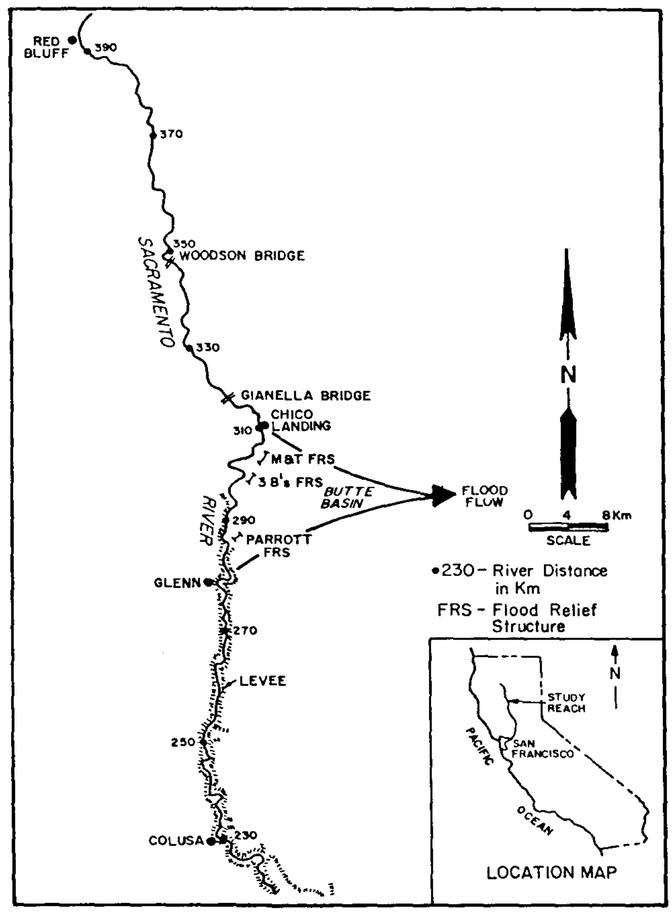

Figure 1 — Location map for study reach of Sacramento River.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Geomorphologist and Hydraulic Engineer, respectively, Water Engineering & Technology, Inc., Fort Collins, Colorado.

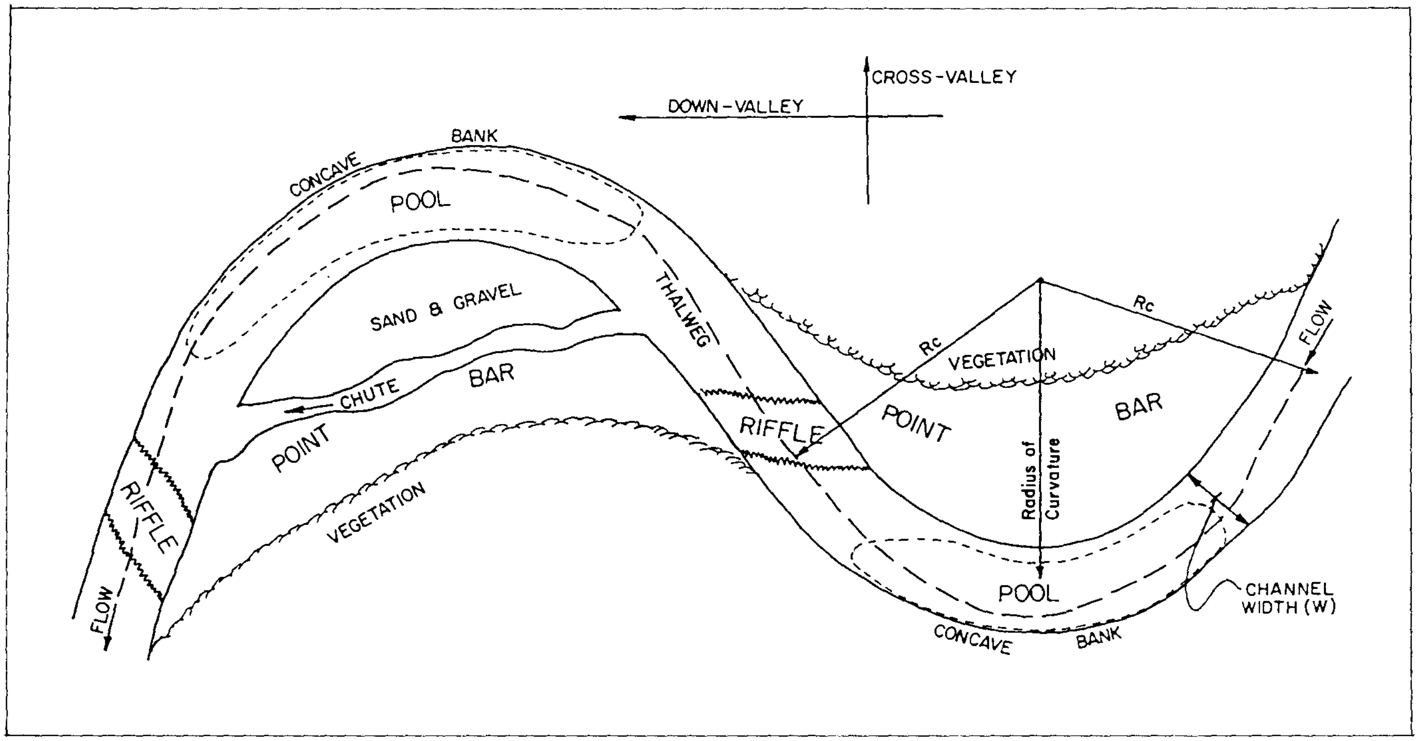

Figure 2— Schematic diagram showing in planform the geomorphic surfaces and features that are associated with meander bends.

Nanson and Hickin 1983). Initially bends migrate in a cross-valley direction (extension) (fig. 2), but eventually bends advance in the down- valley direction (translation) (Brice 1977; Knighton 1984; Leeder and Bridge 1975; Nanson and Hickin 1983, 1986).

Meander bends eventually cut off when the radius of curvature decreases below a certain value which is specific to each stream. Reduction of the radius of curvature of a bend causes backwater upstream of the bend, and this is expressed physically as a reduction in the slope of the water surface. Since the sediment transport capacity of the flows is proportional to the slope of the water surface, a reduction in slope reduces the sediment transport capacity of the flows. This causes deposition of sediment in the upstream limb of the bend between the pool and riffle (fig. 2). Deposition of sediment reduces the flow capacity of the channel and this causes flows to be diverted over the point bar (fig. 2). These flows erode the point bar surface and form chutes (Carson, 1986; Lisle, 1986). However, cutoffs can occur as a result of either chute development (Lewis and Lewin 1983; Brice 1977) or neck closure (Fisk 1947). The review of literature suggests that changes in river behavior should be predictable. Any prediction of future behavior is based on past behavior, streams being no exception (Schumm 1984). Implicit in this approach is the assumption that the sequence of hydrologic events (i.e., flood flows) that have controlled the behavior of the river in the past will be repeated.

Channel Migration and Bank Erosion

Data on channel planform (1:12,000) were available from the California Department of Water Resources (DWR) River Atlas (DWR 1984) and 1986 aerial photographs (1:400). Hydrologic records from 1879 were available at the U.S. Geological Survey gaging station at Bend Bridge, which is located upstream of Red Bluff. The planform data were used to construct a data base which could be used to investigate channel migration and bank erosion in the 32km-long reach between Glenn and Chico Landing (fig. 1). Changes in rivers are generally associated with large floods and, therefore, it is important to differentiate between short-term and long-term behavior. Short-term behavior of the river was based on a 5-year period of record between 1981 and 1986 because large magnitude flow events occurred in both 1983 and 1986. Long-term behavior of the river was based on the period of record (1896 to 1986).

Short-Term Migration Rates

Bagnold (1960), Leeder and Bridge (1975) and Nanson and Hickin (1983, 1986) have demonstrated that lateral migration rates of meandering rivers can be correlated with the radius of curvature (Rc) of bends. Migration rates are highest when the radius of curvature to channel width (W) ratio (Rc/W) is about 2.5. Radii of curvature (Rc) and 1981-1986 migration rates (MR) for 11 bends were measured to obtain short-term data on river behavior. Radii of curvature ranged from 381 to 838 meters and migration rates varied from 37 to 10 meters/year. A least- squares regression of the data is:

$$MR = 53.57 - 0.049Rc \quad (R^2 = 0.69) \qquad (1)$$

Long-Term Migration Rates

In order to determine long-term behavior of the river, radii of curvature and migration rates for the period of record (1896- 1986) were utilized. The radii of curvature were assigned to 9 class intervals that varied by 76-meter increments from 229 to 838 meters. The average channel width in each bend was determined by measurement from the DWR Atlas and the 1986 aerial photographs, and both the migration rate and radius of curvature were divided by the channel width (Nanson and Hickin 1986). The average width of the river in the study reach is 150 meters. The relationship between the radius of curvature-width ratio (Rc/W) and the migration rate-width ratio (MR/W) is shown in figure 3. Also shown in figure 3 are the means and standard errors for the 9 class intervals and the curves which define the upper limits of Nanson and Hickin's (1986) data. The mean migration rates on Sacramento River are close to Nanson and Hickin's maximum values. This suggests that migration rates on Sacramento River are high in comparison with the Canadian sand and gravel streams.

The relationships between the mean migration rates and the radii of curvature were established on logarithmically-transformed data. For the radii of curvature greater than 381 meters (Rc/W > 2.5) the least-squares regression is:

$$MR = 6.98 \times 10^4 Rc^{-1.333} \quad (R^2 = 0.83) \qquad (2)$$

and for the radii of curvature less than 381 meters (Rc/W < 2.5) the least-squares regression is:

$$MR = 2.2 \times 10^{-6} Rc^{2.875} \quad (R^2 = 0.94) \qquad (3)$$

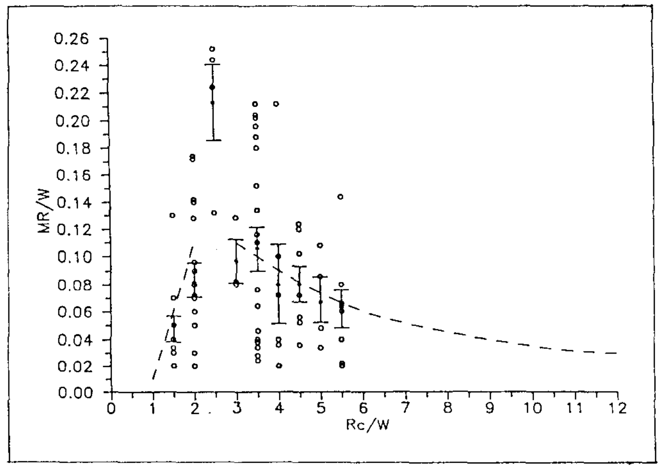

Figure 3— The ratio of migration rate (MR) to channel width (W) plotted against the ratio of radius of curvature (Rc) to width. The asterisks and bars represent the means and standard errors, respectively. The curves are from Nanson and Hickin (1986).

The reason for subdividing the data is provided by figure 3. Nanson and Hickin's (1986) curves show that for Rc/W values between 1 and 2.5 there is a direct relationship between MR/W and Rc/W. Conversely, for Rc/W values greater than 2.5 there is an inverse relationship between MR/W and Rc/W.

Brice (1977) considered that most bends on Sacramento River would cutoff by the time that the radius of curvature had reduced to 381 meters. However, a number of low radius of curvature bends (less than 381 meters) are located in the lower part of the study reach near Colusa. This may be due to the fact that the sediments are finer, more cohesive and, therefore, more resistant to erosion.

For a given class interval of radius of curvature between 381 and 838 meters (Rc/W > 2.5) the long-term migration rates are lower than short-term rates by 57 to 73 percent. This is consistent with the general observation that large magnitude, low frequency, events significantly effect changes in the river, and that change occurs because of the occurrence of large floods. Further, both the short-term and long-term data indicate that bends with radii of curvature of about 380 meters erode the fastest, but bends with radii of curvature that are either greater or lesser than 380 meters have lower rates of erosion.

Radius of Curvature and Cutoffs

The progressive development of a meander bend to the point where it cuts off is an example of exceeding an intrinsic geomorphic threshold (Schumm 1977). The cumulative frequency distributions of the radii of curvature of bends between Glenn and Chico Landing in 1969, 1981 and 1986 were determined from aerial photographs. The radii of curvature were assigned to 8 equally-spaced class intervals (305 to 838 meters). Between 1969 and 1986 the median radius of curvature declined from 600 to 550 meters. The median radius of curvature for a cutoff is 380 meters, but the range is from 305 to 610 meters. Ninety percent of all cutoffs occur when the radius of curvature is less than 533 meters. The radii of curvature of bends that had cut off since 1908 (10) and pre-1908 meander scars on the floodplain (22) were measured. The radii of curvature of four bends that had cut off following revetment were also measured.

Statistical analyses (t-Tests, 90% probability level) of the cutoff data were conducted. The results indicate that there are no statistically significant differences between the mean radii of curvature values of the floodplain (417 + 98m), post- 1908 (419 + 95m) and revetted (390 + 163m) cutoffs. This can be interpreted as indicating that changes in hydrology and upstream sediment supply due to dam construction and gravel mining (DWR, 1984) have had little effect on the meander dynamics in the Butte Basin reach. This may be due to the fact that the dams have not significantly reduced the peak flows and that sediment supply to this reach has been maintained by within-channel erosion in the reach between Red Bluff and Chico Landing (fig. 1).

A dimensionless cutoff index, which is defined as the ratio of the radius of curvature to the migration distance (Rc/MD) was developed to predict cutoff occurrence. Equation 1 was used to determine the MD values for the cutoff index for both the recent (10) and floodplain (22) cutoffs. With the exception of two floodplain cutoffs, the Rc/MD values were less than 4. The mean and standard deviation for the recent cutoffs were 2.7 and 1.0, respectively and the values for the floodplain cutoffs were 2.6 and 0.9, respectively. Therefore, cutoffs can be expected to occur when the value of the cutoff index (Rc/MD) lies between 1.7 and 3.7.

The cutoff indices for 14 bends between Glenn and Chico Landing were calculated using measured values of MD between 1981 and 1986 (table 1). The data indicate that seven of the bends have Rc/MD values that lie within the range of values that were identified for cutoffs ($1.7 < Rc/MD < 3.7$). Associated with these Rc/MD values for these seven bends are two other characteristics that were identified on the 1986 aerial photographs: (1) the presence of a mid-channel bar in the upstream limb of the bend, and (2) the presence of chutes across the point bar. Therefore, it appears that cutoffs can be predicted on the basis of the value of the cutoff index and the presence of the two ancillary features. This was tested on the bend at river distance 278.4km which had cutoff in 1986. This bend was revetted prior to 1981 and, therefore, no migration of the bend took place between 1981 and 1986. However, the radius of curvature of the bend decreased from 572 meters in 1981 to 343 meters in 1986. The MD value for a radius of curvature of 343 meters (Eq. 1) is 181 meters and, therefore, the cutoff index (Rc/MD) is 1.9. The aerial photographs confirm the presence of both a mid-channel bar in the upstream limb of the bend and the chutes on the point bar.

Table 1— Characteristics of bends between Glenn and Chico Landing, Sacramento River.

River Distance (km)	Radius Curvature (Rc) 1986 (m)	Short- term Migration Distance (MD)(m)	Cutoff Index (Rc/MD)	Presence of features 1986		
				Upstream Bar	Chute	Revetted Bank
307.8	838	49	17.1	No	No	No
306.4	495	152	3.3	Yes	Yes	No
304.8	381	186	2.1	Yes	Yes	No
304.0	229	55	4.2	Yes	Yes	No
303.0	533	21	25.4	No	No	Yes
301.6	572	155	3.7	Yes	Yes	Yes
299.2	572	162	3.5	Yes	Yes	Yes
297.6	533	88	6.0	No	No	No
293.9	838	61	13.7	No	No	No
292.8	572	143	4.0	Yes	Yes	No
288.0	533	149	3.6	Yes	Yes	No
287.2	572	116	4.9	No	Yes	Yes
285.6	381	146	2.6	Yes	Yes	Yes
280.0	686	40	17.2	No	No	No

Channel Planform and Water-Surface Elevations

The reduction in the radius of curvature of a bend increases the hydraulic resistance of the flow, which causes increased backwater upstream of the bend. This is expressed by a reduction in the slope of the water surface upstream of the bend which reduces the conveyance capacity of the channel and, therefore, promotes overbank flows.

In order to demonstrate the effects of channel planform on water-surface elevations, step-backwater runs (HEC-2) were conducted for the reach of river between Gianella Bridge and Woodson Bridge (fig. 1). Gaging stations are located at both bridges, which permits calibration of the water-surface profiles. Discharges of 360, 850 and 1980 (bankfull) cubic meters/s. were routed through cross sections that were surveyed in 1923 and 1987. The HEC-2-derived water-surface elevations were plotted against a straight-line valley distance (projected profile) upstream of Colusa, which is in contrast to the normal practice of using river distance. Since river distance changes through time, the use of a projected profile allows different surveys to be evaluated on a common basis (Harvey and others 1988).

The 1923 and 1987 HEC-2-derived projected water-surface profiles for the three discharges are shown in figure 4. Two bends, located at 66.2 and 76 kilometers above Colusa, cut off between the surveys in 1970 and 1976, respectively. The effects of the planform on upstream water-surface elevations can be seen very clearly in 1923. At the three routed discharges the water-surface elevations increase by about 1 meter upstream of the bends. Following the cutoff at 66.2 km in 1970 the water-surface elevations for the three discharges were reduced by about 1 meter upstream of the bend because the channel downstream was relatively straight and, therefore, did not create any backwater. In contrast, following the cutoff at 76 km in 1976 the water- surface elevation upstream of the bend increased or remained about constant because bends downstream of the cutoff were causing backwater.

The comparative water-surface profiles demonstrate that channel planform and its changes have significant effects on water-surface elevations, but the effects of cutoffs also depend on the planform of the channel downstream of the location of the cutoff. Because of the backwater effects of short radius of curvature bends, overbank flooding and sedimentation will occur more frequently in locations upstream of these types of bends. However, a cutoff may or may not reduce the extent of overbank flooding and sedimentation. The overbank effects of a cutoff will depend on the presence or absence of downstream bends.

Application

The ability to predict changes in river planform is important for managing rivers for erosion and flood control. Prediction of future changes is dependent on understanding the past behavior of the river, but uncertainty in prediction is introduced because of the stochastic nature of flood events which cause the changes. On the Sacramento River the ability to predict future changes is especially important in the Butte Basin reach (fig. 1). The Butte Basin reach is a naturally occurring flood overflow area at the head of the leveed section (fig. 1).

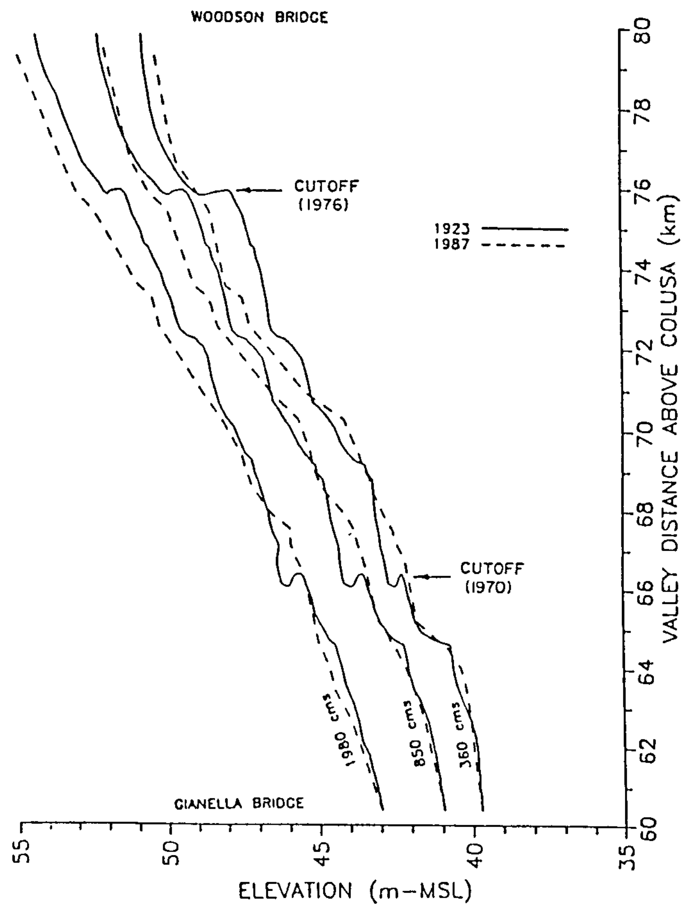

Figure 4 — Projected water-surface profiles for discharges of 360,850 and 1980 cubic meters/s derived from 1923 and 1987 cross sections between Gianella and Woodson Bridges. The solid lines represent the 1923 water-surface profiles and the dashed lines represent the 1987 water-surface profiles. Cutoffs occurred in 1970 at 66.2 km and in 1976 at 76 km.

The design-flood capacity of the leveed reach is 4286 cubic meters/s and, therefore, flows in excess of this discharge must overflow through 3 flood-relief structures (FRS) if the integrity of the levees is to be maintained.

Satisfactory operation of the flood overflows is dependent on the location of the channel with respect to the flood-relief structures, and on the planform of the river downstream of the structures. Therefore, meander migration and bend cutoffs could have serious consequences for flood control on Sacramento River. Successful operation of two of the FRS is currently threatened by potential changes in the bends at 285.6km (Parrott FRS) and 304.8km (M and T FRS). Bank erosion has been prevented by revetment at 285.6km, but the cutoff index is 2.6 (table 1) and both chutes and a mid-channel bar are present. If this bend cuts off, it is highly likely that the water-surface elevation of flood flows in the location of the Parrott FRS will be reduced by about 1 meter because the downstream reach is straight (fig. 4). Continued bank erosion can be expected at 304.8km (M and T FRS) because it is not revetted. The short-term migration rate is 36 meters/yr (Eq. 1), and the long-term rate is 25 meters/yr (Eq. 2). The cutoff index is 2.1 and chutes and a mid-channel bar are present. A cutoff of this bend will not on its own cause reduced water-surface elevations at the M and T FRS because the channel downstream is sinuous and it is causing back-water upstream (fig. 4). However, continued erosion of the concave bank (fig. 2), and down-valley migration of this bend has the potential to cause a neck cut off at the next bend downstream, and therefore, in the longer term overflows through the M and T FRS are threatened.

Conclusions

Lateral channel migration, which involves both point bar deposition and concave bank erosion (fig. 2), can be predicted by meander bend radius of curvature. Long-term rates of channel migration (Eq. 2) vary from 57 to 73 percent of short-term rates (Eq. 1) in bends whose radius of curvature ranges from 381 to 838 meters. Ninety percent of bends cut off when the radius of curvature is less than 533 meters. Bend cutoffs can be expected to occur when the cutoff index values are between 1.7 and 3.7. Meander bend cutoffs can reduce upstream water-surface elevations by up to 1 meter, and therefore, overbank flooding is highly dependent on channel planform changes. The ability to predict changes in river planform and their effects on water-surface elevations provides a rational basis for managing the Sacramento River.

Acknowledgments

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SESSION B: CENTRAL VALLEY RIPARIAN HABITATS

To the majority of people who responded to the first expressions of concern over the catastrophic loss of riparian habitats in California, the focus was entirely on the magnificent forests of mixed deciduous trees that bordered the rivers of California's Great or Central Valley. The plants primarily at risk were trees. People could see them as forests but the thought was that it was cottonwoods and oaks and the large arboreal willows, along with a scattering of ash and box elders, that were in need of preservation.

At the 1981 Riparian Systems Conference, a number of excellent papers described the great biological wealth and historical extent of riparian forests in Valley. In the years that have followed that landmark conference the focus has shifted in three distinct ways. The obvious shift was toward identifying and preserving, through purchase or other means, important examples of these forests. A second shift, arising directly from the emphasis at the 1981 Conference on systems within the riparian environment, was to recognize that there is much more at stake than just trees. Not only is the forest an extraordinarily complex community, but there is a mosaic of habitats involved, including grassland, ponds, varied successional stages leading to several different forest types, and an abundance of associated wetlands. The third shift was toward active management efforts aimed at maintaining ecological functions and enhancing the natural values of those riparian systems.

The papers that we present here include one that addresses the question of how much riparian habitat there actually was in the Central Valley historically. This is followed by three papers that deal with protection efforts and surveys for protection purposes. One describes an effort to designate sites for a national registry of natural landmarks. Another seeks to link potential sites with conditions that govern their appropriateness as preserves. A third deals with a recently initiated effort to preserve and restore riparian systems along the San Joaquin River near Fresno, where the concern is dominated by educational values of this scarce habitat.

The final two papers are drawn from the poster sessions. They are notable for being oriented toward other values—on the one hand, wildlife populations, and on the other, the linkage between riparian systems that are essentially terrestrial and the adjoining marshlands, now virtually gone.

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FEASIBILITY OF MAPPING RIPARIAN FORESTS UNDER NATURAL CONDITIONS IN CALIFORNIA[1]

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Abstract: The California State Water Resources Control Board is conducting hearings to set quantity and quality standards for river flows into San Francisco Bay. Comparisons of present conditions with "natural conditions" prior to European settlement were introduced into the hearings. Consumptive use relations were developed for various riparian and water-related plants, and estimates of the total annual volume of runoff production and consumptive use were developed. A discussion of those computations and a general discussion of the relation of historic riparian forests to "natural flows" into San Francisco Bay is presented.

The California State Water Resources Control Board presently is holding hearings concerning standards for fresh water inflows into San Francisco Bay. During those hearings, the State Department of Water Resources (DWR) introduced data concerning "unimpaired flows" into the Bay Delta (DWR, 1987). They stated "Unimpaired flow could be synonymous with natural flow if all of the items in the unimpaired computation matched the natural flow computation." The data were "better described as unimpaired data, primarily because of the difficulty in computing four items of significance." One of those four items was "Consumptive use of the riparian vegetation... of the Central Valley under a natural state could be significant but (is) difficult to estimate." A first step in the reconstruction of natural flows would be to estimate the areal extent of riparian forests under natural conditions.

Sacramento River System

The Sacramento River and its major tributaries built natural levees along their banks. When they overflowed, the water slowed in the vicinity of the overbank and deposited the sediment that was carried by the river. The deposition created natural depressions which drained through sloughs. When enough water entered the basin to fill it to overflowing, the water would cut through the natural levee and erode a channel or slough. "The connecting slough channels, together with the steep slope of the trough, provide sufficient drainage so that all flood waters above Chico Creek flow back quickly into the Sacramento River upon the subsidence of each flood, covering the lands flooded for only a period of two or three days. . . From a short distance below Stony Creek to its mouth, the Sacramento River has built up its banks on both sides by the deposit of sediment from the overflowing flood waters, to an elevation of from five to fifteen feet above the basins left on each side." (McClure, 1925, p. 19).

McGowan (1961) wrote "valley streams were generally confined to their banks. However, when a river in flood escaped... its banks and spread out over the surrounding countryside, it dropped its coarser sediments first along the edge of the river and... built a natural levee up to ten feet in height on top of its banks... As flood waters moved farther away from the river... their velocity was further decreased so that they now deposited the finer type of sediments... The overflow waters, which built up the land so that it slanted away from the river, eventually reached a trough. . . where they met water being drained from streams which flowed toward them. These troughs, called "basins", became the reservoirs for winter flood waters...Originally, tules, fifteen feet high, covered these basins from which water did not drain off sometimes until August." The Sacramento River overflowed its natural banks when peak flow exceeded stream capacity. The natural levees, basins and overflow lands, and sloughs which drained them created the environment for the riparian system.

Travelers' Accounts of Riparian Vegetation

Descriptions of the Central Valley, such as those above and by earlier explorers, can be used to determine the areal extent of the riparian vegetation before extensive modification by European settlement. The routes described by individuals in their diaries can be compared with published maps of vegetation to help to modify or verify those maps. Kuchler (1977) and Fox (1987) have published maps which can be used to plot estimated routes based on written accounts. (Fox's map is used later in this paper because it is at a good scale, about 1:2,000,000, to show most of the Delta and the riparian forest on one page.) Some accounts of areal extent

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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of riparian vegetation can be used with the maps and travellers' accounts.

Extent of Natural Tule Areas

Cronise wrote in 1868 "Along the San Joaquin River, which spreads out into numerous sloughs, there is, in the northwestern part of (San Joaquin County), an immense expanse of tule marsh—not less than 200,000 acres, much of which is covered at all times by a few inches of water, nearly the whole being submerged at high stages of the tide. Late in the season...large sections of these lands become dry on the surface—the dense body of rushes... having meantime wilted and dried up, the latter often take fire, and burning with terrific fierceness and living tules. In all counties of tule lands, these fires are common, generally occurring in the fall and winter." Based on Cronise's figures and calculations based on his statements, the estimate of the area of tule lands in the Central Valley in 1868 is about 600,000 to 700,000 acres before any major drainage projects.

Savannas, Not Tules, Recorded

Spanish Expeditions

The first Spanish explorers described the immense plains in the Delta. On September 23, 1776, a joint river and land expedition of Spanish explorers started up the river (Bolton, 1926), but only the land exploration continued, and "as soon as it crossed the mountains through a pass of low hills... found itself in the plain which is crossed by the large river (San Joaquin)... they were much farther up than had been agreed upon... decided to continue through the plain up the river. He (followed) the stream for three entire days, traveling rapidly. . . The plain through which that river runs... is as level as the palm of the hand, without any trees except in the bed of the river. It is an immense plain, for he did not see the end of it... After traveling much further on the bank of the river. . . he crossed the great river (and) On the other side of the river he found that the same plain and level land continued. They traveled over it all day."

The Moraga expedition of 1808 gave a similar report (Cutter, 1957). He wrote "Today we left (near present-day Livermore) travelling northeast. After about 12 leagues we arrived at the (West Channel of the San Joaquin in its delta area). Having crossed a branch of that river, we spent the night safely... Leaving camp where it was pitched yesterday, this morning...I continued on toward the east, and after about 2 leagues I found the river and I followed it south for about 4 leagues. No ford could be found in this distance... In the afternoon I sent the corporal in a northerly direction in search of the ford in the river. He found it, but on the opposite side he was confronted by a very large tular and could not continue." (9 Oct 1808) "Today we... moved to the river discovered yesterday...I sent the corporal downstream... He couldn't reach (the mouth of the American River) because of the abundance of tules." (15 Oct 1808) "Today we left for the (Mokelumne River). I went downstream towards the marshes and found nothing good except an immense oak grove." (20 Oct 1808) "Today we followed the (Merced) river downstream, exploring it to its junction with the San Joaquin.. . the low plains of the river are nitrous to within a distance of 2 leagues, more or less, before reaching the San Joaquin.. . There are some beautiful willow groves..."

von Kotzebue

The Spanish were interested in the exploration of the San Joaquin inland from their line of missions. They reported extensively on the tules which grew along the San Joaquin in the Delta. Other explorers tended to go up the Sacramento. The Russian, Admiral von Kotzebue, ventured up the Sacramento to the fork with the Feather. He wrote of his trip (von Kotzebue, 1967) "On the 18th of November (1824) the weather was favorable, and we set out... working our way between the islands into the northern portion of the bay... We reached... at a distance of thirty miles from our ship, the common mouth (Carquines Straits) of the two before-mentioned rivers which here fall into the bay... I ascended the highest hillock on the shore... to the north flowed the broad beautiful river formed by the junction of the two, sometimes winding between high, steep rocks, sometimes gliding among smiling meadows, where numerous herds of deer were grazing. In every direction the landscape was charming and luxuriant... we continued our voyage up the stream... We landed... after working only a few miles, and pitched our tents for the night in a pretty meadow... When we had proceeded eighteen miles from our night camp, and twenty-three from the river's mouth, we reached the confluence of the (Sacramento and San Joaquin) . . . Since the river Pescadores (San Joaquin) was already known, I chose the other... after we had ascended it some miles, a violent ... wind forced us ashore; latitude 38 22' (about mile 38) . . . we were obliged to give up for this day. . . pitched our tents in a pleasant meadow . . . I then climbed a hill... and observed that the country to the west swelled into hills of a moderate height, besprinkled with trees growing singly... Between (the mountains) and the river, the country is low, flat, thickly wooded, and crossed by an infinite number of streams, which divide... it into islands... At sunrise... we continued our voyage... The river now took a north-westerly direction.. . The country on the west bank was of moderate height; that on the east was low. The power of the current impeded our progress, though our rowers exerted all their strength.. . ...Early the next morning we prepared for our return, and soon quitted these lovely and fertile plains..."

Leonard

Zenas Leonard traveled to Suisun Bay from the Merced River in early November 1833. He wrote (Ewers, 1959) "This plain (going down the Merced to the San Joaquin) is well watered and is quite productive, as we found a large quantity of wild pumpkins and wild oats... The land is generally smooth and level, and the plains or prairies are very extensive, stretching...as far as the eye can reach... (rivers run) parallel with each other through the plain... with their banks handsomely adorned with flourishing timber of different kinds... This grove of timber may be found along the river at any point, and generally extends about four miles into the plain. Between this grove of timber and the forest extending from the foot of the mountain, there is a level prairie of the richest soil, producing grass in abundance large prairie covered with wild oats... This plain lays on the south side of the river." (February 15, 1834) "Continued our journey up Sulphur River (San Joaquin), passing through a fine country, most of which is prairie, covered plentifully with wild oats and grass."

Belcher

The English Captain Belcher explored the Sacramento in 1837. He wrote (Pierce and Winslow, 1969) "Having entered the Sacramento... The marshy land now gave way to firm ground, preserving its level in a most remarkable manner, succeeded by banks well wooded with oak, planes, ash, willow, chestnut, walnut, poplar, and brushwood. Wild grapes in great abundance overhung the lower trees, clustering to the river...On the 30th (October 1837), about four p.m., we found the deep boats stopped at (the forks of the Feather and the Sacramento)... Throughout the whole extent... the country is one immense flat...Our course lay between banks, varying from twenty to thirty feet above the river-level... These were, for the most part, belted with willow, ash, oak, or plane,... which latter, of immense size, overhung the stream... Within, and at the verge of the banks, oaks of immense size were plentiful. These appeared to form a band on each side, about three hundred yards in depth, and within (on the immense park-like extent, which we generally explored when landing for positions) they were to be seen in clumps... wandering over what might otherwise be described as one level plain or sea of grass..."

Phelps

William Dane Phelps traveled up the Sacramento in 1841 to visit Capt. Sutter, at his fort at Sacramento. Phelps wrote (Busch, 1983) "About a mile inside the Sacramento we passed the mouth of the St. Joachin... we continued on for about 20 miles. All the distance the banks were low and covered with rush flags or Tules as they are called here. At 11 PM having passed all the Tule, we ran along the high banks on which were many high trees... stopped by the side of a beautiful wood, and dined under the wide spreading limbs of a gigantic oak... The immense size of the trees, the dense thickness of the unpenetrated forests in some places, and the level plains with here and there a bunch of scrub oaks without underbrush in others, together with a profusion of wild flowers... The forests consist mostly of sycamore, a variety of oak, but mostly the white, ash & some wallnut." (29 July 1841) "The river here is broader than below, and the banks higher. The country looks fertile and with just trees enough to give it a pleasant appearance. . . (We) started (for Sutter's Fort) at 1/2 past 4 and riding over a beautiful gently undulating country abounding with rich feed and agreeably diversified with trees & wild shrubbery."

M'Collum

M'Collum (Morgan, 1960) describes the San Joaquin in 1849. "Bound for the southern mines... we were... going up. . . the San Joaquin to Stockton... The passage up the San Joaquin was a dreary one. The river for the greater portion of the way winds like a tape worm, through low marshy ground, where the tules, grow to an enormous height, not allowing us to see out... As you approach Stockton, the uplands, oak-openings and glades of timber, begin to approach the river. . . The tide of the ocean... sets up here, from one to two feet."

Bryant

Edwin Bryant came overland to California (Bryant, 1985). On August 30, 1846, his party reached Johnson's farm on Bear Creek, 40 miles upvalley from Sacramento. August 31 they "marched south seven miles, and encamped on the bank of a chain of small ponds of water. The grass around the ponds was rank and green, and we were protected from the hot rays of the afternoon sun by the shade of evergreen oaks." They traveled on south down the valley 26 miles to the American River. "The valley of the Sacramento, as far as we have travelled down it, is from 30 to 40 miles in width, from the foot of the low benches of the Sierra Nevada, to the elevated range of hills on the western side. The composition of the soil is trodden up by immense herds of cattle and horses which grazed here early in the spring, when it was wet and apparently miry. We passed through large evergreen oak groves, some of them miles in width." They marched down the overflow basin from the Bear River on the east side of the Sacramento to the American River, and noted evidence of previous spring overflows, but no tules.

Bryant continued "September 13th.-We commenced to-day our journey from New Helvetia to San Francisco ... we travelled in a south course over a flat plain... and encamped on a small lake. . . near the Coscumne river... The stream is small, but the bottom lands are extensive and rich... The grass on the upland plain over which we have travelled, is brown and crisp from the annual drought. In the low bottom it is still green." "September 14.-We crossed the Coscumne river... and travelled over a level plain covered with luxuriant grass and timbered with the evergreen oak, until. . . we crossed the Mickelemes river... and encamped on its southern bank in a beautiful grove of live-oaks... The soil of the bottom... produces the finest qualities of grasses. The grass on the upland is also abundant... Our route has continued over a flat plain, generally covered with luxuriant grass, wild oats, and a variety of sparkling flowers... Large tracts of the land are evidently subject to annual inundations. About noon we reached a small lake surrounded by tule... Passing through large tracts of tule we reached the San Joaquin at dark, and encamped on the eastern bank... The ford of the San Joaquin is about forty or fifty miles from its mouth... Oak and small willows are the principal growth of wood skirting the river... Entering upon the broad plain we passed, in about three miles, a small (alkali) lake. The grass is brown and crisp... We passed during the afternoon several tule marshes, with which the plain of the San Joaquin is dotted. At a distance, the tule of these marshes presents the appearance of immense fields of ripened corn. The marshes are now nearly dry, and to shorten our journey we crossed several of them without difficulty. A month earlier, this would not have been practicable... While pursuing our journey (across the Delta to the Ranch of Dr. Marsh) we frequently saw large droves of wild horses and elk grazing quietly upon the plain."

Bryant visited with Dr. Marsh. "Sept.17... After breakfast I walked with Dr. Marsh to the summit of a conical hill... from which the view of the plain on the north, south, and east, and the more broken and mountainous country on the west, is very extensive... The hills and the plain are ornamented with the evergreen oak, sometimes in clumps or groves, at others standing solitary... the San Joaquin, at a distance of about ten miles, is belted by a dense forest of oak, sycamore, and smaller timber and shrubbery. The herds of cattle are scattered over the plain,—some of them grazing upon the brown, but nutritious grass; others sheltering themselves from the sun, under the wide-spreading branches of the oaks." The southern part of the San Joaquin Delta as seen from its western edge, prior to the coming of the Americans, seemed to have scattered tracts of tules in some parts.

Bryant travelled up the Sacramento. "October 24 (1846)... About two o'clock, P.M., we entered the mouth of the Sacramento. The Sacramento and San Joaquin rivers empty into the Bay... at the same point ... and by numerous mouths, or sloughs... These sloughs wander through an immense timbered swamp... The banks of the river and several large islands which we passed during the day, are timbered with sycamore, oak, and a variety of smaller trees and shrubbery. . . The islands of the Sacramento are all low, and subject to overflow in the spring of the year. The soil of the river bottom, including the islands, is covered with rank vegetation, a certain evidence of its fertility..." Bryant continued "October 25... As we ascended the stream the banks became more elevated, the country on both sides opening into vast savannas, dotted occasionally with parks of evergreen oak."

Comparison with the Fox Natural Vegetation Map

Figure 1 is a partial copy of Fox's map (1987) of natural vegetation for the middle part of the Central Valley. Point A is in the vicinity where the 1776 Spanish expedition hit the San Joaquin and traveled upstream without mention of trees. The band of riparian forest shown by Fox is 5 miles in width. B1 to B2 show the reach that the Moraga expedition of 1808 explored along the San Joaquin and at the mouth of the Mokelumne and the Merced Rivers.

Point C is the farthest point reached by Captain Belcher and by von Kotzebue. They reported oaks and savannah after the first few miles up the Sacramento. Tules shown by Fox north of the Sacramento should be riparian forest and savannah. Point D1 is about the point at which Phelps in 1841 reported he ran along high banks on which were many high trees. This report agrees with those of Belcher and von Kotzebue. Point D2 is where Phelps traveled overland. The area of tules shown by Fox should be much reduced in size.

The line marked E is the approximate route of Edwin Bryant in 1846, and is close to the "road across the plains" on Lt. Derby's map of 1849 (Thompson, 1961), which shows the road about 4 miles from the river, with riparian forest a mile wide on the west bank and about three miles wide on the east bank from the Feather to the American.

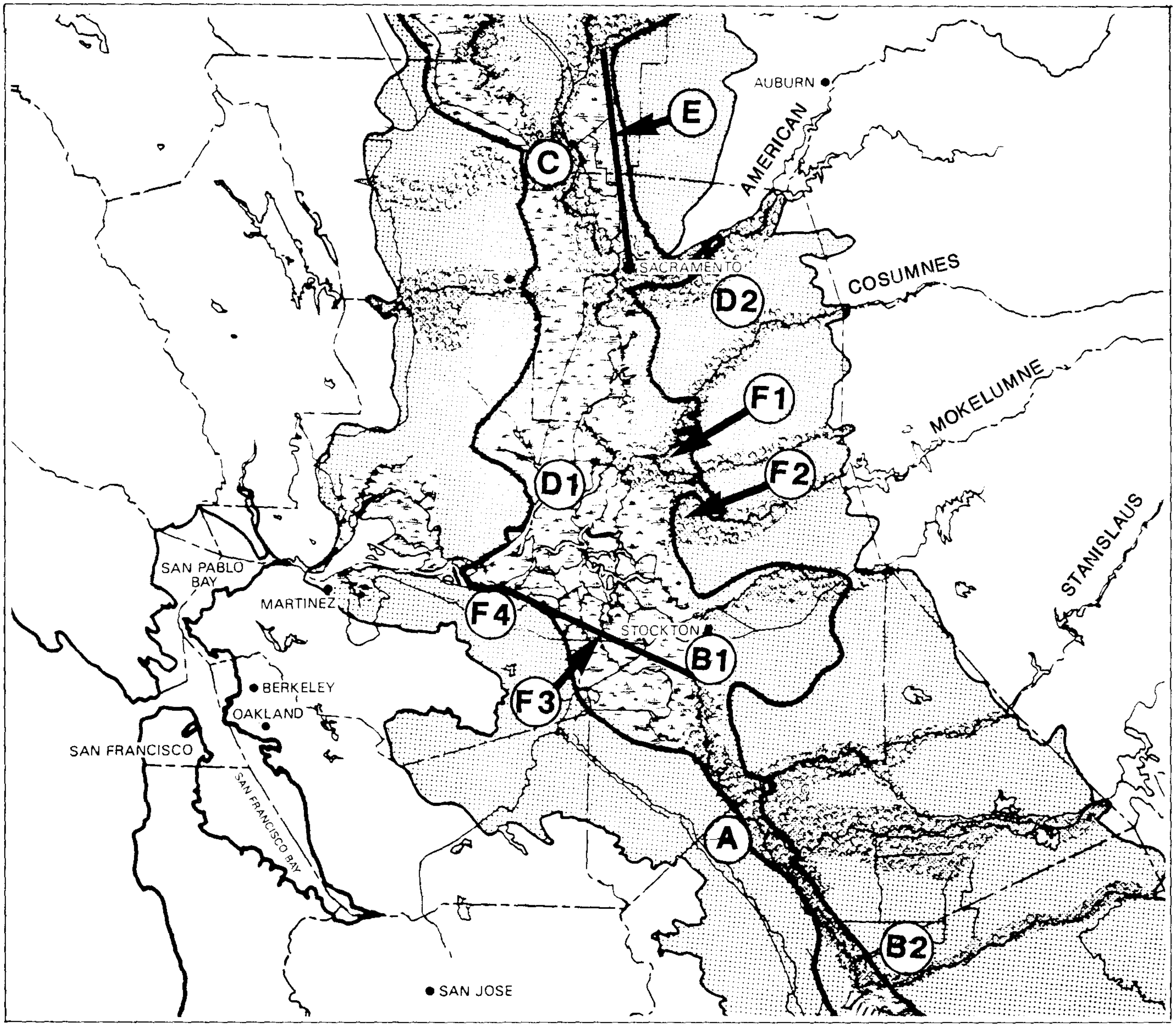

Figure 1 — Partial copy of Fox's map for Central Valley showing location and routes of early travelers.

Points F1 to F4 trace the route of Bryant. At F1 on the crossing of the Cosumnes he reported grass in the "low bottom" of the river, at F2 on the crossing of the Mokelumne "the bottom... produces the finest qualities of grasses." The line marked F3 is in the vicinity of where Bryant broke off the usual road and struck off across the south part of the Delta. Much of the area shown as tules by Fox was mixed plains dotted with tule marshes which went dry late in the summer. Point F4 is where Bryant climbed a hill south of Antioch and looked over the south Delta.

Estimates of Extent of Riparian Forests

Smith (1977) says "The riparian woodlands occurred on the natural levees formed by the Sacramento, Lower Feather, American, and other aggrading streams... Based on historical accounts, it has been estimated that there were about 775,000 acres of riparian woodlands in 1848-1850." Roberts and others (1977) estimated 800,000 acres in 1848, and Fox estimated 938,000 acres

(1987, Table 3) for the Sacramento Basin. Katibah (1984) gave a more detailed listing of the locations of the riparian forest stands in presettlement times. Katibah's listing cannot be matched precisely with Fox's, but an approximate comparison is as follows:

Location	Fox Table 3	Katibah Table 1
	acres	
Sacramento Basin	938,000	583,400
Delta	198,000	100,700
San Joaquin Basin	298,000	187,500
Tulare Basin	515,000	50,000
Total	1,949,000	921,600

Katibah's estimates are conservative and subject to refinement. Sacramento plus Delta, 684,100 acres is compared with 775,000 of Smith and 800,000 of Roberts. Katibah appears to be about 15 percent below the others. Scott and Marquiss (1984) agree with the 800,000 acres, quoting an unpublished report. Fox appears high.

Conclusions

A more extensive study of the routes of the various travelers, the study of unpublished diaries, and a comparison with published maps and accounts of extent of riparian vegetation can be used to map more thoroughly the areas covered by various types of vegetation during the time immediately prior to European settlement and, in particular, before the time of American settlement in the Central Valley. A more accurate mapping of the riparian forests can be helpful in the determination of natural water use and water availability in the Central Valley.

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GREAT VALLEY RIPARIAN HABITATS AND THE NATIONAL REGISTRY OF NATURAL LANDMARKS[1]

Robert F. Holland and Cynthia L. Roye[2]

Abstract: The National Registry of Natural Landmarks is a program established by the National Park Service that seeks to recognize nationally significant examples of the Nation's natural history. Nearly 100 Great Valley riparian sites were evaluated using Park Service criteria. Three sites illustrative of the range of this biotic theme were recommended to the National Park Service for designation as National Natural Landmarks.

The National Natural Landmark program recognizes nationally significant examples of ecological or geological features of the Nation's natural history. Since 1962 over 500 Landmarks have been designated by the Secretary of the Interior and listed by the National Park Service in the National Registry of Natural Landmarks.

The Landmark program is intended to encourage preservation of sites which illustrate the geological and ecological character of the United States, to enhance the educational and scientific value of these sites, to strengthen appreciation of natural history, and to foster public interest and concern for the conservation of the Nation's natural heritage (Federal Register 1975). The ultimate goal of this program is to ensure preservation of the vast majority of ecosystem types present in this country prior to the activities of European man so as to present an intact picture of our country in its pristine condition (Stebbins and Taylor 1973).

Until the 1980's, the primary method used to identify potential Landmark sites was through a series of studies of natural phenomena, or "themes", in each of Fenneman's (1928) 33 physiographic regions of the United States. Both biotic and geologic theme studies were completed. Each study resulted in a description of the major features of a region and an initial inventory of sites considered to be excellent examples of the themes found within the region. Sites were then evaluated in the field according to study-specific criteria and compared to other sites representing the same theme to determine which were most appropriate for designation as National Natural Landmarks. Although many excellent Landmark sites were identified through the regional theme studies, in some cases themes were too broad to allow meaningful comparison of sites. In other cases it was difficult for evaluators to locate similar sites to make the required comparisons.

In the early 1980's the Western Region of the National Park Service began using a more systematic approach to the identification of potential Landmark sites: 1) regional themes were described: where necessary to encompass the diversity present within the natural region, smaller, recognizable assemblages of plants and animals which repeatedly occur within the theme were identified as subthemes to make site comparisons more feasible; 2) all known good sites of each subtheme were identified; 3) uniform criteria of national significance were applied to each site; and 4) site-specific reports were written for sites best meeting these criteria.

The purpose of this study was to research, classify, and describe the Great Valley Riparian Forest theme (including subthemes) of Fenneman's South Pacific Border Region, and to recommend sites illustrative of that theme as National Natural Landmarks. The study was part of a multi-state pilot project in which the Western Region of the National Park Service attempted to use state Natural Heritage Inventories as a source of background information and staff expertise in locating potential Landmark sites. These inventories originally were established by The Nature Conservancy to collect, manage, and use biological, ecological, and related information for conservation planning in an attempt to preserve the diversity of our natural heritage. The Natural Diversity Data Base, which is now part of the California Department of Fish and Game and maintains the California natural heritage inventory, was contracted to prepare a Landmark evaluation of the Great Valley Riparian Forest theme.

Landmark status is open to lands within the United States, Puerto Rico, the Virgin Islands, and the Pacific Trust Territories. Lands managed by the National Park Service are ineligible for Landmark recognition. To be considered for designation, a site must meet a set of criteria demonstrating that it has national significance. These criteria were used in evaluating all sites and in comparing their relative suitability for Landmark designation. They are summarized in tabular form.

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Phase I, Classification

Stebbins and Taylor's (1973) theme study treats all Great Valley riparian habitats as one "Special Ecosystem" which they called Riparian Woodland. Several classifications of such habitats have appeared since Stebbins and Taylor's theme study. These indicated a much broader range of habitat types than any one site possibly could possess. A classification by Jensen and Holstein (1983) was chosen as most appropriate for this study. They recognized three riparian forest units: Great Valley Cottonwood Riparian Forest, Great Valley Mixed Riparian Forest, and Great Valley Valley Oak Riparian Forest. These communities constitute the subthemes of this Landmark study.

There are surprisingly few data on the composition and structure of these forest types. These data, mostly in Sands (1977) and Warner and Hendrix (1985), and field work throughout the Great Valley indicated that these three subthemes could be generally described as follows:

Great Valley Cottonwood Riparian Forest Subtheme

This community of medium to tall (to 100 ft), broad-leaved winter-deciduous trees typically has well closed canopies that are densely stocked with Fremont cottonwood (*Populus fremontii* Wats.) and valley willow (*Salix gooddingii* Ball.). Understories of various other willow species are common. This subtheme encompasses early seral riparian forests in which the tree canopy has been closed long enough to inhibit establishment of sun-loving species but not long enough for shade-tolerant species to grow into the canopy. Disturbance by high flows occurs most years and appears to be an important factor in stand regeneration. Most stands are even aged, reflecting episodic reproduction of the shade-intolerant dominants.

Great Valley Mixed Riparian Forest Subtheme

Great Valley Mixed Riparian Forest also is a community of medium to tall (to 100 ft), broad-leaved winter-deciduous trees. The tree canopy is fairly well-closed and is composed of several species including Fremont cottonwood, sycamore (*Platanus racemosa* Nutt.), California black walnut (*Juglans hindsii* Jeps.), Goodding's willow (*Salix gooddingii var. variabilis* Ball.), red willow (*Salix laevigata* Bebb.), yellow willow (*Salix lasiandra* Benth.), and box elder (*Acer negundo var. californicum* Torrey and Gray). These and other shade-tolerant shrub species such as Oregon ash (*Fraxinus latifolia* Benth.), and buttonbush (*Cephalanthus occidentalis* L.) form a dense understory. Lianas such as wild grape (*Vitis californicus* Benth.), virgin's bower *(Clematis ligusticifolia* Nutt. *in T. & G.),* and poison oak *(Toxicodendron diversilobum* Torrey and Gray) are conspicuous, giving the community an appearance popularly associated with tropical jungle. Great Valley Mixed Riparian Forests usually occupy sites that are farther from the active river channel or that are at somewhat higher elevations relative to the active channel; flooding on these higher sites is less frequent and less intense. Most stands are uneven-aged, reflecting the shade-tolerance of the dominant species and the longer recurrence intervals between major disturbances such as flooding, windthrow, or fire.

Great Valley Valley Oak Riparian Forest Subtheme

Great Valley Valley Oak Riparian Forest once occurred extensively along the highest parts of the floodplains where flood damage was least likely and least severe. Where it survives, this forest is dominated by the winter-deciduous valley oak (*Quercus lobata* Nee.). Canopies are moderately to densely closed and up to 100 feet tall. Individuals of sycamore and Oregon ash frequently are scattered in the canopy and sub canopy. Many valley oak stands have basal area distributions suggestive of episodic reproduction. Shrub canopies are best developed in light gaps caused by fire, flood, or windthrow. Wild grape is the only conspicuous liana, often smothering shrubby patches before being shaded out by the closing tree canopy. Canopy structure typically is less complex than that found in Great Valley Mixed Riparian Forest.

Phase II, Site Evaluation

The Natural Diversity Data Base inventory of Natural Communities provided a preliminary list of about 100 sites for the three subthemes studied. Sites were visited and field survey forms were filled out for each site with reference to the Park Service criteria in Table 1. In some cases the forests no longer existed because of type conversion to agriculture or urbanization. Sites which did not fit Park Service criteria for obvious reasons such as these were eliminated from further consideration as potential Landmarks.

Table 1. — Criteria for evaluating the national significance of proposed National Natural Landmarks

Primary Criteria

Illustrative Character — The site must be representative of the subtheme under study. The site has the species composition and physical features typical of that ecosystem. The site offers an exceptional opportunity to illustrate or interpret the natural history of the nation.

Present Condition — The site approximates an undisturbed natural environment. The site is essentially free from disturbances which detract from its natural character.

Secondary criteria

In comparing sites which have met these primary criteria a second set of criteria is used:

Diversity — In addition to its primary natural feature, the site contains high quality examples of other ecological and/or geological features. The presence of other native plant communities such as marshes, willow thickets, and grassy savannas, in addition to the forest community gave sites an advantage in meeting this criterion.

Rarity — The site provides high quality habitat for one or more rare, threatened, or endangered species, or contains a rare geological or ecological feature.

Value for science and education — The site is associated with a significant scientific discovery or concept, has a long-term history of on-site research, or offers unusual opportunities for interpretation and public education about the natural history of the particular subtheme.

For the 53 sites remaining, the evaluator interviewed as many people as possible who had knowledge of the site to gather information about land use history and condition. Contacts included farmers working in adjacent fields, ranchers, local landowners and managers, Department of Fish and Game unit biologists, Soil Conservation Service personnel, irrigation and levee district staff members, and local conservationists. From the site visits combined with these interviews, it proved possible to narrow the field to six to ten sites for each subtheme. This subset of sites was re-evaluated using the same Park Service criteria and, based on this improved knowledge, three sites emerged for recommendation as National Natural Landmarks:

- South Fork Kern River, Kern County: Great Valley Cottonwood Riparian Forest Subtheme
- Feather River, Sutter and Yuba Counties: Great Valley Mixed Riparian Forest Subtheme
- Cosumnes River, Sacramento County: Great Valley Valley Oak Riparian Forest Subtheme.

Phase III, Evaluation Report

The next phase of the recommendation process was to write a detailed evaluation of each of these three sites. Evaluations included location, boundaries, and size of the site as well as a thorough description of site's plant communities and animal habitats. We addressed the land use and present condition of the site, any damage expected to occur from continuation of current management practices, and the effects of publicity should the site be designated as a National Natural Landmark. We provided maps of the site boundaries and land ownership details for each parcel within the proposed Landmark.

We evaluated each site's features in relation to the Park Service criteria and offered an opinion, based on our professional judgment, of whether or not the sites merited designation as National Natural Landmarks. We were able to find sites so representative of each subtheme that three were recommended for designation.

Management guidelines were prepared that detailed actions needed to ensure that significant features would not be damaged, altered by unnatural means, or destroyed. These suggestions did not carry the implication that the National Park Service would actually manage the site, but rather were suggestions the Park Service could provide to landowners to promote conservation of the area's integrity. We found that parts of all three areas already were under partial management for conservation of their natural values. Existing management plans were instructive for at least a portion of each area. Guidelines for those portions not currently such management were added.

South Fork Kern River

The South Fork Kern River, Kern County, supports the largest surviving example of the Great Valley Cottonwood Forest subtheme. The site is dominated by

Fremont's cottonwood, yellow willow, red willow, and valley willow with a dense understory of saplings of these species, abundant stinging nettle (*Urtica holosericea Nutt.*), and mulefat (*Baccharis viminea DC.*). There are several small marshes along natural sloughs and some stands of grassland on high ground within the forest. A number of sensitive birds are known to nest in this forest including about 25 percent of the California Yellow-billed Cuckoo (*Coccycus americanus occidentalis Ridgway*) population.

We recommended 1856 hectares (4583 acres) along the South Fork for Landmark status designation. In addition to the largest surviving cottonwood forest, this site has a diversity of seral stages and a natural hydrograph which is unparalled among the other surviving Cottonwood Forest sites. The site is owned by private parties, The Nature Conservancy, and the United States Army Corps of Engineers. Both the Conservancy and the Corps manage their holdings (about half of the acreage) for their natural values. Most of the privately owned parcels are used for cattle grazing.

Feather River

The Bobelaine-Lake O'Connor area along the lower Feather River supports the largest known surviving example of the Great Valley Mixed Riparian Forest subtheme. We recommended that 1502 hectares (3756 acres) be designated as Landmarks. Fremont cottonwood and sycamore dominate the diverse forest here, and the varied understory includes box elder, Oregon ash, California black walnut, and willows. The shrub layer is dense and diverse. Draperies of several liana species are impenetrable in some areas. Small stands of the Great Valley Valley Oak Riparian Forest and extensive willow thickets also are found within the recommended Landmark.

Several rare riparian-dependent animals use the area for roosting and breeding. These include the Federally listed Endangered Valley Elderberry Longhorn Beetle (*Desmerocerous californicus dimorphous* Fisher), the California yellow-billed cuckoo, and Swainson's hawk (*Buteo swainsonii* Bonaparte). Both the cuckoo and the hawk are listed as Endangered under California law. There also is a large rookery of great blue herons (*Ardea herodias L.*) and great egrets (*Casmerodious albus L.*), and a thriving population of river otters (*Lutra canadensis* Schreber) and ringtail cats (*Bassariscus astutus* Lichenstein).

This area is of such high quality that most of it has already been acquired by the California Department of Fish and Game or the National Audubon Society for protection of natural values. Most privately owned parcels are used for cattle grazing or are idle.

Cosumnes River Area

This area consists of three tracts along the lower Cosumnes River near its confluence with the Mokelumne. We recommended expansion of a Landmark which was designated in 1976. Taken together, the three tracts recommended by this study are the largest known surviving example of the Great Valley Valley Oak Riparian Forest Subtheme (432 hectares, 1079 acres). All three sites are dominated by healthy, vigorously reproducing stands of valley oak. The sub canopy consists of young valley oaks, Oregon ash, buttonwillow, and box elder. Wild grape lianas are common. The tracts differ in species associated with the dominant valley oak reflecting their differing distances from the river channel. Some small sloughs and quiet backwaters support examples of freshwater marshes and small stands of the Great Valley Mixed Riparian Forest subtheme. Swainson's hawk (State-listed Threatened) and both lesser and greater sandhill cranes (*Grus canadensis canadensis L. and Grus canadensis tabida* Peters, also State- listed as Threatened) have significant roosting areas here.

Most of the area is privately owned and receives summer and fall cattle grazing; a small part is owned by The Nature Conservancy and forms the Cosumnes River Preserve. The Conservancy continues to expand its preserve as additional properties become available.

Registry

The evaluation report and all comments from land owners, managers and any other interested parties are reviewed by the National Park Service to determine which sites qualify for nomination to the Secretary of the Interior. If the Secretary agrees with the findings of the Park Service, the site is designated as a National Natural Landmark.

The National Park Service contacts each landowner to explain the Landmark Program and to invite the landowner to register his or her land as a National Natural Landmark. Registration constitutes a voluntary, non-binding agreement between the Secretary of the Interior and the landowner to preserve the significant natural features of the site. The landowner receives a certificate and bronze plaque indicating the site is a registered National Natural Landmark. The landowner does not relinquish any rights to the land and the agreement may be terminated by either party.

The National Natural Landmark Program was created administratively within the National Park Service. No legislation or administrative procedures afford specific protection to Landmarks. Official recognition is the only direct protection afforded. Landowners often find pride in owning a site recognized as being of national significance and may be less inclined to convert the land to uses which would deprive the site of Landmark status (The Nature Conservancy 1975).

When sites are owned by public agencies, Landmark recognition may sway management decisions toward preservation of natural values and stimulate Cooperative Management Agreements between the agency holding title and agencies mandated to preserve natural resources, such as the California Department of Fish and Game.

For areas already under management for the preservation of natural values, such as portions of the three sites recommended by this study, Landmark designation commends the owners for their careful stewardship and increases public awareness. Such designation may enhance the availability of funds for acquisition when and if landowners within the recommended Landmark boundaries chose to sell their property.

One further indirect protection is pointed out by The Nature Conservancy (1975). Under the National Environmental Policy Act of 1969, Federal agencies undertaking major Federal actions must file statements detailing the effect of such actions on the environment. If proposed actions will have impact upon a National Natural Landmark, any adequate Environmental Impact Statement should note that fact and actions may be modified as a result.

In addition to instituting a more systematic approach, the National Park Service determined that the methods used in this pilot study were less costly, site by site, than Landmark identification and evaluation techniques that had been used in the past. Although not yet in use nationwide, the methods used in this pilot study are now accepted by the Park Service as a valid way to identify and evaluate sites for possible Landmark designation.

The project benefited the Natural Diversity Data Base by bringing to light several riparian stands which had not been included in the inventory previously and by providing more recent and complete information for all sites visited.

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PLANT COMMUNITY DEVELOPMENT, SITE QUALITY ANALYSIS AND RIVER DYNAMICS IN THE DESIGN OF RIPARIAN PRESERVES ON THE MIDDLE SACRAMENTO RIVER, CALIFORNIA[1]

Niall F. McCarten[2]

Abstract: Loss of riparian habitat along the Middle Sacramento River, over the last 100 years, has reduced a once contiguous riparian forest to a series of disjunct remnants of varying size and quality. With limited financial resources to purchase and protect some of the remaining riparian plant communities, it has become necessary to develop methods to select which of the remaining habitats are to become protected. A site evaluation method was developed that included vegetation quality, type and rarity, size, viability, unique features, rare plants, shape, and potential for growth. Using this method 240 plant community sites that included 5 plant community types were evaluated and ranked. The evaluation method and the results are outlined and a critique of the method discussed in light of long term riparian nature preserve design.

The loss of riparian vegetation and habitats in California has resulted in the need for an immediate coordinated effort by government agencies and private organizations to develop a plan to preserve what little remains. However, the cost of preservation, in conjunction with the unwillingness of some riparian land owners to sell, restricts the amounts and locations of land that can be acquired. In order to develop a strategy for the preservation of the remaining riparian habitats in California three pieces of information are needed: 1) location and types of remaining riparian vegetation, 2) the quality of individual contiguous riparian areas and 3) a preserve plan for which areas should be acquired.

The middle Sacramento River, between Keswick Dam and Verona, is a riparian corridor 167 kilometers long. The combined impacts from agriculture, levee building and bank stabilization (rip-rap) has reduced this once contiguous riparian gallery forest to a series of disjunct riparian islands. Previous studies have made a qualitative determination of the types of plant communities that remain along some sections of the middle Sacramento River (Conard and others 1977; Katibah and others 1984; Roberts and others 1977; Sands 1977; Thompson 1961; Warner and Hendrix 1984). Only one previous study by Michny (1984) quantitatively determined that approximately 4,000 hectares of riparian "woodland" have potential for habitat preservation. Previous studies have not, however, compared all the riparian sites as to plant community type, determined the quality of these sites, their size, and ranked them to identify specific areas for preservation.

Current riparian preservation strategies for the middle Sacramento River have focused primarily on areas that support rare species. Only rarely have sites been preserved based on vegetation or other features (see Katibah and others 1984). It also appears that the preservation strategies have not considered the long term viability of the sites chosen. The dynamics of the Sacramento River are sufficiently well documented to suggest that many of the largest riparian forests along the river today will likely not persist beyond 20-75 years from now (Scott and Marquis 1984). Further, the normal successional sequence of riparian forests prevents us from assuming that the type of community preserved today will be the same type 20 or more years later (Strahan 1984).

Study Objectives

This paper has two purposes: 1) discuss a method to evaluate and rank individual riparian communities, and 2) discuss the selection of individual riparian sites for preserves considering the dynamics of the Sacramento River.

The reason for developing the evaluation method was to provide a riparian community site quality analysis and ranking for the Sacramento River Riparian Atlas (1988).

Methods

The site quality evaluation method developed for the middle Sacramento River study was designed to account for all levels of site quality and size excluding active agricultural land. The study required a vegetation quality analysis for individual plant communities.

[1] Presented at the Symposium on California Riparian Systems; September 22-24, 1988; Davis, California.

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Site Variables

Eight variables were used to evaluate overall site quality: 1) vegetation quality, 2) community rank, 3) size of community, 4) viability, 5) unique features, 6) rare plants, 7) shape of community stand, and 8) potential for stand expansion.

Vegetation Quality

Five plant communities occur in the study area that have been classified in the California Department of Fish and Game's natural community system (Holland 1986). These communities are: great valley mixed riparian forest, great valley cottonwood riparian forest, great valley valley oak riparian forest, great valley willow scrub and coastal and valley freshwater marsh. A description of the three riparian forest communities is included elsewhere in these proceedings (Holland and Roye 1989).

Vegetation quality was primarily evaluated based on the biological features of the community structure that were determined from field surveys. The four features considered were: 1) tree density i.e. canopy closure, 2) species diversity 3) extent of seedling establishment, mainly for areas of disturbance now undergoing regeneration, and 4) maturity of the community. Vegetation quality was evaluated on a scale of 1 through 4 (i.e, 1=poor, 2=fair, 3=good, 4=excellent).

Community Rank

Vegetation quality was weighted using a plant community ranking value that reflects the level of rarity for each community. The California Natural Diversity Data Base (CNDDB) has ranked some of the rarer plant communities in California including the riparian forest and the freshwater marsh. The valley oak riparian forest is ranked highest by CNDDB due to its rarity. The cottonwood and mixed riparian forest and freshwater marsh are all ranked equally and lower than the valley oak riparian forest. The willow scrub community is not considered rare and has not been ranked. Community ranking values used were 1 through 3, with 3 representing the rarest community type. These community rankings were multiplied by the vegetation quality values.

Size of Community

Community size is important in preserve design since it is related to the capacity of an area to buffer external threats (Lovejoy and others 1986). The stand sizes used in this study were for individual plant communities. Four size classes were used and point values assigned as follows: 1 =< 50 acres, 1.5 = 50-75 acres, 2 = 76-100 acres, 3 => 100 acres.

Site Viability

The viability of a site is its potential to survive natural or human-caused forces over time. This variable mainly represents the survivorship potential from river realignments. Impacts from river erosion was based on the level of river bank cutting. Viability values ranged from 0 through 5, with a high level of viability equal to 5.

Unique Features

Sites were assigned points for a variety of features that mainly correspond with overall site diversity. For example ox bow areas that had an associated freshwater marsh were given 3 points, mixed riparian communities that included valley oak as a subdominant were given 2 points. The highest number of points given in this category was 5 for an individual site, but technically the category had no a priori maximum value.

Rare Plants

Although no rare plants were found during the study, 5 points would have been given for their presence. This category includes state or federally listed species, as well as non-listed rare plants. The point assignment was determined relative to other categories where the value of 5 also was the maximum value.

Shape of Community Stand

The shape of a preserve has been recognized as an important factor in determining the effects of external disturbances or threats (Janzen 1986, Lovejoy and others 1986). In particular, so-called "edge effects" from neighboring areas having contrasting land use can be important potential threats (Harris 1984, Janzen 1986).

Two major areas of potential edge effects for the Sacramento River are river course changes on one side and human-caused disturbances on the other. Site quality of a particular plant community with respect to shape was determined using a circumference-to-area ratio index (CAI). The assumption is that areas having a small CAI have the least amount of exposed vegetation to external threats such as circular shaped areas. In contrast narrow strips of vegetation have a high level of external exposure (high CAI) and a higher potential external threat. Values based on shape range from 1-5 with 5 representing a perfect circle.

Table 1- Riparian sites and total area in each quality level by plant community, middle Sacramento River, California, 1988.

	Quality				
Riparian Community	Excellent No. Sites	Good No. Sites	Fair No. Sites	Poor No. Sites	Total Area(ha)
Cottonwood	10	15	26	12	1,320
Mixed Riparian	6	8	7	3	614
Willow Scrub	2	6	10	2	352
Freshwater Marsh	10	-	-	-	121
Totals	50	69	82	33	5,907

Potential for Stand Expansion

Site evaluation of potential revegetation areas was determined independently for the Sacramento River Atlas project (Kraemer 1988). However, some assessment was included to evaluate potential expansion of a riparian community stand. This determination was based entirely on the amount of neighboring habitat. Values ranged from 1 through 5 were added for potential growth as follows: 1 point was given for potential expansion less than doubling the current size; 2 points for doubling the current size; 3 points for tripling the current size etc.

Site Values

Two hundred forty riparian community sites that included the 5 plant community types were evaluated and ranked. Each plant community site was given a site value based on the following relationship:

$$Q_s = V_q \times R \times S_i + V_i + U + P_r + S_h + P_g$$

where Qs = community site quality, Vq = vegetation quality, R = community rank, Si = community size, Vi = viability, U = unique features, Pr = rare plants, Sh = community stant shape and Pg = potential for stand expansion.

Site Ranking

Each of the 240 site values were used to develop a distribution bar graph for each of the plant communities. Coastal and valley freshwater marsh which had only ten sites were ranked equally. The site value distribution curves often had distinct breaks in value groupings making it relatively easy to assign a four category quality rank. The four quality levels were excellent, good, fair and poor. Each of these levels were given a corresponding letter (i.e., A = excellent, B = good, C = fair, and D = poor). The reason for the grade-type ranking was due to the requirements of the Sacramento River Riparian Atlas project. The Sacramento River Riparian Atlas mapped each riparian community using a letter grade code. In addition, the program's philosophy was only to consider excellent and good quality sites in choosing areas as potential preserves.

Results

A total of 240 community sites were evaluated including 123 mixed riparian forest, 62 cottonwood riparian forest, 24 valley oak riparian forest, 21 willow scrub, and 10 freshwater marsh community types (Table 1). The total area for all riparian community stands is 5,907 hectares (Table 1).

Only 23 percent of the site are off excellent quality, 29 percent of the sites are good quality, 34 percent of the sites are fair quality, and 14 percent of the sites are poor quality. Only 12 percent (720 hectares) of the 5,907 hectares of remaining riparian vegetation on the middle Sacramento River is publicly owned. Approximately half of the publicly owned riparian vegetation can be considered protected. Most of the remaining riparian habitat along the Sacramento River is subject to deforestation which currently is at a rate of about 170 hectares per year (Department of Water Resources 1979).

Discussion

This study has provided a detailed analysis of the extent and quality of the riparian plant communities that were found along the middle Sacramento River in 1987. The results of the analysis found that it was relatively easy to determine site quality classes using a numerical method. The large number of sites and the range of site quality was the key to this study. The the large variation in site quality produced a good distribution from which to segregate quality classes. Site quality characterization for large numbers of sites, such as in this study, should consider a numeral evaluation method such as this. However, comparison of only a few sites (i.e., < 25) to determine the quality could more easily be done without a numerical analysis.

The method presented here was used in the Sacramento River Riparian Atlas (McCarten and Patterson 1988). The vegetation information in conjunction with wildlife habitat analysis, spawning gravel data, and potential revegetation site data have provided an assessment of the location of "high quality" riparian habitats. Similarly, The Nature Conservancy has utilized the vegetation quality data for their riparian preserve program (Phelps 1988). For The Nature Conservancy program Mr. Tod Wells and I added the community site values for all contiguous communities to produce a single cumulative value. The site vegetation values for contiguous riparian areas were then compared with other factors to determine areas for potential riparian preserves (Phelps 1989).

The vegetation quality analysis method used here has proved useful for choosing riparian sites that are high quality and under the current philosophy for preserve design help target particular locations for preserves. The results of this study provide the basis on which to develop a long term preserve plan for the Sacramento River. That plan should not only consider the larger more mature sites (i.e. those ranked as "excellent"), from each plant community type. Nor should the focus of land acquisition only be toward rare species. Harris (1984, p. 158) has outlined criteria for selecting specific "habitat islands" as follows: 1) geographic position within the system, 2) intrinsic diversity, 3) particular species, e.g., rare species, 4) contribution to within species genetic diversity, 5) presence of endemics, and 6) contribution to the system of "habitat islands." In essence, the selection of a particular site should be considered on the basis of its overall contribution to the system being preserved.

The successional ecology of the riparian plant communities, in response to river course and substrate depositional changes over time, requires a dynamic view of a Sacramento River riparian preserve. Due to the island nature of the remaining riparian sites in conjunction with the dynamics of the system, the concept of "long-rotation islands" (Harris 1984, p. 155) may be useful in preserve planning. This concept has been applied to old growth forest systems (Harris 1984), but aptly applies to the formation, successional changes and eventual loss of riparian habitats at particular sites.

Recommendations

When considering plant community sites that have been ranked as excellent, good and even fair for preserves other factors must be taken into account. Selected sites should include those that have potential for stand expansion; are buffered from river course changes i.e., ox bow islands; have broad contiguous stretches along the river; have both young and mature vegetation i.e., early and late successional stages such as willow scrub and mixed riparian forest; have rare plants and animals; represent examples from all plant communities that are well distributed along the river; and have incipient depositional areas where the river course is moving away from the new habitat.

These recommendations promote the view that the goal of a riparian preserve system should consider more than location, size and quality of the present habitats as they appear. The preserve design should also consider the location, size and quality of habitat years from now. Large riparian gallery forests preserved today are likely to be located in the middle of the Sacramento River bed within the next fifty years. On the other hand small patches of willow scrub and developing cottonwood riparian forest will be the gallery mixed riparian forests in the future.

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SAN JOAQUIN RIVER RIPARIAN HABITAT BELOW FRIANT DAM: PRESERVATION AND RESTORATION[1]

Donn Furman[2]

Abstract: Riparian habitat along California's San Joaquin River in the 25 miles between Friant Darn and Freeway 99 occurs on approximately 6 percent of its historic range. It is threatened directly and indirectly by increased urban encroachment such as residential housing, certain recreational uses, sand and gravel extraction, aquiculture, and road construction. The San Joaquin River Committee was formed in 1985 to advocate preservation and restoration of riparian habitat. The Committee works with local school districts to facilitate use of riverbottom riparian forest areas for outdoor environmental education. We recently formed a land trust called the San Joaquin River Parkway and Conservation Trust to preserve land through acquisition in fee and negotiation of conservation easements. Opportunities for increasing riverbottom riparian habitat are presented by lands from which sand and gravel have been extracted.

Study Area

Natural vegetation in the San Joaquin River bottomlands between Friant Darn and Freeway 99 creates a broad corridor of different vegetation communities. The most critical of these vegetative communities is the riparian community which interfaces water, vegetation and wildlife resources, bisecting or bordering on diverse habitat.

Along the 25 miles of the San Joaquin River bottomlands below Friant Darn only about 6 percent of the original riparian habitat may be found (Counties of Madera and Fresno, and City of Fresno 1986). Losses of riparian habitat along the San Joaquin River are attributable to agricultural and urban encroachment, sand and gravel extraction, road construction, snagging, clearing, and riprapping.

In 1986 the California Department of Fish and Game mapped the riparian vegetation corridor along the San Joaquin River for Madera and Fresno Counties, and the City of Fresno as they studied the San Joaquin Riverbottom between Friant Dam and Freeway 99 (Counties of Madera and Fresno, and City of Fresno 1986). Figure 1 shows the San Joaquin River riparian vegetation corridor. Table 1 summarizes the results of that mapping by acreage and by category.

Table 1 – Riparian wildlife/vegetation corridor

Category	Corridor Acres	Corridor Percent
Water	1,088	14.0
Trees	588	7.0
Shrubs	400	5.0
Other riparian[1]	1,844	23.0
Sensitive Biotic[2]	101	1.5
Agriculture	148	2.0
Recreation	309	4.0
Sand and gravel	606	7.5
Riparian buffer	2,846	36.0
Total	7,900	100.0

[1] Land supporting riparian-type vegetation. In most cases this land has been mined for sand and gravel, and is comprised of gravel ponds.
[2] Range of a Threatened or Endangered plant or animal species.

The majority of the undisturbed riparian habitat lies between Friant Dam and Highway 41 beyond the city limits of Fresno. Of the 588 acres of riparian woodlands in the San Joaquin River corridor, 264 acres are classified as Great Valley Riparian Forest and lie on and adjacent to the Ball Ranch, approximately 3 miles below Friant Dam (Atlantis Scientific 1987).

Discharges into the San Joaquin River are controlled by the Bureau of Reclamation at Friant Dam. Approximately 95 percent of the average annual runoff of the San Joaquin River is diverted at Friant Dam for export south to Kern County and north to Madera County. The Bureau releases enough water into the river channel to deliver 5 cubic-feet-per-second past the last riparian water right holder at Gravelly Ford, about 37 miles downstream. Since instream flows were reduced in 1954, agriculture, urban uses, and sand and gravel extraction have occurred within the 25- to 100- year floodplain between Highway 41 and Freeway 99.

Below Highway 41 down to Freeway 99 much of the original riparian woodland has been removed for sand and gravel extraction, for golf courses, and for agriculture. The river in many areas has been diverted to flow through gravel ponds. This portion of the riverbottom also contains many older gravel ponds surrounded by woody vegetation comprised of shrubs, willows, and cottonwoods.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Executive Director, San Joaquin River Committee, Fresno, California.

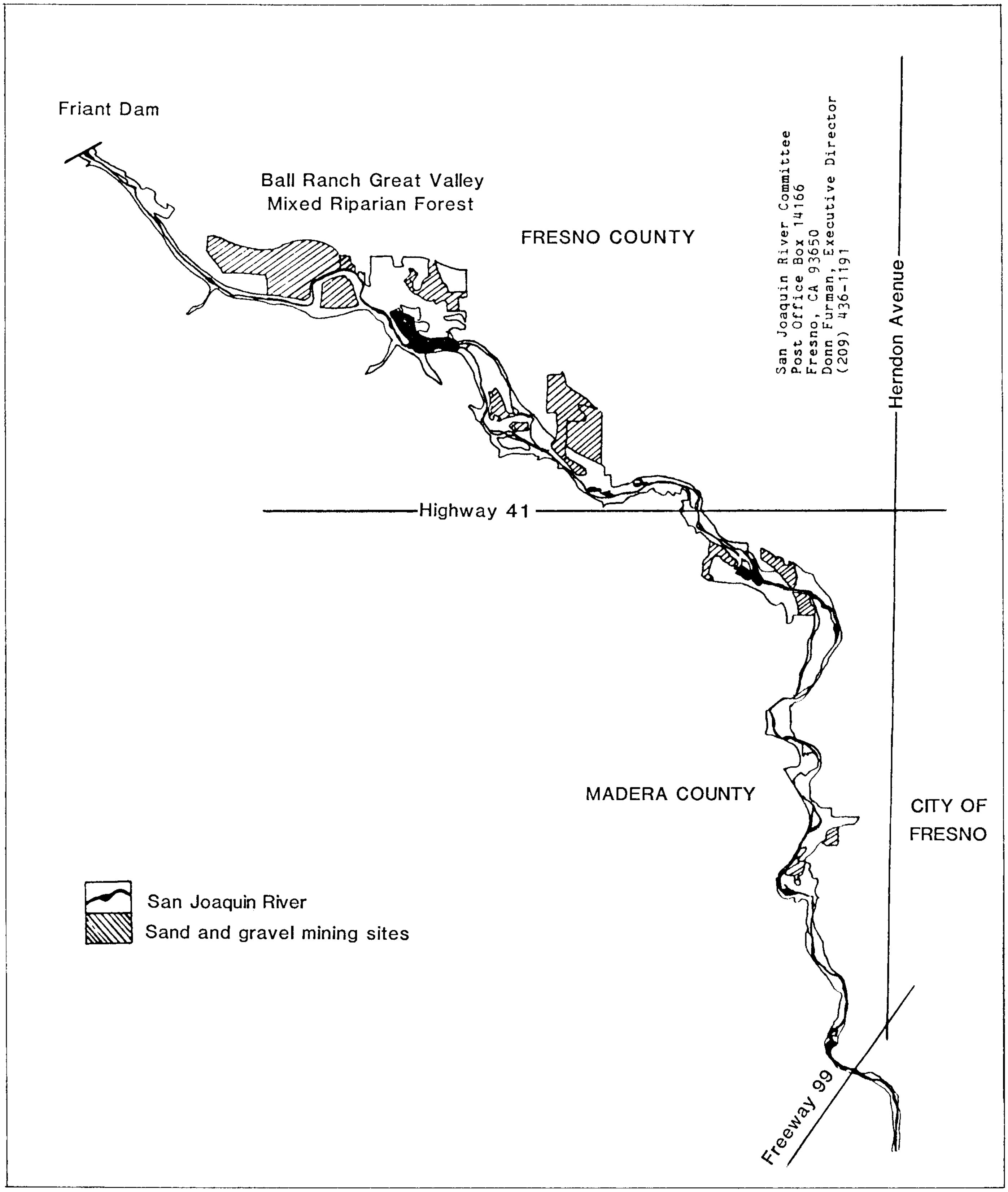

Figure 1- San Joaquin River riparian vegetation corridor. Mapping of San Joaquin River riparian vegetation corridor along the San Joaquin River between Friant Darn and Freeway 99. Prepared by the California Department of Fish and Game for the San Joaquin River Area Reconnaissance Study.

Threats to San Joaquin River Riparian Habitat Between Friant Dam and Freeway 99

San Joaquin River riparian habitat is threatened primarily by urban encroachment into the floodplain. Two proposed residential developments would place approximately 2,300 units on 835 acres within the river corridor. The proposed Ball Ranch residential development called for removing all but 22 of the 264 acres of Great Valley Mixed Riparian Forest in order to regrade the property to elevate housing pads one-foot above the 100-year floodplain.

Residential development directly threatens riverbottom riparian habitat in the San Joaquin River corridor through removal. It also indirectly threatens riparian habitat by increasing the need for future flood control measures such as channelization, clearing, snagging, and riprapping. At the present time the San Joaquin River below Friant Dam is not controlled by levees. Some minor levee work has been done along short stretches to protect sand and gravel processing plants.

Local agencies that exercise jurisdiction along the San Joaquin River corridor between Friant Dam and Freeway 99 include Fresno County, Madera County, and the City of Fresno. The City of Fresno placed a moratorium on residential development in 1986. It is currently considering adoption of riverbottom open space zoning that will preclude permanent residential structures. Land uses permitted under this zoning include agriculture, sand and gravel extraction, compatible commercial such as catfish farms, and public and private recreation including golf courses. The City has proposed policies to protect riparian vegetation.

The Madera County Board of Supervisors has placed a moratorium on residential development of riverbottom lands in its jurisdiction pending development of a specific plan. The current Madera County General Plan designates all areas not subject to intensive development for continued agricultural, grazing, and open space uses (County of Madera).

Fresno County's General Plan calls for open space land uses within their portion of the San Joaquin Riverbottom (County of Fresno 1976). Fresno County's jurisdiction is the largest of the three agencies. It contains most of the remaining undisturbed riparian habitat. The County adopted River Influence Area Policies in 1976, one of the objectives is which to conserve and enhance the natural wildlife habitat.

The Fresno County Board of Supervisors have indicated a willingness to consider amending the General Plan to permit residential housing. To date, no development proposal has been presented to the Fresno County Board of Supervisors for a vote.

Another threat to riparian habitat in the San Joaquin Riverbottom is potential recreational development. A 20-acre equestrian park and two golf courses have been proposed along the San Joaquin River within the 100-year floodplain.

Aggregate mining is a significant use of the San Joaquin Riverbottom. 95 percent of the aggregate used in Fresno and Madera Counties comes from the San Joaquin Riverbottom. At the present rate of consumption, the riverbottom aggregate resources can last approximately 25 years. In the past, aggregate mining was both along the channel and in the channel. This practice of mining the riverbed has now ceased.

California's Surface Mining and Reclamation Act of 1975 required that mine operators prepare operational and rehabilitation plans for their sites. Many of the sand and gravel companies operating under old conditional use permits issued by the two counties were not required to preserve riparian vegetation or maintain a riparian buffer. These operations are now in the process of preparing new rehabilitation plans.

Finally, road construction is a threat to riparian habitat. The City of Fresno's northern growth has brought about proposals for new freeway and road construction across the San Joaquin River to link residential areas in Madera County to the City.

Preserving and Restoring Riparian Habitat within the San Joaquin River Corridor

The San Joaquin River Committee whose activities I direct was formed in 1985 to support preservation and restoration of San Joaquin Riverbottom plant and wildlife resources. We are a nonprofit organization with over 800 members incorporated under Section 501(c)(4) of the Internal Revenue Code. We perform public advocacy through grassroots organization and public education.

We work with local and state representatives to support preservation of riverbottom riparian land and continuation of open space land uses. We helped to qualify Proposition 70 which allocates $5 million for purchase of riparian habitat in the San Joaquin Riverbottom between Freeway 99 and Friant Dam.

The San Joaquin River Committee has facilitated discussions with local school districts about utilization of the San Joaquin for outdoor environmental education.

We have held numerous public meetings to educate the public on issues affecting the riverbottom. We have covered a wide range of topics from reclamation of gravel ponds for wildlife to San Joaquin River flooding and flood control to public law issues affecting the conservation of open space.

An important part of the San Joaquin River Committee's overall program to educate the general public has been special events that bring people to the river. The most successful of these have been canoe floats where we take hundreds of people on day long floats down the San Joaquin.

The San Joaquin River Committee publishes a quarterly newsletter. The newsletter has proven effective in educating the public on the importance of preserving riverbottom riparian habitat.

While the San Joaquin River Committee has been very effective in "holding the line" on loss of riparian vegetation, the fact that it is primarily an advocacy group has precluded its being able to accept tax-deductible donations of money, land, and easements. We determined that forming a land trust would be beneficial for a longterm program of land preservation.

In March of 1988 we formed the San Joaquin River Parkway and Conservation Trust (the Trust), incorporated consistent with Section 501(c)(3) of the Internal Revenue Code.

Land trusts across the United States are committed by their charters to long-term management of land and land-based resources and to education about natural resources and the need for their stewardship. Land trusts are locally based, largely self- supporting, and run mainly by volunteers. Land trusts purchase and manage land, negotiate conservation easements, contract with public agencies to manage land, and conduct educational programs. They can act quickly and independently to acquire land when it becomes available, a process that can take months for government agencies. Two well-known national organizations that perform land trust functions are The Nature Conservancy and the Trust For Public Land.

Local community leaders who have agreed to serve as initial directors for the Trust reside in both Fresno and Madera Counties. The directors represent a broad range of interests including developers, environmentalists, lawyers, bankers, teachers, sand and gravel mining, businesses, farmers, cattle ranchers, landowners, and community activists.

The Trust has formed advisory committees of local citizens to develop a riverbottom conceptual plan, to develop recommendations on land acquisitions, to research, develop and conduct educational programs, and to fundraise for ongoing activities and specific land projects.

A recent project of the Trust calls for preparation of a conceptual map of a greenbelt-parkway along the San Joaquin River. This conceptual map will map riparian resources, identify sensitive areas for plant and wildlife, and pinpoint critical riverbottom lands for the Trust to acquire.

Two methods of protecting riparian lands are acquisition of land fee simple and acquisition of easements. Conservation easements are an attractive way to accommodate a landowner's desire to preserve land while restricting public uses and the public's interest in preserving a greenway. Easements exist at common law as a partial interest in real property which entitles the owner to some limited use of the property or restricts the landowner's use of the property for the benefit of the easement owner.

Easements are attractive to land trusts because they preserve land without the higher costs of acquisition. Easements are attractive to landowners because they reduce the appraised value of the land while allowing the land to remain the same.

Lands with the least economic value will be the most easily acquired. These lands will include areas prone to flooding—the river corridor itself with its band of riparian habitat—and areas mined for sand and gravel that have little potential for other kinds of development.

An excellent example of such a property is a 286-acre site under consideration for purchase by the Wildlife Conservation Board. This property includes a small island with low woody vegetation, a series of large irregular-shaped gravel ponds with young riparian vegetation, a large marsh, and reclaimed upland that floods in high water.

The efforts of the San Joaquin River Committee and the San Joaquin River Parkway and Conservation Trust have just begun. Hopefully, the lessons learned as we work to preserve and restore riparian habitat along the San Joaquin River will benefit other river corridors in California.

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MIDDLE SACRAMENTO RIVER REFUGE: A FEASIBILITY STUDY[1]

Charles J. Houghten and Frank J. Michny[2]

The woodlands and other streamside habitat of the Sacramento River's riparian system have been severely reduced within the last century. This riparian habitat and its ability to sustain diverse populations of fish, migratory birds, mammals, and other wildlife have been significantly impacted by water control projects, agricultural developments, and other land uses. The species of particular concern are the western yellow-billed cuckoo (Coccyzus americanus), Swainson 's *hawk* (Buteo swainsoni), *bank swallow* (Riparia riparia), *wood duck* (Aix sponsa), *chinook salmon* (Oncorhynchus tshawytscha), *and the California hibiscus* (Hisbiscus californicus), *as well as the threatened valley elderberry longhorn beetle* (Desmocerus californicus dimorphus) *and endangered bald eagle* (Haliaeetus leucocephalus).

The Study

In response to directives in House Appropriations Committee Report (No. 99-174) and Conference Committee Report (No. 99-1002) on the fiscal year 1987 Interior and Related Agencies Appropriations Bill, the U.S. Fish and Wildlife Service conducted the "Middle Sacramento River Refuge Feasibility Study." The study identified alternative management actions that could help protect the remaining riparian resources of the Sacramento River between Colusa and Red Bluff, California (Map 1), yet avoid major conflict with other interests or activities. A principal component of the study was the identification of 66 riparian habitat areas within four reaches (or sections) of the 160 kilometer river corridor. The sites, as well as the reaches, were evaluated for their overall habitat value, and prioritized for protection. The report was forwarded to Congress on October 16, 1987, and made available to the public in January 1988.

Extent of Riparian Habitat

About 6,885 hectares of riparian vegetation remain within the study area. Of this, nearly 1,215 hectares are currently protected by State or Federal agencies. The remaining 5,670 hectares of riparian vegetation, which include approximately 3,645 hectares of woodlands, are privately owned, and threatened with further loss of habitat with high value to wildlife.

Key Management Issues

Any habitat protection program along the Sacramento River must interface with bank stabilization work conducted by the U.S. Army Corps of Engineers (Corps). In the two lower reaches (south half) of the study area (Map 2), resource issues are being effectively coordinated with the Corps. In the upper reaches (north half) of the study area (Map 3), a comprehensive bank stabilization project placing stone revetment ("riprap") on approximately 35 percent of the river's banks is a more sensitive issue. The principal reasons for concern about this bank stabilization project include: (1) the need has not been clearly demonstrated; (2) salmon spawning may be negatively affected; (3) further losses to riparian vegetation may occur that will reduce the variety of wildlife; and (4) past mitigation efforts generally have been unsuccessful. However, conflicts between bank stabilization and habitat protection can be minimized, particularly if banks were stabilized in an environmentally sensitive manner, and on a "site specific" basis.

Other key issues identified during the course of the study included landowner concerns about trespass, and recreationist desires for public access. After a series of meetings with area landowners and representatives of various local, State and Federal agencies, the study concluded that a comprehensive program to protect and restore riparian habitat could be implemented with minimal conflict with other activities.

Findings—One Possible Approach

The study revealed several feasible approaches for protecting and restoring the study area's riparian resources. One is establishment and maintenance of a riparian zone refuge by State or Federal resource agencies, private conservation groups, or by multiple organizations.

The primary goal of land management agencies under a riparian zone refuge concept would be to protect the

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existing and currently unprotected 5,670 hectares of riparian habitat within the study area riparian zone. A secondary objective could be the enhancement of areas that are suitable for habitat restoration. A specific refuge boundary has not been proposed in order to provide flexibility in land acquisition and protection techniques.

If a refuge is to be established, habitat protection could be accomplished by purchase of fee title or conservation easement, cooperative agreement, or by other means. Areas of intensive recreational use, public access, residential areas, and agricultural areas could be excluded from the program. Lands would be acquired on a willing-seller basis only.

Appropriation

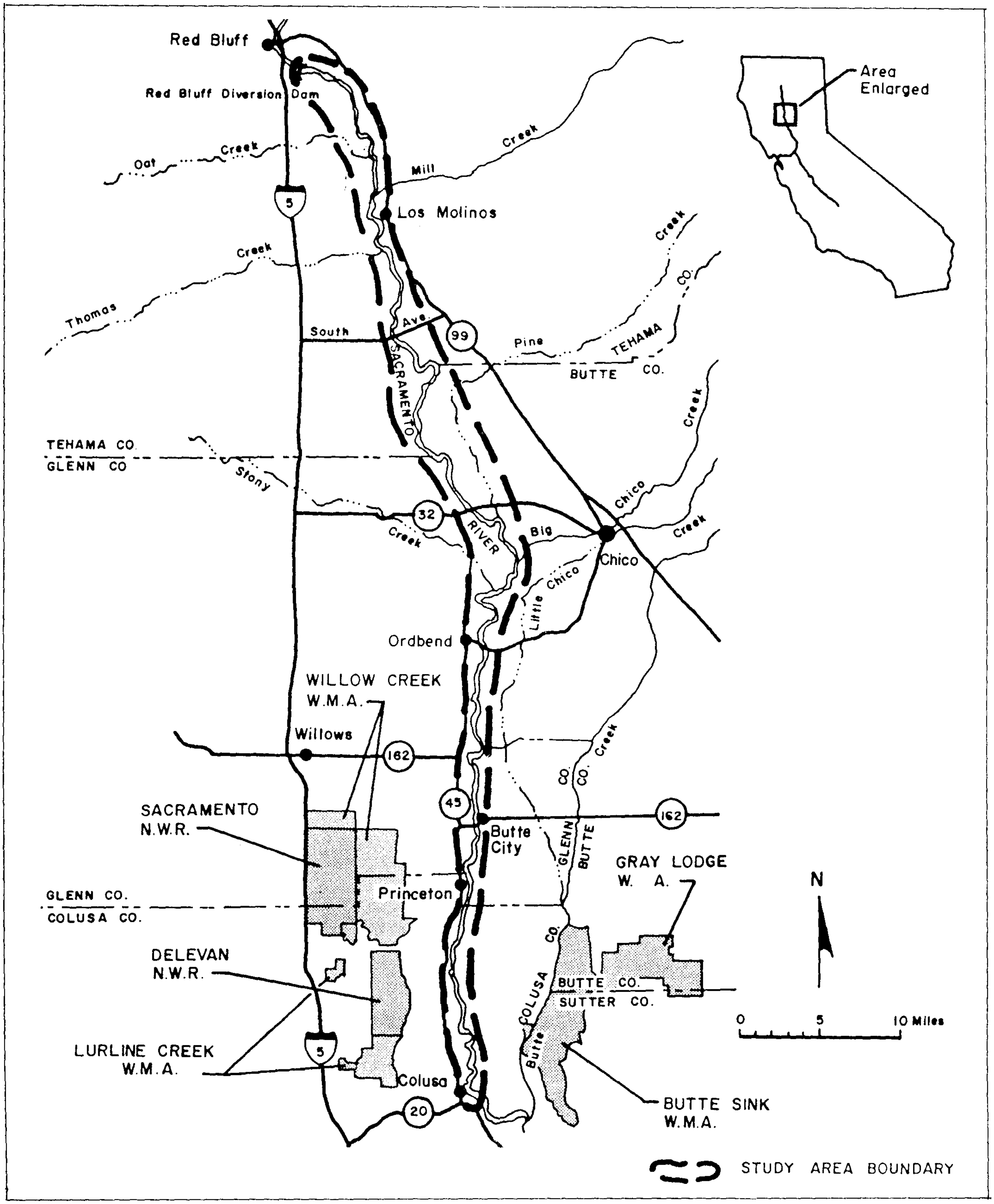
Since the completion of the study, Congress has appropriated $1,000,000 for initial acquisition of lands and establishment of the Sacramento River National Wildlife Refuge. An Environmental Assessment of this land acquisition project is underway and is expected to be completed in Fall 1988.

Conclusions

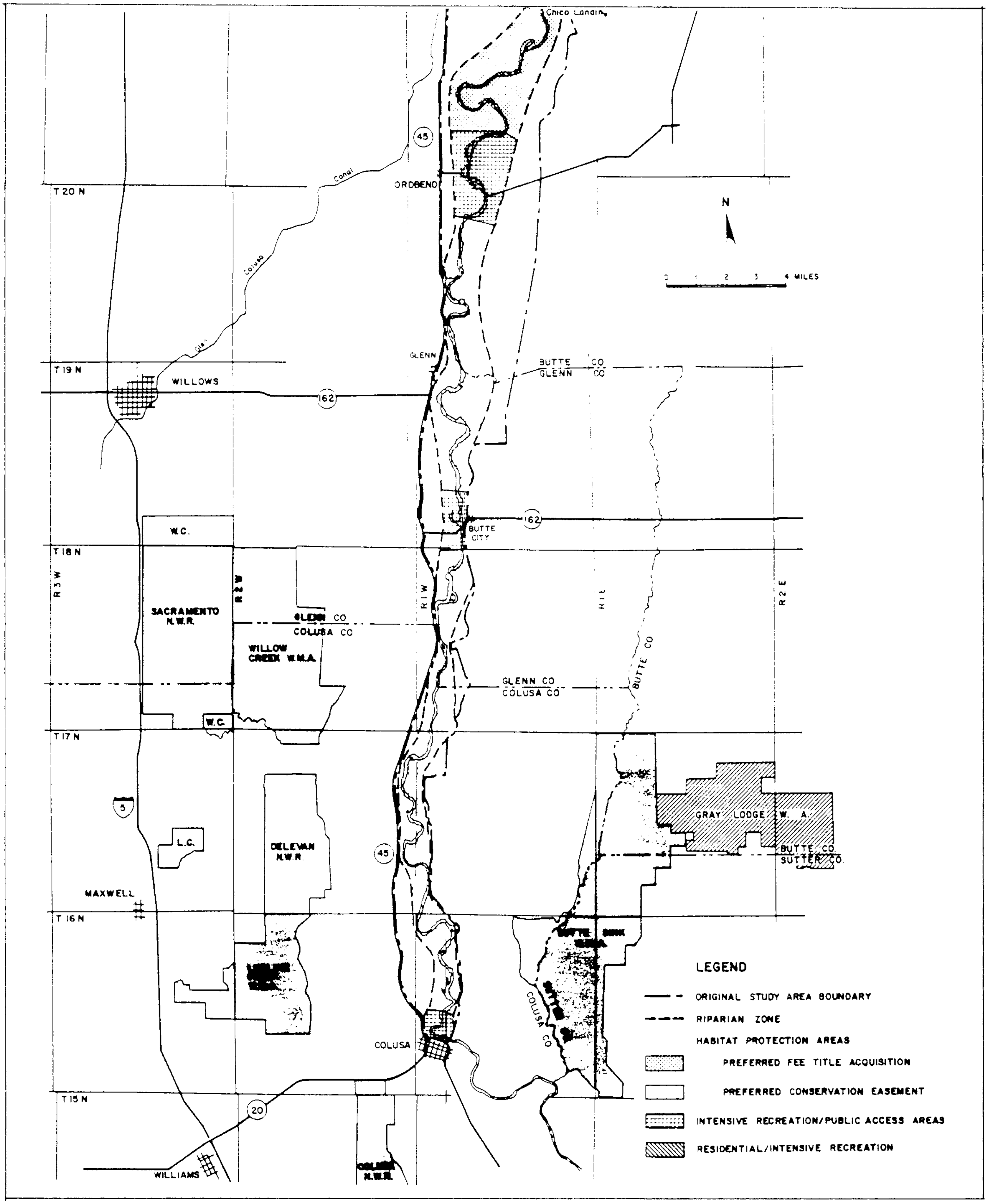
Coordination and cooperation among governmental agencies and area landowners will be a key in the success of a habitat protection program along the Sacramento River. We recommend that the applicability of the riparian zone refuge approach be further investigated for other California riparian systems.

Acknowledgments

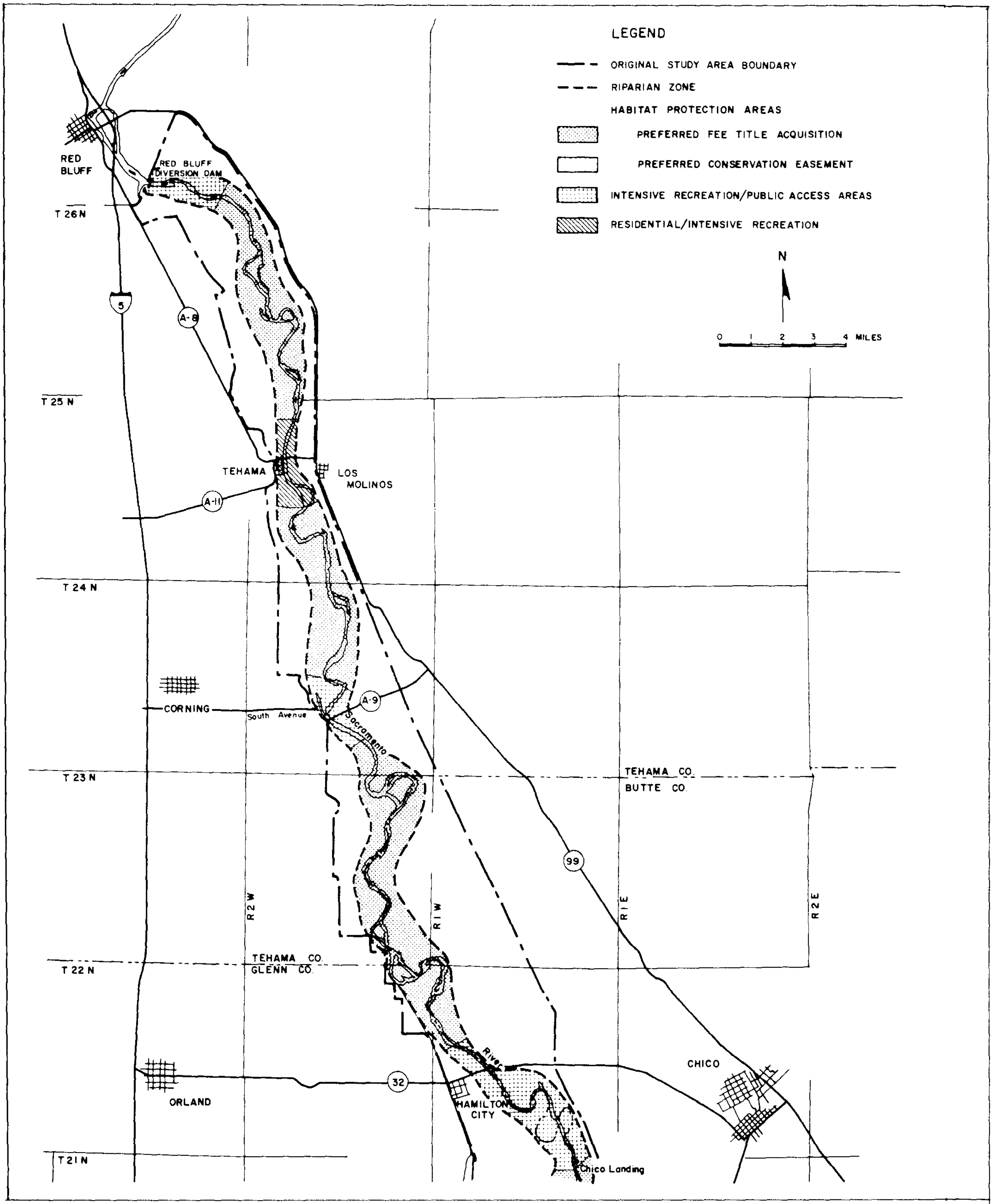
The study of the Sacramento River reported here was conducted in coordination with the U.S. Army Corps of Engineers and resource agencies of the State of California. Public input received during the course of this effort was greatly appreciated. We especially thank participants Cathy Osugi, Rich DeHaven, and Barry Garrison, U.S. Fish and Wildlife Service, and editorial coordinator Roberta Burzynski, U.S. Forest Service.



Map 1—Middle Sacramento River Refuge Feasibility Study Area



Map 2—Middle Sacramento River Refuge Feasibility Study Area Refuge Proposal, South Half



Map 3—Middle Sacramento River Refuge Feasibility Study Area Refuge Proposal, North Half

DEVELOPING MANAGEMENT PLANS FOR CALIFORNIA RIPARIAN SYSTEMS [1]

Michael Josselyn, Molly Martindale, Dianne Kopec, and Joan Duffield[2]

Project Scope and Methods

Twelve riparian systems in California between the Sacramento-San Joaquin Delta and the upper Sacramento (near Chico) were studied to develop operation and management plans to restore and enhance riparian habitat (Figure 1). Each of the study areas had recently been acquired by the California Department of Fish and Game (DFG) and were designated as Ecological Reserves or Wildlife Management Areas due to their significance as rare and endangered species habitat.

The study involved field inventories of plants and animals on each of the sites, examination of current and historic aerial photographs, and mapping of wetland habitats. In addition, site specific information such as soil maps, parcel maps, and other cultural features was collected. This information was collated into a set of maps and tables for each of the sites. In conjunction with DFG personnel, target species were selected for the area management goals. For each target species, life history and habitat requirements were determined as well as any description of current population status, if known, within the study sites. Based on the habitat requirements, a set of area management objectives was established which would best serve the needs of those species.

Each of the sites is affected by human activities. Sherman and Decker Islands have been used as dredge spoil disposal sites. Only a portion of Decker Island is owned by the state and grazing has extended over much of the island. Webb Tract Berms have suffered severe erosion due to boat wakes, dredging activities, and flooding such that of the 285 acres purchased by the State in the 1970's, only 80 acres remain. Woodbridge is surrounded by agricultural lands and must manage its water supply to reduce saturation of surrounding agricultural fields. Riparian areas along both the Feather and the Sacramento Rivers are surrounded by orchards and in some cases the orchards extend into the riparian forest.

Habitat Needs and Management Objectives

The target species for each of the sites is given in Table 1. Most of these species are either state or federally-listed rare or endangered species or are considered species of special concern. Almost all the sites supported six or more of these species, only the Woodbridge site was managed exclusively for the sandhill cranes. Based on the habitat requirements for each of the target species groups, the surrounding land use constraints, and fiscally feasible activities, area management objectives were established for each complex. Some of the key objectives are summarized below.

Delta Island Complex

- Habitat management must strive for a balance between levee maintenance and provision of mudbanks and floodplains for rare plant species.

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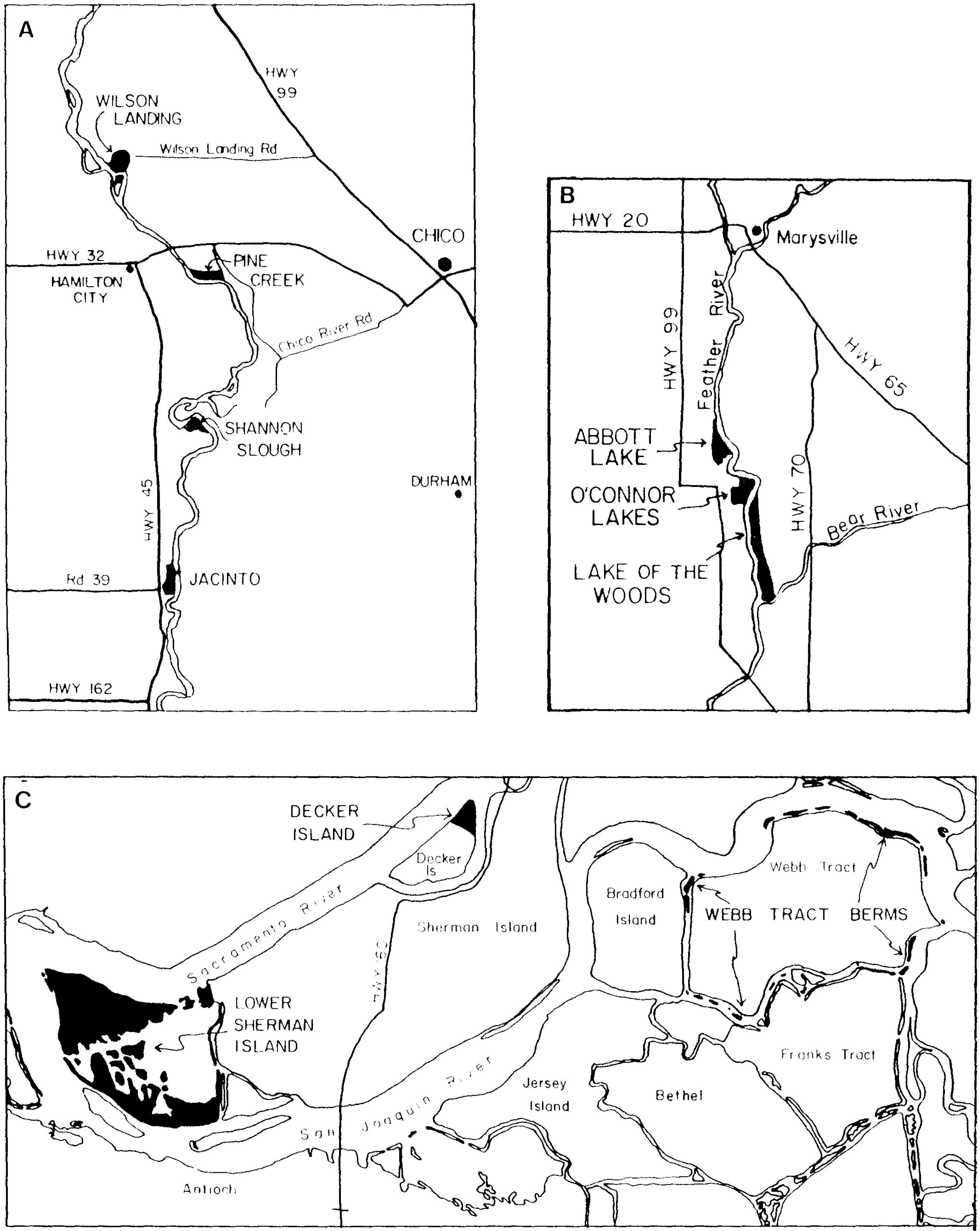

Figure 1 —Location map for ecological reserves and wildlife areas.

Woodbridge Ecological Reserve

- Expansion of shallow water with low vegetation to support roosting habitat for Sandhill Cranes.
- Provide extended open water habitat for waterfowl nesting.

Lower Feather River Complex

- Restore water levels within the backwater lakes.
- Restore mixed riparian forest within the floodway.
- Maintain tall snags and eliminate easements for firewood cutting.

Sacramento River Wildlife Areas

- Removal of nuisance species such as fig and salt cedar.
- Planting of valley oak and elderberry.
- Evaluate downstream impacts of streambank erosion control.

Table 1. Target species for management goals for the Sacramento River, Lower Feather River, Woodbridge and Delta Islands Complexes.

COMPLEX	PRIMARY SPECIES	SECONDARY SPECIES
Sacramento River	Valley Oak Forest Valley Elderberry Longhorn Beetle Yellow-billed Cuckoo Swainson's Hawk River Otter	California hibiscus Bank Swallow Yellow Warbler Yellow-breasted Chat Purple Martin Long-eared owl Ringtail
Lower Feather River	California Hibiscus Valley Elderberry Longhorn Beetle Giant Garter Snake Yellow-billed Cuckoo Swainson's Hawk River Otter	Turkey Vulture Bank Swallow Tricolored Blackbird Heron Rookery Ringtail
Woodbridge	Sandhill Cranes (Greater and Lesser) California hibiscus	None
Delta Islands	California Hibiscus Mason's Lilaeopsis Suisun Marsh Aster Delta Smelt Sacramento Splittail	California Black Rail Salt marsh harvest mouse Heron rookery Black-shouldered kite

Costs

Total management and implementation costs for these project areas range between $250,000 and $600,000 over a 5 year period. These expenditures are necessary if these rare habitats are to serve for the diversity of wildlife now restricted by agricultural and urban development in the Central Valley.

SESSION C: RANGELAND AND DESERT RIPARIAN SYSTEMS

The importance of riparian systems in providing for a variety of uses (including wildlife and fisheries habitat, water quality, recreation, and livestock grazing) is well documented in the papers in this and several other conferences and symposia held since 1976. Nowhere are riparian systems more important than in deserts and rangelands. The reason is because deserts and most rangelands occur in areas of low or seasonal precipitation or both, resulting in relatively few riparian areas and greater habitat contrast between the riparian and adjacent upland communities.

Recognition of the importance of desert and rangeland riparian systems has resulted in augmented riparian programs on the part of both the Bureau of Land Management, U.S. Department of the Interior, and the Forest Service, U.S. Department of Agriculture. These programs were summarized and commented upon in a report commissioned by Congress (General Accounting Office, Public Rangelands: Some Riparian Areas Restored but Widespread Improvement will be Slow, Report GAO/RCED-88-105, 1988).

Controversy, too, has helped drive this new riparian initiative. Probably foremost among the controversial issues is livestock grazing and its effects on riparian areas. Overgrazing of riparian areas was commonplace in the West in the late 19th and early 20th centuries. Even in recent times, when upland rangelands have been improved, riparian zones have continued to suffer from overuse. Traditional grazing systems designed to improve upland rangelands do not usually work in riparian areas.

As the papers in this session show, this trend is changing. Management techniques have been designed and implemented to improve the condition of riparian areas. These techniques have ranged from total exclusion of livestock to the implementation of grazing systems designed to improve riparian vegetation. Execution of these actions to improve riparian areas depends not only on land management agencies but on private landowners and ranchers as well. Many ranchers are becoming increasingly aware of the value of riparian areas and are working to improve the management of these areas, as the paper by Flournoy and others demonstrates.

Off-road vehicle use and other forms of recreation are impacting desert riparian systems also, especially in California, where urban populations place heavy pressure on nearby areas. Desert riparian systems are afflicted too by the spread of several introduced species of the genus *Tamarix* at springs and along rivers. The paper by Van Cleve and others discusses management actions taken to ease both of these conflicts.

According to the recent Congressional report (cited above), neither the Bureau of Land Management nor the Forest Service has completed comprehensive inventories of the riparian resources on Federal lands. There is a similar lack of inventory information on the riparian resources on private lands. Clearly, more extensive inventories of riparian areas are necessary. The paper by Gradek and others details the inventory efforts of the Bureau of Land Management in California.

An adequate and widely accepted classification system for riparian areas is a necessary precursor to any inventory. Such a system should take into account the important physical and biological components of riparian systems. The azonal nature of riparian systems makes classification more difficult than that of zonal upland ecosystems, but successful approaches have been implemented, as the papers by Bennett and others and Swanson show.

Riparian systems tend to be resilient: the presence of water year-round allows riparian vegetation to respond rapidly to management, as the papers by Key and Gish attest. Once improved management has been implemented it is important to allow riparian systems to repair themselves, as the paper by Elmore demonstrates. Too often we have tried to impose our own will upon the systems through the use of structures such as checkdams and streambank revetments, instead of first giving riparian vegetation a chance to do the job.

Much work still must be done to improve the degraded riparian areas of the West. This conference hopefully will stimulate land managers, both public and private, to continue working toward improving the condition of these critical ecosystems.

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RANGELAND RIPARIAN SYSTEMS[1]

Wayne Elmore[2]

Abstract: The management and recovery of degraded riparian systems is a major conservation issue. Presently there are many grazing management strategies being applied based on the name of the technique with little incorporation of basic stream processes. Managers must understand the exact workings of grazing strategies and the individual processes of each stream before prescribing solutions to degraded riparian systems.

"Riparian" is a word that strikes fear in the hearts of many, anger in some and feelings of peaceful surroundings to others. It is a word that has grown to mean many things to many people, but is rarely understood. It has become an emotional subject that has led to one of the key public land issues in the United States today. Many people are beginning to believe in the old Will Rogers saying "Thank God we don't get all the government we pay for."

Early Oregon explorers and residents observed what our riparian areas once looked like. Peter Skene Ogden, after traveling in 1825 through the Crooked River Basin in Eastern Oregon observed willows from side to side across the valley bottom. Most of this scene is now gone. The Indian word "Ochoco," for which our Central Oregon mountains are named, means "streams lined with willows," yet today willows are uncommon. Senior ranchers in Central Oregon tell stories about the problems once encountered gathering cattle in the "thick willow stands" on Big Summit Prairie. The "thick willow stands" have been reduced to scattered clumps. Historic evidence indicates that most riparian zones were then in better condition than they are today.

The Riparian System

In recent years the management or riparian areas has typically been the primary responsibility and interest of wildlife and fisheries biologists (Elmore 1987). Improvements have been primarily judged in relation to habitat for big game, song-birds and fish. But riparian areas are more than just habitat for wildlife. They actually are functioning systems that provide physical filtering of water, bank stability, water storage, and assist in the recharge of underground aquifers along with the adjacent uplands. Wildlife habitat is a product of those functions, and should not be considered as the only emphasis for managing riparian systems. In fact, many times wildlife benefits are among the lowest economic value received from riparian restoration.

To fully evaluate the benefits and incorporate riparian management into land use plans, I believe that we must go back to basic functions.

These functions include:

1. Physical filtering of water–Riparian vegetation can withstand high velocities of water and still remain intact. One of its functions is to slow the flow of water, literally "combing" out sediments and debris. This water purification process also helps to build banks; so channels typically become narrow and deep where once they were wide and shallow. Vegetation, such as grasses, sedges and rushes, lays down under high flows, and literally forms a blanket of protection over the banks. This process reduces bank cutting and aids in deposition of sediments. Where deposition has occurred through time, extensive wet meadows or flood plains develop (Elmore and Beschta 1987).
2. Bank stability–The diversity of grasses, forbs, sedges, rushes, shrubs and trees produces a variety of fibrous and tap roots that bind and hold settled soils in place. The binding effect of the roots helps maintain the positive factors of the bank building processes during high flows. A combination of both woody rooted and fibrous species have a reinforcing effect. The woody rooted species provide physical protection to the hydraulic forces of eroding water and allow forbs, grasses and sedges to bind the finer particles. In combination, this diversity of plant species is much more effective in promoting bank stability than is any one species by itself.
3. Water storage and recharge of underground aquifers–The aquifers in many areas of the west are going dry and one of the processes of riparian systems is to help recharge a percentage of a given aquifer. For many degraded riparian systems, all flows are contained in the channel and cannot access the banks or floodplains where water can spread. It is widely accepted that we can lower a water table and drain a stored underground aquifer through channelization or erosion. It is not readily accepted, however, that we can reverse that process and store water through recovery of riparian systems and deposition in formerly degraded channels. Riparian systems slow the flow of water and allow it to spread and soak into the banks like a sponge, which raises water

[1]Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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tables. When banks rebuild through filtering of sediments, they increase the area for water absorption and improve recharge of aquifers by allowing gravity to work on the stored waters.

Upland areas must not be excluded in this paper because they are an integral part of the riparian system. Overland and subsurface flows also influence sediment loads, water cycles, and recharge of aquifers.

Other processes I have observed in Eastern Oregon riparian systems, that have shown a substantial ecological improvement, include increases in the base flow (minimum flow level, i.e. the discharge to which the stream returns after storms or snowmelt periods), reduction in buildup of ice, and physical filtering of sediments by ice. Almost all of the processes I have observed as negative in our stream systems today become positive factors when those streams are in good ecological condition. The education we transfer to the managers and users of our natural resources must contain this basic information.

Management Evaluations

Understanding riparian system functions is essential to their management. In management applications as we endeavor to restore streambank conditions, we are often applying techniques based primarily on the name given the technique and not on what that technique actually does. For example, the three Pasture Rest Rotation grazing system works very well in Central Oregon on low gradient streams that are primarily grass-sedge-rush sites, but can be a disaster on streams that need shrubs for bank stability. If we look "inside" this grazing system, we find that it was designed to fit the physiological needs of grass plants and not riparian shrubs. If we look even closer at what happens under this grazing system in desert rangelands, we can see why shrubs generally decline. The first year we graze the pasture early during the growing season. The second year we graze the pasture after upland grass seeds ripen (usually mid-July), and the third year we rest the area from grazing.

During the spring use period, we receive little if any utilization on willows by livestock. Upland grasses are green and growing, providing a much more palatable forage source than shrubs. During the second year, the common utilization rate for upland grasses in this grazing system is 60 percent. These grasses are now dry and unpalatable and by the time we have achieved the desired 60 percent utilization on uplands, we have gotten 80 to 90 percent utilization on riparian zones. Our observations in Oregon show livestock will begin using the current annual growth on willows during the seed ripe treatment (mid-July through September), when riparian utilization reaches 45 percent. They will increase their use on shrubs again at approximately 65 percent and again at 85-90 percent utilization. The third year we rest the pasture and, hopefully, no use occurs. In analysis we can see that we are basically losing three years of growth on willows and only getting two years of growth back. However, at the same time we are meeting the physiological need of the sedges, rushes and grasses.

There are many things we could do to solve this problem. One is to restrict riparian utilization during the seed ripe treatment to 50 percent or less. Another is to make the riparian area a separate pasture. A third is to add more pastures to achieve more rest, or finally we could exclude the stream from grazing. The point is you must know what your proposed management is going to do, and how it will work in each individual stream system.

Other grazing systems that we commonly use in Eastern Oregon are deferred (graze after seed ripe every year) and early or spring grazing. Deferred or seed ripe use every year can quickly remove small shrubs from streams systems because of heavy riparian utilization, but can also increase sedge and rush communities in wide low gradient valley systems. Early or spring use every year can be beneficial to riparian system recovery, but many times this system can be detrimental to upland grasses if grazing always occurs during the critical part of the growing season (when flower stalks emerge from basal bud). It is very apparent that utilization of riparian vegetation should not be a major concern unless it affects stream function. This occurs commonly with deferred grazing systems on sites where regrowth is limited and in the use of three pasture rest rotation where shrubs are needed for bank stability and sediment filtering.

Figure 1 is a simplified look at how we try to analyze our riparian systems and proposed management techniques. Every management strategy exerts an amount of stress on our riparian systems. The ability that each stream has to handle this stress depends on its own natural stress or sensitivity. Some streams with high natural sensitivity such as those with bentonite soils and high erosion potential are immediately in the caution area and probably can stand little, if any, management stress (human influences). Others that are low gradient with sandy loam soils, for example, can recover under much higher management stress. In our evaluation, the stress of management must not be confused with livestock numbers. Often, for streams in poor condition, livestock reduction was proposed as a solution. However, no recovery in the stream occurred. It was not the numbers of livestock that was the problem, but the management strategy. For example, Bear Creek in the Prineville BLM District previously had 73 animal use months (forage needed to sustain a cow for one month) of grazing under a season long strategy. This was more management stress than over 300 animal use months now exerted during early spring grazing. As a result of decreased stress, the creek is making significant improvement with a four fold increase in grazing use. There are many other examples in Oregon and throughout the Great Basin, as exhibited in research work by Bill Platts and others (Platts and Raleigh 1984; Platts and Nelson 1985).

Exclusion of livestock is a management strategy that has been proven to work in inducing the recovery of riparian areas. It continues to receive a lot of criticism from many managers and users of the public lands for several reasons. Some of them are: expense of fence construction, maintenance, wildlife concerns and livestock water. However, if we look at many streams in poor ecological condition they have become, in effect, upland exclosures. The attractant nature of streams to livestock during summer grazing periods many times excludes livestock use on 90 to 95 percent of the adjacent upland areas. What we typically observe with streams in poor ecological condition are all of the negative things we receive with improper grazing concentrated in one area. At the same time, we receive none of the positive factors of grazing in the upland areas where they were planned. We are also, I believe, many times comparing exclusion of livestock to improper grazing and not comparing it to proper grazing. There should be three scenarios in our evaluations, not two.

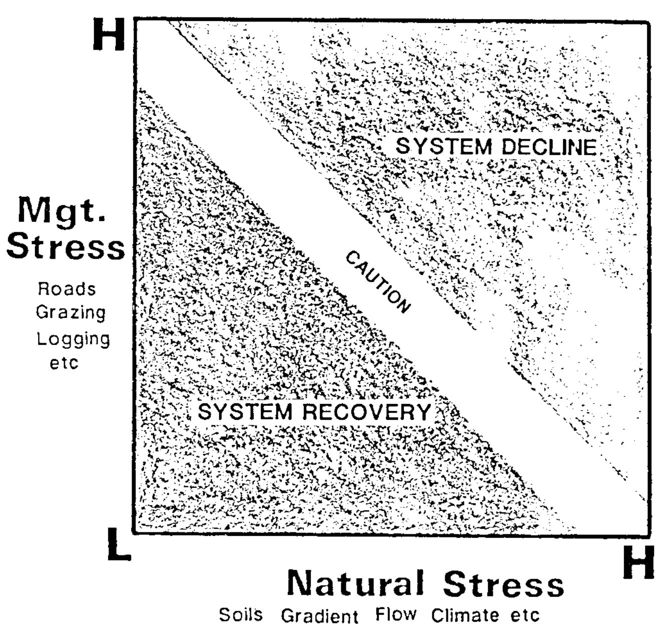

Figure 1—Natural stress or sensitivity of streams vs. management stress. Factors like soils, gradient, water column, climate, etc. must be considered when designing management strategies for system recovery.

Conclusions

We must begin to realize that we can look at things in a different way and that changes in management can provide recovery in our stream systems. The benefits from those changes far outweigh the costs of continuing with our present practices.

The watershed, not just the stream system, must be our focal point. As our energy and dollars focus on restoring degraded streams, we also have to look at the uplands. We cannot forget that the speed and clarity that water comes off our uplands has a big impact on what happens in the stream system. If our goal is a higher quality and quantity of useable water, then the other 98 percent of our rangelands must be a part of our program.

We are at a critical time in the management of riparian areas and associated uplands. "Members of the livestock industry can provide leadership in understanding and solving complex riparian questions (Elmore and Beschta 1987). We must begin to look at both private and public lands because riparian areas have never been able to tell the difference in ownerships, only in management. If we don't change our management, we will either lose the benefits of our natural resources, or we will lose the flexibility to manage for multiple use. The American public is concerned about useable water quality and quantity as evidenced by the recent Congressional override vote on the President's veto of the Clean Water Act. The public will demand more from the management of our natural resources and we must start now to meet those demands. Just remember, you will never see a picture of a degraded riparian zone on a calendar so why should we have them in our landscapes. Riparian management – full stream ahead.

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USING STREAM CLASSIFICATION TO PRIORITIZE RIPARIAN REHABILITATION AFTER EXTREME EVENTS[1]

Sherman Swanson[2]

Abstract: Historic use of many stream riparian areas and associated watersheds has impaired the capacity of riparian vegetation and floodplains to reduce stream energy and trap sediments. As low-gradient streams with erodible banks increase in width and change their pattern, they approach a threshold of instability. Once a stream exceeds a threshold, it must proceed through a process of geomorphic gully evolution that includes degradation, widening, and aggradation phases. Opportunities for enhancing and maintaining favorable conditions of stream morphology and associated riparian values vary throughout this process. The highest priority stream reaches for watershed, riparian, and stream management are those approaching the threshold. After the degradation phase, the marginal reaction to management input increases as the gully widens. Riparian grazing can be managed in a variety of ways to avoid detrimental effects. A useful alternative to a riparian exclosure is a riparian pasture that can be managed for optimum riparian resource values.

The pattern of settlement and the history of use of the American West has left today's natural resource managers with many riparian problem areas and horror stories. Many stream environment zones that have degraded are now unraveling and have been doing so for decades Cottom and Stewart (1940). Some have not yet reached the threshold leading to collapse. Others are progressing through the process of geomorphic and ecological recovery. As years pass, additional stream reaches succumb to the convergence of a major runoff event and an approach to a threshold. This happened to many streams in the early 1980's when successive winters produced abnormally high runoff that each year prolonged the period of high flow.

Active stream-channel dimensions conform to the bank-full flow that typically represents the normal high water mark (Wolman and Miller 1960). This bank-full flow comes only once or a few times in most years. It is effective in forming the channel that conveys it because it represents the greatest cumulative energy level. Larger flood events last for too short a time to generate much effect even though their energy level is extreme for a short time. Low-flow events lack the energy even though their duration is substantial. However, when approaching a threshold (Van Havern and Jackson 1986), there can be substantial effect during a flood if either or both of two conditions occur: 1. The cohesiveness of stream channel materials weaken significantly; or 2. The forces impinging on the stream-channel materials increase because of some change in the cross-valley profile that confines the flood wave.

Historical land management has often created both of these conditions. Furthermore, inappropriate management of mining, road building, timbering, fire, or grazing has caused many watersheds to release water and sediment at substantially increased rates. Increased flows force the stream to adjust and they may exceed the capacity of the natural or stressed stream channel to convey them without significant alteration. Although streams approach and exceed thresholds of instability under natural conditions, it normally requires dramatic geologic or climatic change for a large number of streams to approach threshold within a time period as short as man's influence on the West. It seems inappropriate therefore, to attribute the inordinately devastating effects of rare but natural events to "acts of God".

This paper uses concepts developed from stream classification (Rosgen 1985) to describe the role of riparian vegetation and floodplains in maintaining stream channel morphology in low-gradient streams. From these concepts is drawn an approach for prioritization and management of such streams. Although many of the principles apply broadly, the management field of livestock grazing is emphasized.

Function of Riparian Vegetation in Stream Morphology

At the Sheldon Antelope Range in Northwestern Nevada, Nebraska sedge (*Carex nebraskensis*) dominated communities have an average of more than 2 meters of roots and rhizomes per cubic centimeter in the top 10 centimeters of the soil profile (Manning 1988). It is no wonder that it and other broad-leaved sedges have gained a reputation for stabilizing sediment and binding stream-bank soil (Youngblood and others 1986). Although other species of herbaceous plants may not have as great a root-length density, it is not uncommon to

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see stream banks that are stable because of the tough sod produced by plants that thrive in the moist conditions found with a high water table. Willows and other woody riparian species have also achieved a measure of notoriety for their role in stream-bank stability.

Besides providing cohesiveness to otherwise erodible alluvial materials, vegetation provides roughness that increases friction at the water-land interface. This decreases velocity and decreases the energy available for doing work including detachment of channel materials and transport of bedload or suspended sediment. The filtering effect of riparian vegetation is partly responsible for deposits of fine fertile soils on many floodplains such as mountain meadows. Within the active channel it is also instrumental in the process of narrowing streams that are recovering from bank erosion.

It is natural for streams on low (<1.5 percent) gradients with floodplains to meander (especially C6, C4, and C3 stream types (Rosgen 1988)). This involves a balance of erosion on the outside turns and deposition on the inside turns. In order for streams to remain stable, the rate of these two processes must remain in approximate equilibrium. If the outside erodes faster than the inside captures and stabilizes sediment, a narrow deep stream that could provide tremendous habitat for cold-water fish may become wide and shallow. As the stream widens, the stream pattern changes accordingly. Streams tend to form meanders that are approximately 7 to 10 times as long as the stream is wide (Leopold and others 1964). Characteristically, as a stream widens it breaks through meanders and the broad sweeping curves of the new channel lead to decreased stream length. Sinuosity is inversely related to channel gradient for a given reach of stream maintaining constant elevation at the top and bottom ends. Therefore, as the stream straightens, the gradient and velocity increase. The total energy is thus expended over a shorter length of channel. It can exceed critical shear and accelerate erosion.

Function of Floodplains in Stream Morphology and Gully Evolution

One of the characteristics of a narrow deep sinuous (C6) (Rosgen 1985) stream (fig. 1) is that the surface of the water is near the surface of a broad flat floodplain. The high water table provides abundant water to the vegetation that in turn provides the bank stability upon which stream morphology depends. The broad flat floodplain is necessary for dissipation of energy during flood events.

Figure 1–The broad floodplain of a narrow, deep sinuous channel dissipates flood energy allowing vegetation to build and stabilize stream banks.

Tractive force is directly related to depth of flow and slope. Therefore as a stream floods it has increased energy available to do work (erosion) on the stream channel largely in proportion to the increase in depth. A stream that can spread out over a broad floodplain increases depth only a small amount during a flood event therefore it can withstand floods of tremendous magnitude with little erosion. Such streams will generally deposit fine sediment on the floodplain and build stream banks during flood events.

As stream reaches with broad valleys capture sediment, they gradually steepen. Under natural conditions, the stream valley may become too steep for meander maintenance Patton and Schumm (1981). When meanders begin to cut and the stream straightens, the concentrated energy can downcut the channel by exporting channel materials. This can initiate a nick point that develops into a headcut (fig. 2) and proceeds upstream, assuming a life of its own.

Any net export of channel material causes the stream to lose some accessibility to its floodplain. As the floodplain loses its ability to dissipate flood energy, the energy of the confined and therefore deeper stream energy accelerates the process of downcutting until the stream reaches a gradient that is low enough, or the new channel materials are coarse enough, to stop downcutting. At this point the stream approaches local base level. A totally confined stream (gully or arroyo) on a low gradient (<1 percent) is labeled F by Rosgen (1988). Initially the stream width is the same as the gully-bottom width (fig. 3), the old floodplain is a terrace, and there is essentially no floodplain. Therefore energy is very concentrated and high water continues to do work by eroding the gully walls.

Figure 2–Headcuts concentrate the energy of flowing water, thereby accelerating erosion, downcutting, and confinement.

Figure 3–Initially downcut streams are as wide as the gully bottom and have no floodplain.

The water table that previously supported dense vegetation on the old floodplain is lowered as a result of downcutting. Riparian vegetation is then replaced by more xeric species such as sage brush (*Artemisia tridentata*) and cheatgrass (*Bromus tectorum*). The over-steepened gully walls typically remain unvegetated or lightly vegetated because of their natural instability and xeric soil conditions. Even as vegetation colonizes the water edge at the bottom of the gully wall, it is subject to extreme tractive force during high water because of the confinement of the stream. Therefore, the active channel in the bottom of a gully soon achieves a high width/depth ratio (10- 40). It stays wide and shallow until the gully walls erode apart far enough for there to develop a useful floodplain in the bottom of the gully. It then would be labeled a C type by Rosgen (1985).

The farther apart the gully walls become, the more the floodplain can dissipate energy and the more effect streambank vegetation can have in controlling the morphology of the active channel (fig. 4). As gully banks recede, there will eventually be aggradation on the expanding floodplain. Then floodplain widening can proceed under the dual influence of gully bank erosion and filling of the trapezoid-shaped gully. The gully banks define terraces that eventually may again become floodplain if the gully fills sufficiently.

At any point in the recovery, the aggrading sediments may again be cut by a new cycle of gully evolution. This cycle of aggradation and degradation has occurred repeatedly in some mountain meadows since the Pleistocene (Wood 1975). The time between cycles depends on a combination of factors including sediment supply from the headwaters, size and shape of the valley, climate, etc. Modern man has triggered the degradation phase of this cycle prematurely in thousands of locations by land use practices.

Roads and trails on floodplains are notorious for their effects on streams because of their tendency to help the stream cut through meanders. Some roads and trails have been captured by floodwaters to become stream channels. Their straight path allowed the tractive forces of floods to excavate a completely new channel, a gully. "Improved" roads may accomplish the same effect by covering part of the old floodplain area with road-fill material. This not only removes potential valley bottom for the stream to meander across but also confines floodwater and thereby increases its depth and energy.

Figure 4– The emerging floodplain of a widening gully dissipates energy and promotes vegetative stabilization of the active channel.

Other land-use activities may also produce gullies. Many stream valleys are used for transporting logs. In previous decades, the stream itself was sometimes the vehicle. The grazing effects of concentrated livestock in riparian areas is widespread where grazing management has not prevented distribution problems. Livestock grazing (or abrasion by logs) on stream banks can have the effect of caving in the overhanging banks (fish cover) that otherwise form on low-gradient meandering streams with erodible soil. As the stream banks erode from the physical effect of trampling or because of weakened root systems, the opposite bank must be able to capture and stabilize sediment in order to maintain the equilibrium and the narrow channel. If residual vegetation is not available during the period of high water, or if the grazing and trampling effects are too great, the net effect is first widening and then, if the gradient of the valley becomes too steep, downcutting. Many if not most streams located in wide valley bottoms have downcut to some extent in the last century and a half. The tremendous amount of sediment coming from these eroded stream banks and gully banks has in turn caused additional problems downstream.

Prioritizing Land Management Settings in Evolving Landscapes

Land managers must accept the history of land use that has preceded them. By understanding that history and the physical and ecological attributes of it, they can better appreciate the trend of their landscapes and the potential of those landscapes to respond to management. Effective land managers recognize the limits of their financial, physical, temporal, and managerial resources. They focus attention on land management practices that will most significantly improve resource values over some future period. In an evolving landscape, it is not useful to compare what could be with what is. One must instead compare what could be assuming option A, with what might be assuming option B. This must be done in individual settings to determine if the possible or proposed actions will be worthwhile. It also must be done in many settings simultaneously to determine where and how limited resources can do the most good. Economists term this the best marginal reaction.

Major problems or opportunities are commonly concentrated in small areas of a land unit, along certain roads, stream reaches, etc. Here is the place to begin prioritizing. However, care must be taken to avoid the approach of simply attacking that which is most ugly. Considering the evolution of stream valley degradation and aggradation discussed above, it is clear that land management input invested during certain phases of the cycle will yield far greater benefits over time than would comparable input invested during another phase.

Highest Priority Stream Reaches

The highest priority streams are the ones that still have and use their floodplain, especially if the use of it could be lost through downcutting (figs. 1 and 2). Streams that still rely on stream bank vegetation growing at the same or nearly the same level as the floodplain will be most likely to respond to appropriate riparian grazing strategies. This is in part because of the availability of water and the vegetative resilience that comes with water availability. It is also due to the energy dissipation influence of the floodplain. If the stream bank is composed of fine-grained erodible soil, especially sand, silt, loam, or fine gravel, and if the stream is or was highly sinuous (C6, C4, and C3), it is probably most dependent on bank vegetation.

If the stream has begun to downcut, it may be approaching a threshold of instability which, once exceeded, may require a long period of gully downcutting, widening, and filling to duplicate present riparian values. Proper management is especially critical in stream valleys that are long and deeply filled with erodible alluvium that has consistently depended upon streambank vegetation for streambank and meander integrity. Once headcuts form, they are very difficult to heal vegetatively. The time to act is before the threshold is exceeded and the nickpoint initiated.

Lowest Priority Stream Reaches

The lowest priority streams are the ones that are unlikely to respond to management even if they are the ugliest and even if they were once the prettiest (fig. 3) Where a stream has downcut and is totally confined in the bottom of a gully, stream energy is concentrated and management inputs are likely to be wasted. It is common for land managers to remember or presume how the meadow or streamside floodplain used to look and to want to refill the gully.

High check dams are a commonly used method for attempting to achieve this. Predictably these normally wash out. As it approaches local base level, a gully progresses through its natural evolution of widening. Behind dams, widening is accelerated because energy is redistributed against the bank at an elevated stage. Designers who recognize this often prolong the life of a dam by extending the keyways well into the banks. The concentrated energy dissipation at the dam is also a hazard if the dam is too steep on the downstream side, if the downstream banks are not adequately protected, or if the plunge pool is inadequately armored. If the dam is effective at redistributing flood waters over the old floodplain, some of the water must at some point re-enter the gully. The concentrated energy dissipation at that point commonly initiates a headcut that can also bypass the dam. The hazard of this may increase as flood waters attain higher elevation behind a dam that is filling with vegetation-stabilized sediment.

It is possible to capture significant resource values, at least in the short run, with check dams in gullies (Swanson and others 1987). However, the financial cost can be high and the risk of failure increases with the quantity of water available to do work. The best application of check dam treatment is high in the watershed on small gullies that have reached local base level or where bedrock protects the lowest of a series of dams from an upstream migrating headcut. In general, low structures (1/10 to 1/4 of the active channel bank-full height) are preferred to high structures (1/4 to 2/3 gully bank height). For a discussion of how to choose the correct design for fish habitat improvement structures for particular stream types, refer to the work of Rosgen and Fittante (1986). They point out that many stream "improvement" structures, when placed in inappropriate stream types, cause more damage than benefit. Any of a variety of structures can produce benefit if properly used in the correct stream type.

Another common response to gully erosion, when it results from livestock grazing, is dramatically altered livestock management. Although protection of the riparian vegetation colonizing the gully bottom may provide some decrease in the width/depth ratio of the active channel in the bottom of the gully, and may slow the rate of gully widening, the effects are minimal. The opportunity for benefits to exceed costs are lowest in the early phases of the degradation/aggradation cycle discussed above. The marginal reaction of an investment in intensive livestock grazing management increases as the gully bottom widens.

Increasing Priority Stream Reaches

A dramatic shift in the potential of a gully bottom stream to produce a narrow stream channel conducive to cold-water fish appears to occur at about the time the gully bottom becomes wider than the active channel (fig. 4). At this time the floodplain inside the gully has begun forming and can begin to dissipate some flood energy. Riparian management and riparian vegetation then become significantly more important.

The marginal reaction of investments increases most with gully widening if the benefits are measured on site. These benefits include improved fish habitat, riparian vegetation, and aesthetics (fig. 5). To the degree that sediment is a concern downstream, the rate of gully widening (erosion) becomes more important. Sometimes the benefits of even a little riparian management and riparian vegetation along the bottom of a narrow gully prove worthwhile. However, if sediment is a big problem, the marginal reaction of investments to prevent the gully in the first place could have paid for some rather intense management. Also, such receiving streams will likely have suffered significant alteration from the sediment received after initial gully formation. Some stream types (such as flat gradient (<1 percent) gravel or sand bed streams with fine-soil banks, C3 and C4 (Rosgen 1985)) substantially increase bank erosion after an input of sediment. Sediments deposited in bars occupy channel capacity and force the stream to redistribute energy against its erodible banks. Sediment also fills reservoirs and may become trapped in coarser gravels that must be clean to provide adequate fish spawning habitat.

Other receiving streams can tolerate substantial input of sediment without significant alteration of channel morphology or resource values. The sediment is simply routed downstream to larger streams or rivers.

Figure 5– Gullies that are old, wide, and well managed become valued again for riparian vegetation, fish, and wildlife habitat, water and sediment storage, and aesthetics.

Grazing Management for Riparian Benefits

Livestock distribution is the number one grazing problem in the western United States. The heart of the problem is commonly over used riparian habitat. Controlling utilization is a central precept of grazing management. However, it must be recognized that this is not simply controlling the number of grazing animals or the length of time that they are in a pasture.

Typically cattle graze certain species and certain areas before they graze others. The species and areas are likely to change from season to season and the effect of grazing and trampling has a different effect on different species and areas at different times. This allows a careful observer to identify problem areas and practices that cause unacceptable damage. The manager can then use a variety of livestock management tools to avoid the problem. Grazing systems specify the season, the length of time, and the number of animals that can graze a pasture. Often grazing systems specify a rotation pattern so that periods of grazing that are in some way detrimental do not occur every year. Range improvements, such as water development and vegetation manipulation, that encourage livestock to increase use of previously under-utilized areas can also take pressure off riparian areas.

Perhaps the most direct means of control is a well maintained fence. Fences, however can serve diverse purposes. The design of a fence means a great deal to both the use of the area and the cost of the fence. Use of riparian exclosures has made it obvious that stopping bad grazing practices can produce tremendous benefits to streams and to fish and wildlife habitat (Platts and Rinne 1985). From riparian grazing research (Platts 1986) and accumulating experience (Elmore and Beschta 1987), it is also becoming apparent that improved grazing practices can produce improved riparian and stream conditions. Improved grazing management can do this without placing an exclosure fence in a recreation or wildlife use area.

A useful practice especially along streams with broad floodplains and expansive areas of abundant riparian vegetation is the riparian pasture (Platts and Nelson 1985). This avoids the problem of cattle concentrating in a small riparian part of very large pastures and allows grazing managers to efficiently tailor riparian grazing to optimize riparian values. Some riparian grazing management techniques such as grazing systems and seasons of use that are appropriate for particular settings are discussed by Elmore in this volume.

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TEN YEARS OF CHANGE IN SIERRAN STRINGER MEADOWS: AN EVALUATION OF RANGE CONDITION MODELS[1]

Barbara H. Allen[2]

Abstract: Grazed Sierra Nevada stringer meadow systems were sampled on Blodgett Forest Research Station in northern California between 1977 and 1987 to determine cattle use, and to examine changes in production and species composition over time. Utilization of meadow species averaged 61 percent over the 10 years, but use increased to more than 80 percent utilization after 1985. Production averaged 2733 kg/ha but has significantly declined in recent years. Relative species composition has not changed, nor has total vegetative cover between 1979 and 1986. Range condition models based on changes in species composition were not useful for assessing these stringer meadow systems. Managers should instead base livestock management on stream bank conditions and meadow productivity.

Montane meadows in California range in size from a few square meters to several hundred hectares interspersed through every forest type (Allen 1987). Meadows provide forage and cover for an estimated 260 animal species, including at least 12 sensitive, rare, or endangered animals (Timossi 1988). Water and recreation from meadows are valuable resources (State of California 1988).

Although small in extent, meadows in the Sierra provide up to half the summer forage for livestock. Historically, heavy stocking rates and consequent overuse changed meadow hydrology, species composition, and production. Although Federal laws have regulated livestock use since 1891, many meadow systems are still in poor condition (Ratliff 1985).

Range condition can be defined as "the current productivity of a range relative to what that range is naturally capable of producing" (Society for Range Management 1974). Most range condition models use species composition as the foundation for assessing condition or "range health". For example, the quantitative climax approach (Dyksterhuis 1949), compares current species composition to climax species composition. The Forest Service's score card approach adds vegetation production, soil erosion, and soil cover criteria to species composition when assessing condition (USDA 1969). Generally, productivity and forage values are assumed to be highest when the rangeland plant community is near climax, and lowest when the vegetation is in an early seral stage (Sampson 1952).

Early studies in the Midwest showed that grazing can cause changes in species composition through selective use of specific plant species (Dyksterhuis 1949, Ellison and others 1951). Continuous grazing at heavy stocking rates, or during the wrong season, decreases palatable (and also climax) plant species and increases invader and increaser species (Dyksterhuis 1949). Changes in rangeland vegetation resulting from overgrazing allow condition to be expressed in condition classes, generally 'excellent', 'good', 'fair', or 'poor'' (Sampson 1919).

Reduction of grazing can result in a return of climax species and improved range condition (Branson 1985). Improvement can also be quantified by condition class– the changes retracing the path of range deterioration (Heady 1975). These concepts were applied to rangeland ecosystems throughout the western United States.

This paper reports a study to evaluate long-term changes in production and species composition on grazed stringer meadow systems, and to determine the value of range condition models for meadow management.

Methods

This study began in 1976 as part of a larger mixed conifer forest grazing study (Kosco 1980) at Blodgett Forest Research Station, near Georgetown, CA, at 1500 meters elevation on the west slope of the Sierra Nevada. The study site's Mediterranean climate has cool, wet winters and little summer rainfall. Precipitation is concentrated between October and March, averaging 171 cm/yr. The range between 1977 and 1987 included a low of 58 cm and a high of 279 cm. Winter high temperatures averaged 8°C, while daytime summer temperatures averaged 28°C.

Meadows comprise less than 1 percent of the study site. Some herbaceous vegetation grows in disturbed areas such as clearcuts, skid trails, and along roads, but most grows in stringer meadow systems, which follow natural drainages (fig. 1). Some areas remain wet throughout the year, while slightly higher areas dry out as the summer progresses. This results in a visual (as well as statistical) difference in botanical composition within and between meadows.

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Figure 1—Stringer meadows vary from a few meters across to about 40 m, following the water courses in the mixed conifer forest.

Cattle grazed the study area between May 30 and September 30 every year. The study area is not fenced; the cows and calves are free-roaming, following water courses and forage supplies in meadows and clearcuts. The permittees distribute animals over their allotment, which includes the study area, by riding, salting, and culling of animals. Thirty-five cow/calf pairs (140 animal unit months) were allocated to graze the study area.

Production/Utilization

Fourteen square meter, paired, caged and uncaged plots were used to determine meadow production and utilization between 1977 and 1987. Visibly distinct types based on species composition were recognized during a reconnaissance survey of the study site. Cages were placed to characterize meadow vegetation on the whole study area. This resulted in 14 cages being placed on 8 meadow systems.

Herbaceous production was determined from clipped 1/16 m^2 quadrats taken from the center of each caged plot. Clipping occurred at peak above-ground production, generally mid-September. Each spring the cage was moved to a new location near the previous one to reduce cage effects on production.

Utilization of herbaceous vegetation was estimated by clipping a 1/16 m^2 grazed plot paired with each caged plot used for the production estimates. Utilization was calculated from the equation:

$$\text{Utilization} = (\text{UGHW} — \text{GHW}/\text{UGHW}) \times 100$$

Comparisons of meadow production and utilization were made using analysis of variance (Zar 1984) over all years. Multiple comparisons between means for years were examined using Duncan's multiple range test at alpha of 0.05 (Norusis 1986).

Species Composition

Species composition was recorded using a 10-point frame within each cage before it was clipped in 1979 and 1986. Fifty points per cage were recorded; totaling 700 points per year on the meadows.

Species composition between 1979 and 1986 was compared using ANOVA and the nonparametric Mann-Whitney test for differences between means (Norusis 1986).

Permanent Exclosure

A 3.5 by 5 m exclosure was erected in 1977 to provide information on long-term changes in species composition without grazing. The exclosure represented Forest-wide meadow species composition with a mixture of grass, forbs, rushes, and sedges. The exclosure was sampled with 300 points using a 10-point frame in 1979 and again in 1986. Significant differences in plant groups were compared between years using the binomial distribution (Zar 1984). Exclosure production was sampled from 5 clipped plots and compared to average meadow production on caged plots in 1988.

Results

Changes in Production and Utilization

Average above ground biomass production on Blodgett Forest meadows varied significantly among years between 1977 and 1987 (fig. 2). In general, years prior to 1985 produced significantly more standing crop than after those years, except for 1977 which followed 3 consecutive years of drought. Mulch, the herbage remaining at the end of the grazing season, significantly changed during the study (fig. 2). With a pattern similar to production, mulch averaged 1046 kg/ha prior to 1984, but only 581 kg/ha between 1984 and 1987. The three wetter meadow types on Blodgett produced 4210 kg/ha in 1987. Dry meadow types produced an average of 1590 kg/ha, while nine moist types produced an average of 2495 kg/ha.

Utilization, or the proportion of vegetation consumed by grazing animals, differed significantly among years during the study (fig. 3). Utilization averaged 55 percent prior to 1984, and averaged 71 percent after that, peaking in 1986 at 82 percent. Specific plots consistently varied in utilization reflecting differences in production and species composition of the plots.

In 1979, no meadows on the study site had signs of erosion, streambank widening or bare eroded surfaces (Kosco 1980). This was not true in 1987 (fig. 4).

Species Composition

Meadows on Blodgett are relatively depauperate in number of species. Only five species of grasses, several species of sedges and rushes, and 11 forbs were recorded (Table 1). Total vegetative cover averaged 88 percent in 1979 and 84.4 percent in 1986. Grasses do not dominate these meadows. Grass composition totalled 20.8 percent in 1979 and 13.2 percent in 1986.

Forbs form the larger category with *Mimulus primuloides* dominating in 1979 and 1986 at 27.3 and 21.5 percent relative cover, respectively. Except for an increase in sedge cover, no category differed significantly between 1979 and 1986. No statistically significant difference occurred in percent bare ground/litter.

Following Ratliff (1985), species were designated as decreasers, increasers, or invaders (Table 1). Decreasers declined from 19 to 14 percent, while increasers also declined from 60 to 48 percent from 1979 to 1986. These statistically insignificant declines were largely offset by the increase in sedge species which may act as increasers or decreasers in meadows, depending on species.

Finally, the meadow species were assigned to categories of desirable, less desirable, and undesirable based on their relative palatability to cattle using standard USDA Forest Service scorecards for meadow species (USDA 1969). None of these categories changed significantly between 1977 and 1986.

Table 1 - Relative foliar cover of Blodgett Forest meadow species in 1979 and 1986.[1]

	Percent Relative Cover[2]		
Species	1979	1986	D,Inc,Inv[3]
Agrostis thurberiana	3.1	-	Inc
Agrostis sp.	5.2	4.3	Inc
Danthonia californica	8.9	5.9	Inc
Muhlenbergia filiformis	2.8	1.0	Inc
Panicum lanuginosum	0.8	2.1	---
Carex spp.	6.6	23.6	D/Inc
Juncus oxymeris	19.3	13.8	D
Juncos & *Luzula* spp.	2.8	5.3	D/Inc/Inv
Trifolium repens	7.4	1.9	Inv
Mimulus guttatus	1.8	-	---
M. primuloides	27.3	21.5	Inc
Hypericum anagalloides	10.8	12.7	Inc
Viola sp.	1.9	2.6	Inc
Unknown forbs	0.3	1.6	---
Moss species	0.6	0.3	---

[1]A dash indicates that the species was not found that year. Cover percentages calculated from 700 points using a 10-point frame within ungrazed cages.

[2]Differences in species composition are not significant ($p < .05$) between 1979 and 1986, except for the increase in *Carex* species.

[3]D = decreaser, Inc = increaser, Inv = invader. Category designations are from Ratliff (1985).

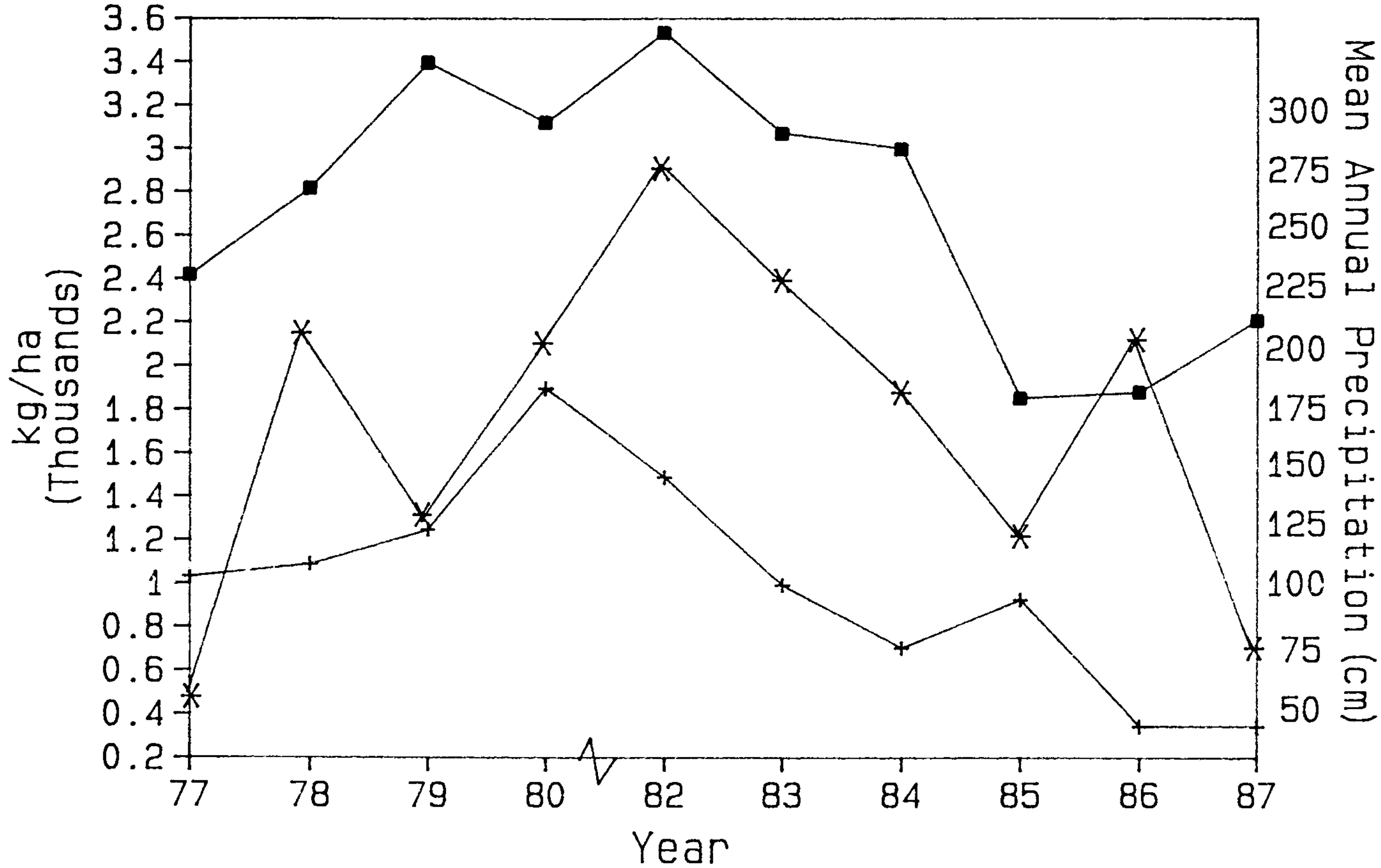

Figure 2—Production averaged approximately 3000 kg/ha prior to 1985 and 2000 kg/ha from 1985-1987. The years 1985 and 1986 produced significantly less standing crop than 1979 and 1982 which were high production years on Blodgett Forest. Mulch follows a similar pattern to production, with significantly more mulch remaining in 1980 than any other year.

Permanent Exclosure

The primary change in the permanent exclosure between 1979 and 1986 was in the statistically significant increase in *Carex* species from 5 to 13 percent cover. No other changes were significant, except for the decline in bare ground from 9 to .3 percent. Composition changes in the ungrazed exclosure were similar to grazed plots. Total grass cover declined from 20 to 13 percent. Rushes slightly declined from 10 to 8 percent, while forbs remained relatively constant at 48 and 49 percent cover between 1979 and 1986. Although not statistically significant, litter increased from 8 to 15 percent and was visually apparent in the meadow. Standing crop production in 1988 was greater (2,733 kg/ha) than production on the rest of the study site (1854 kg/ha), but not significantly.

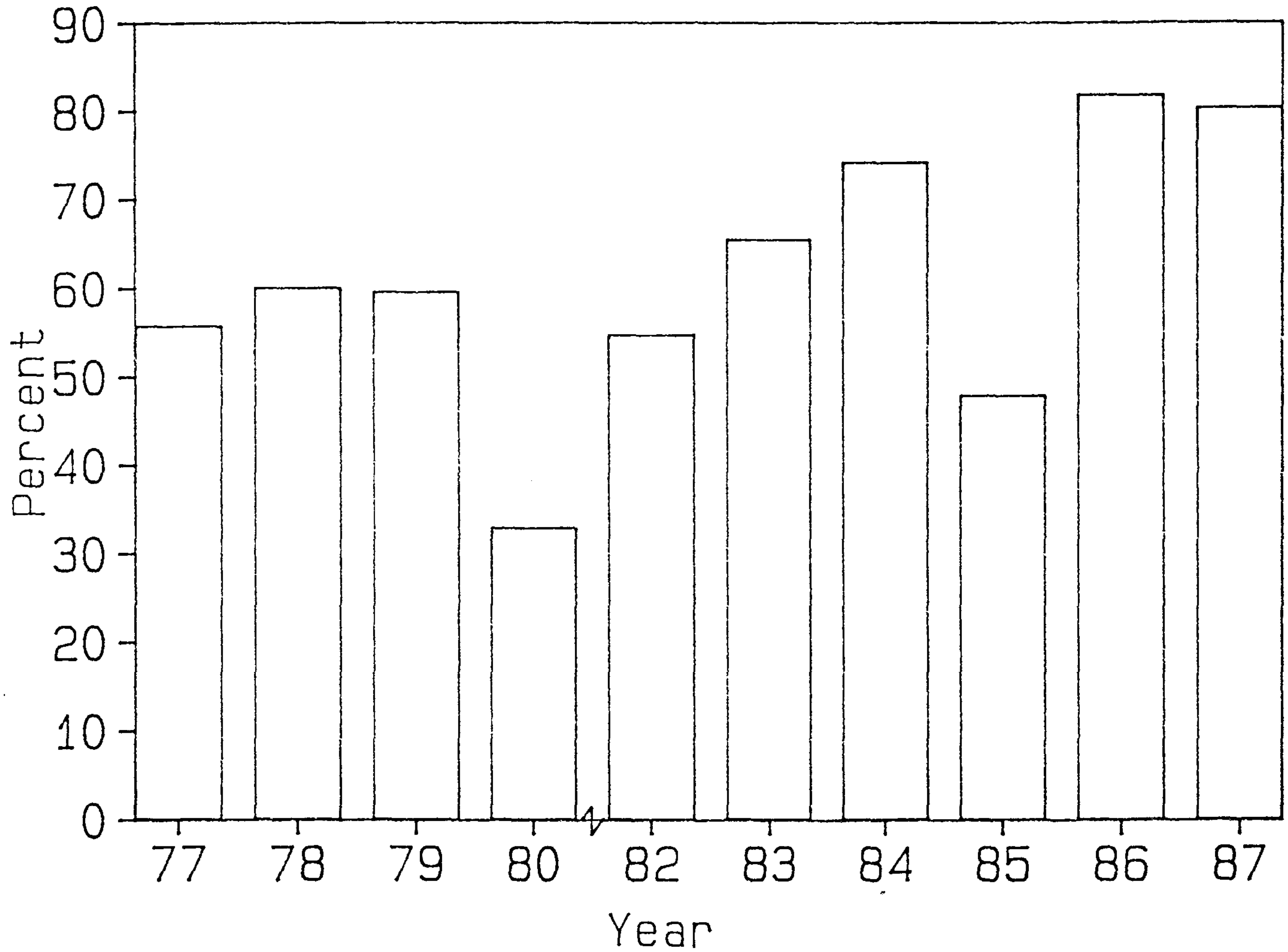

Figure 3—Utilization has generally increased, peaking at 82 percent in 1986. Low levels of utilization in 1980 and 1985 may be due to fewer animals on the study site in those years, or more forage available on the clearcuts.

Discussion / Conclusions

Application of the traditional range condition model based on percent composition of decreasers, increasers, and invaders would rate the current (and 1977) meadow conditions on Blodgett as fair to poor condition (Ratliff 1985). Using Crane's (1950) criteria for rating meadow condition based on the amount of bare ground or litter, the meadows on Blodgett would rate in excellent condition. Application of Forest Service (USDA 1969) soil cover criteria would rate the meadows as good. The three models span all four possible condition ratings on the same meadows from the same data, suggesting low utility.

Species composition of the meadows on Blodgett has not changed (with the exception of an increase in *Carex*) in the last ten years, with or without grazing. Production has significantly declined, utilization has increased, and bare ground and litter have remained approximately the same. Thus, I conclude range condition models that link productivity to species composition are not useful for managing these types of stringer meadow systems.

Figure 4–Streambank erosion and meadow trampling caused by early season use may be contributing to the decline in meadow production.

The permanent exclosure indicates that species composition did not retrace the path of range deterioration as long standing theory predicts (Heady 1975). Cattle graze the meadows on Blodgett Forest seasonlong, recently at high levels of utilization. Meadow species within reach of the livestock are grazed by the end of the grazing season, with the possible exception of the coarse, wetland rush species. One hypothesis is that the meadows were in poor condition ten years ago and remain that way today.

These meadow systems have changed over the last 10 years, however. The data in the literature suggest that these meadows are not producing their potential (Ratliff and others 1983, Crane 1950, Bennett 1965). The available references suggest that these meadows should produce 5000 kg/ha on wet or moist sites, and 2400 kg/ha on dry sites. Using these criteria, peak standing crop on the wetter meadows on Blodgett is approximately 84 percent of potential. Dry meadow peak standing crop is 66 percent of potential. And moist meadow peak standing crop is only 50 percent of potential. Low productivity may be largely due to the large component of forbs in these moist meadows, and relative lack of productive grasses and sedges.

Stringer meadows are a small, but important, component of the mixed conifer ecosystem. Photographic evidence (fig. 4) indicates broken down stream banks, widened stream beds, and locally broken meadow sod in the meadows on Blodgett Forest. These factors may be contributing to low productivity, and damage to streams. Managers face a difficult problem to achieve timber management objectives through heavy livestock grazing on the clearcuts, without damage to the riparian meadow resource. More effective grazing systems to improve these meadow systems need development. Traditional range condition models are of little value either in assessing needs for improved management of these riparian systems, or evaluating the effectiveness of any newly developed practices.

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AN APPLICATION OF BLM'S RIPARIAN INVENTORY PROCEDURE TO RANGELAND RIPARIAN RESOURCES IN THE KERN AND KAWEAH RIVER WATERSHEDS[1]

Patricia Gradek, Lawrence Saslaw and Steven Nelson[2]

Abstract: The Bakersfield District of the Bureau of Land Management conducted an inventory of rangeland riparian systems using a new method developed by a Bureau-wide task force to inventory, monitor and classify riparian areas. Data on vegetation composition were collected for 65 miles of streams and entered into a hierarchical vegetation classification system. Ratings of hydrologic function, vegetative structure, and vegetative use by grazing animals were employed to measure impacts by land uses and potential for recovery with proper management. The data for each of 116 stream reaches was entered into a dBase III program for tabular analyses and will be entered into the Geographic Information System (GIS) for spatial analysis and cartographic output.

In 1987, the Bakersfield District of the Bureau of Land Management (BLM) inventoried 65 stream miles of rangeland riparian habitats in the Kern and Kaweah River watersheds. This inventory employed state-of-the-art methods developed by the Bureau's Riparian Area Management Field Task Force. These methods (U.S. Dept. Interior 1987a) include procedures for extensive and intensive inventories, monitoring, and vegetation classification of riparian areas. To adapt the procedure to this specific area, we used these methods as a broad guideline, and included some modifications from the work of Platts and others (1987). We found this combination of methods effective in describing, quantifying and classifying riparian ecosystems under the Bureau's management. In contrast to efforts in 1982 that centered on wildlife and water resource data needed for a grazing Environmental Impact Statement, this effort included information on vegetative structure, composition, stream morphology, and apparent trend.

This work provides an overview of the structure and condition of the riparian systems in the Kern and Kaweah River Watersheds in central California. The inventory has been used to select sites for more intensive monitoring.

Field Procedure

The first step was to examine thoroughly the results of earlier inventories. Then we developed a form to record data (fig. 1). The form includes selected parameters that had been sampled in the earlier inventories and could be resurveyed to estimate trend in conditions. In addition, it includes a combination of parameters suggested by the Bureau's Riparian Area Management Task Force (U.S. Dept. Interior 1987 a and b), Platts and others (1987).

All perennial streams on public lands in the Kern and Kaweah River watersheds were inventoried. In the field, the inventory crew stratified each stream into reaches. Homogeneous reaches contained similar vegetation composition, channel morphology, degree of impact from grazing, or other management influences. A separate reach was established when any significant change in one of these three factors occurred. Most streams had several reaches since few were homogeneous enough to be considered one reach. Each reach was then marked on 7.5' scale topographic maps and on 1:24,000 scale color aerial photographs. The form in figure 1 was completed for each reach. It provided data on physical features, a riparian site function rating, and a vegetation classification for each reach.

Physical Features

The form records data on physical features such as landform, soil characteristics, channel substrate, channel and side slope gradient, and morphological processes. These data are used in conjunction with aerial photographs and topographic maps to generally describe the stream's character and physical constraints, and to indicate its potential for improvement in condition.

The interaction between these physical features and the vegetation, animal and land use practices at a site creates complex ecosystems capable of frequent changes in conditions. Collecting this information for stratified stream reaches aids in subdividing the streams into more manageable units and identifying those critical reaches in need of special management considerations or rehabilitation.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] District Hydrologist, District Wildlife Biologist and Wildlife Biologist, respectively, Bakersfield District, Bureau of Land Management, U.S. Department of Interior, Bakersfield, California.

Stream: Chimney Creek #3 Date: 8/4/87 Observer: McNeill-Nelson

Reach: 1 Legal Location: T24S, R36E Sec 24

Watershed: Chimney Ck Flow Duration: Intermittent Perennial

BLM Stream Miles: .76 Stream Order: 3rd Landform: Broad Valley

Upstream Elevation: 5560 ft. Downstream Elevation: 5400 ft.

Streambank Soil Texture: Sandy Bank Rock Fragments: Gravel Cobble Stones Boulders

Substrate: Sand Silt Muck Gravel Rubble Boulder Bedrock

Soil Wetness: Wet Drained Riparian Width 15-25 ft

Channel Gradient: 4 % Sideslope Gradient: R gentle% L gentle%

Channel Sinuosity: Straight Winding Meandering

Channel Confinement: Occasionally Frequently Confined Entrenched

Channel Entrenchment: Aggrading Equilibrium Partly Entrenched Incised

Lateral Movement: None Avulsion Progression Channel Width: 3-4'

Streamflow: .094/42 cfs/gpm Water Width 18"

Water Source: Transport Inchannel Seeps Lateral Seeps Water Temp. 15°C

Manmade Alterations: (list & map) Dirt road & PCT cross creek. Old pipes near large cottonwood tree.

Erosion Processes: Headcutting Gullying Sheet Erosion Bank Collapse Livestock Trampling

Apparent Water Quality Impacts: Fecal Algae Growth Minerals Suspended Sediments Trash Mining Wastes

Soil Alteration Rating: 3 Vegetative Bank Protection: 2

Subsurface Water Status: 3 Riparian Site Function Rating: 2.66-Good

Vegetation Classification: Formation: Riparian Scrub

Climatic Zone: Cold temperate Biome: Sierran-Cascade Riparian Scrub

Series: Salix spp. Association: Salix/Eleocharis

Phase: Tree Canopy Cover: Forest (+61%) Woodland (20-60%)

Species: 1 Populus Only

Shrub Canopy Cover: Solid Clumped Sparse

Species: Salix spp.

Herbaceous Cover: 0-25% 26-50% 51-75% +76%

Species: Eleocharis-Meliotus-Juncus

Ungrazed ____ Grazed X 0-25% 26-50% 51-75% 76-100%

Age Distribution of Woody Dominants : Young even-aged stand All-aged stand Old even-aged stand Decadent

Improvement Potential: Moderate-restricted cattle use; instream structures in lower half to stabilize channel.

COMMENTS: Photo #1-15-11 with overlay; Lamont Peak 15' Quad. (Comments continued on reverse)

Figure 1 — Extensive stream riparian inventory field form

Riparian Site Function Rating

The Riparian Site Function Rating (U.S. Dept. Interior 1987a) just below the center of figure 1, was the average of three ratings assigned for each reach. The three ratings, the Streambank Soil Alteration Rating, the Vegetative Bank Protection Rating, and the Subsurface Water Status Rating, evaluate interdependent factors that influence hydrologic function of the riparian site. The ratings range from "4" for excellent conditions to "1" for poor conditions.

The Streambank Soil Alteration Rating (Platts and others 1983) assesses the extent of bank modification and instability caused by natural forces, livestock grazing, and other land uses (table 1). Streambank ratings are based on how far they deviate from the optimum conditions that would exist in an undisturbed state.

The Vegetative Bank Protection Rating (Pfankuch 1975) was developed in recognition of the important role vegetative cover and root mats play in stabilizing streambank (table 2). In turn, stable streambanks support a greater density and variety of riparian vegetation. The vegetation protects banks from erosive forces by reducing the velocity of flood flows.

Table 1 - Streambank Soil Alteration Rating (Platts and others 1983)

Rating Value	Percent	Description
4	0	Streambanks are stable and are not being altered by water flows or animals.
	1 to 25	Streambanks are stable, but are being lightly altered along the transect line. Less than 25 percent of the streambank is receiving any kind of stress, and if stress is being received, it is very light. Less than 25 percent of the streambank is false, broken down, or eroding.
3	26 to 50	Streambanks are receiving only moderate alteration along the transect line. At least 50 percent of the streambank is in a natural stable condition. Less than 50 percent of the streambank is false, broken down, or eroding. False banks are rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
2	51 to 75	Streambanks have received major alteration along the transect line. Less than 50 percent of the streambank is in a stable condition. Over 50 percent of the streambank is false, broken down, or eroding. A false bank that may have gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
1	76 to 100	Streambanks along the transect lines are severely altered. Less than 25 percent of the streambank is in a stable condition. Over 75 percent of the streambank is false, broken down, or eroding. A past damaged bank, now classified as a false bank, that has gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.

The Subsurface Water Status Rating uses the presence of hydrophytic plant species as an indicator of whether a shallow aquifer exists (table 3). When lateral erosion or channel incision occurs, the recharging of the aquifer is impaired. The water table in the riparian aquifer is lowered, and hydrophytic species begin to decline and are replaced by upland species.

Table 2 - Vegetative Bank Protection Rating (Pfankuch 1975)

Rating Value	Description
4	Excellent: Trees, shrubs, grass, and forbs combined cover more than 90 percent of the ground. Openings in this nearly completed cover are small and evenly dispersed. A variety of species and age classes are represented. Growth is vigorous and reproduction of species in both the under and overstory is proceeding at a rate to insure continued ground cover conditions. A deep, dense root mat is inferred.
3	Good: Plants cover 70 to 90 percent of the ground. Shrub species are more prevalent than trees. Openings in the tree canopy are larger than the space resulting from the loss of a single mature individual. While the growth vigor is generally good for all species, advanced reproduction may be sparse or lacking entirely. A deep root mat is not continuous and more serious erosive incursions are possible in the openings.
2	Fair: Plant cover ranges from 50 to 70 percent. Lack of vigor is evident in some individuals and/or species. Seedling reproduction is nil. This condition ranked fair, based mostly on the percent of the area not covered by vegetation with a deep root mat potential and less on the kind of plants that make up the overstory.
1	Poor: Less than 50 percent of the ground is covered. Trees are essentially absent. Shrubs largely exist in scattered clumps. Growth and reproduction vigor are generally poor. Root mats are discontinuous and shallow.

Table 3 - Subsurface Water Status Rating (U.S. Dept. Interior 1987a)

Rating Value	Description
4	Riparian site vegetation composition dominated by hydrophytic plants; reproduction evident. Little or no encroachment of upland plants (plants intolerant to prolonged saturated soil). Upland plants limited largely to the riparian/upland interface.
3	Riparian site vegetation composition dominated by hydrophytic plants. Some evidence of hydrophytic species decline and corresponding increase in upland plants, with upland species advancing from the riparian/upland interface.
2	Riparian site vegetation composition is a roughly equal mix of hydrophytic and upland plant species. Upland species reproducing; little or no reproduction of hydrophytes. Water stress may be apparent in hydrophytic plants.
1	Riparian site vegetation composition dominated by upland species, with some extending to stream channel edge. Hydrophytic species mostly scattered clumps. In extreme cases, hydrophytic species may be totally lacking. Former aquifer presence may be indicated only by isolated hydrophytic remnants such as *Salix* stumps, etc.

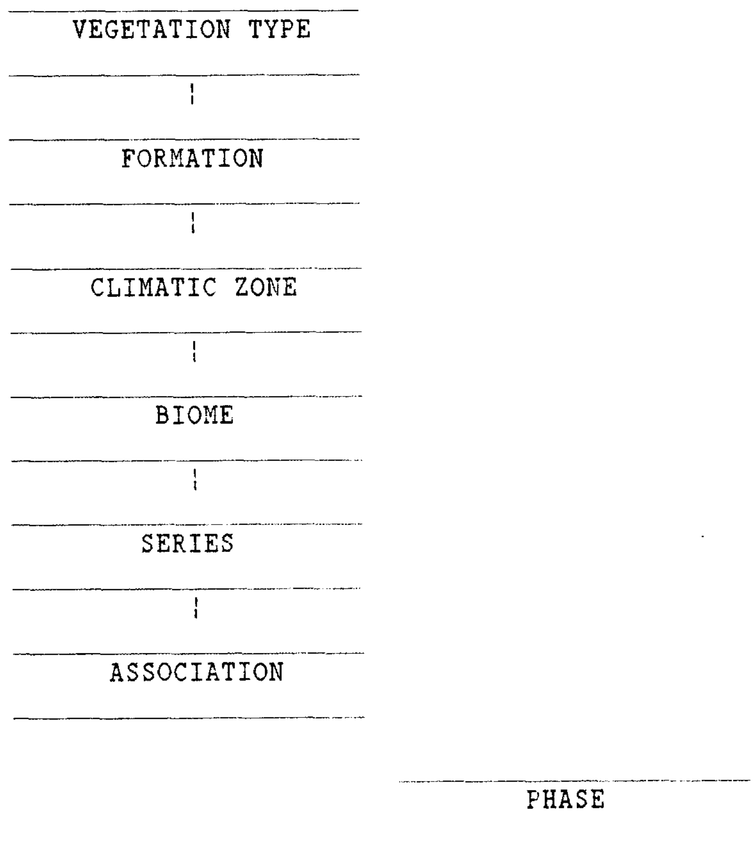

Figure 2 - Structure of the Vegetation Classification System (U.S. Dept. Interior 1987b)

The three ratings are summed and divided by three to obtain the mean. This value can be used to rank stream reaches by riparian site function. The reaches can be assigned a descriptive term for riparian site function using Table 4.

Table 4 - Riparian Site Function Rating

Mean Rating Score	Rating
4	Excellent
3-3.9	Good
2-2.9	Fair
1-1.9	Poor

Vegetation Classification

A system for classifying vegetation was adopted by the Bureau's Riparian Area Management Field Task Force (U.S. Dept. Interior 1987b). A vegetation classification system permits the user to group similar biotic conditions and to establish and quantify the types of habitats present. Classifying vegetation also aids when extrapolating the results of studies to other similarly classified locations. The approach used by the Bureau's task force was adapted from the work of Brown and others (1979, 1980) and from Paysen and others (1982).

The vegetation classification data appears on the lower one-third of the form (fig. 1). The system is hierarchical such that larger, more broadly defined units are split into smaller units as one progresses down the system (fig. 2).

The highest level of classification is the Vegetation Type. The two wildland vegetation types are "upland" and "wetland." Obviously all of the inventoried streams fall under the Wetland Type, so "Vegetation Type" was not listed as an entry on figure 1.

The Vegetation Type is followed by the Formation. Of the six choices defined in the Bureau's system, most of our streams fell in the "Riparian Forest" or "Riparian Scrub" Formations.

The Formation is followed by selection of one of four Climatic Zones. The inventoried streams fell into the "Warm temperate" or the "Cold temperate" Climatic Zones.

Biomes are defined as natural communities characterized by a distinctive vegetation physiognomy and climatic regime within a formation (Brown and others 1979). Commonly identified Biomes were the "California Riparian Deciduous Forest and Woodland," "Sierran-Cascade Riparian Deciduous Forest," "California Deciduous Riparian Scrub," and "Sierran-Cascade Riparian Scrub."

The Biomes are followed by classification into a Series. The Series and the remaining levels of classification are based on the system of Paysen et. al. (1982). The Series is defined by the dominant species or set of species in the overstory. Dominance is determined by aerial crown cover. Examples are "Salix Series" and "Populus Series."

The Association is the lowest level in the classification system and is defined as the dominant species or set of species in both the overstory layer and in subordinate layers. An example would be "Salix/Eleocharis Association". Similar Associations are aggregated into a Series, similar Series into a Biome, and so on.

The category Phase is used to add further information into the classification system, primarily as a means of improving its utility for specific management applications. Phase is offset here to show that it is independent of classification level and can be used anywhere in the hierarchy. We gathered the following data under the Phase: Tree Canopy Cover, Shrub Canopy Cover, Herbaceous Cover, Grazed or Ungrazed, Percent Vegetative Use by Animals (Platts and others 1987) and Age Distribution of Woody Dominants.

Mapping

Each reach was mapped on topographic maps (7.5') and on 1:100,000 scale land status maps. Mapping of reaches by vegetation classification or by other parameters allows the manager to view the spatial relationship between habitat types or areas of impact. An overlay was prepared for 1:24,000 scale color aerial photographs allowing the user to pinpoint areas of interest. Reaches were identified on the overlay along with other important information such as highly impacted areas and areas of erosion. Color slides were taken of each stream reach, and additional photographs were taken of impacted areas.

The data can also be used in the Bureau's Geographic Information System (GIS). Each stream is assigned a reach number and is digitized at 1:24,000 scale from the USGS topographic maps and aerial photographs. The GIS can then be used to integrate the riparian inventory information with other map themes such as grazing allotments, upland vegetation, range improvements, big game seasonal ranges, roads, etc. In addition, computer plots can be generated to display the spatial distribution of stream reaches by vegetative classification, riparian site function rating, or other parameter. The total miles of stream for any parameter can also be calculated by GIS.

Results and Discussion

The 65 miles of inventoried streams were broken into 116 stream reaches that are fairly homogeneous in terms of vegetation composition, channel morphology and degree of impact from livestock grazing. For each of these reaches we collected baseline data on physical features, a classification of vegetation that includes general composition, structure and impacts, and a rating of hydrologic function in the riparian site function rating.

The data was entered into a dBase III program that has been used to group reaches with similar conditions. Reaches can be grouped according to watershed, vegetation use by animals, erosion or water quality conditions, or by any other inventoried parameter that has been entered into the program. Table 5 lists stream reaches that are in three watersheds. The reaches in these watersheds can then be arrayed with any combination of input parameters. In this example, we also asked for the Riparian Site Function Rating (RSFRATING), whether it was grazed and the amount of vegetation use by animals (GRAZEPHASE), the Streambank Soil Alteration Rating (SSARATING) and the Vegetative Bank Protection Rating (VBPROTECT).

This type of data analysis has aided in drawing conclusions and making recommendations. We have ranked the reaches by the riparian site function rating. For those with good or excellent ratings, we have developed objectives to maintain these conditions and have not proposed detailed monitoring. For those reaches with a fair to poor rating we have developed specific objectives for improvement and an intensive monitoring procedure that is being conducted at several of these sites.

STREAM	WATERSHED	RSFRATING[1]	GRAZEPHASE[2]	SSARATING[3]	VBPROTECT[4]
Caliente Ck.	Caliente Ck.	2.0/Fair	G/Extreme	Severe	Poor
Caliente Ck.	Caliente Ck.	2.3/Fair	G/Extreme	Severe	Good
Caliente Ck.	Caliente Ck.	1.3/Poor	G/Extreme	Severe	Poor
Berts Canyon/ Coyote Sp.	Canebrake Ck.	3.0/Good	U/Mod.	Major	Good
Canebrake Ck.	Canebrake Ck.	2.7/Fair	G/Mod.	Severe	Good
Canebrake Ck.	Canebrake Ck.	2.0/Fair	G/High	Severe	Fair
Canebrake Ck.	Canebrake Ck.	1.7/Poor	G/High	Severe	Fair
Canebrake Ck.	Canebrake Ck.	1.3/Poor	G/Mod.	Severe	Poor
Cow Canyon Ck.	Canebrake Ck.	3.0/Good	G/Light	Severe	Excell.
Cow Canyon Ck.	Canebrake Ck.	4.0/Excell.	G/Light	Light	Excell.
Cow Canyon Ck.	Canebrake Ck.	2.0/Fair	G/Light	Major	Fair
Cow Canyon Ck.	Canebrake Ck.	3.3/Good	G/Light	Mod.	Good
Cow Canyon Ck.	Canebrake Ck.	3.0/Good	G/High	Mod.	Good
Spring Canyon Ck.	Canebrake Ck.	1.7/Poor	G/Light	Severe	Fair
Three Pines Ck.	Canebrake Ck.	1.7/Poor	G/High	Severe	Poor
Three Pines Ck.	Canebrake Ck.	2.0/Fair	G/Extreme	Severe	Fair
Three Pines Ck.	Canebrake Ck.	2.7/Fair	G/Mod.	Severe	Good
Three Pines Ck.	Canebrake Ck.	2.0/Fair	G/Extreme	Severe	Fair
Chimney Ck. # 1	Chimney Ck.	4.0/Excell.	U/Light	Light	Excell.
Chimney Ck. # 1	Chimney Ck.	4.0/Excell.	U/Light	Light	Excell.
Chimney Ck. # 1	Chimney Ck.	4.0/Excell.	U/Light	Light	Excell.
Chimney Ck. # 2	Chimney Ck.	3.7/Good	G/Mod.	Light	Excell.
Chimney Ck. # 2	Chimney Ck.	3.3/Good	G/High	Mod.	Good
Chimney Ck. # 3	Chimney Ck.	2.7/Fair	G/High	Mod.	Fair
Chimney Ck. # 4	Chimney Ck.	3.0/Good	G/High	Major	Good
Chimney Ck. # 4	Chimney Ck.	4.0/Excell.	U/Light	Light	Excell.
Chimney Ck. # 4	Chimney Ck.	3.3/Good	G/Mod.	Mod.	Good
Chimney Ck. I.T. #1	Chimney Ck.	2.7/Fair	G/Light	Mod.	Fair
Chimney Ck. I.T. #2	Chimney Ck.	3.0/Good	G/Mod.	Mod.	Good
Chimney Ck. P.T. #1	Chimney Ck.	4.0/Excell.	U/Light	Light	Excell.
Chimney Ck. P.T. #1	Chimney Ck.	4.0/Excell.	U/Light	Light	Excell.
Chimney Ck. P.T. #2	Chimney Ck.	2.3/Fair	G/High	Mod.	Fair
Chimney Ck. P.T. #2	Chimney Ck.	3.0/Good	G/Mod.	Mod.	Good
Chimney Ck. P.T. #2	Chimney Ck.	1.3/Good	G/High	Major	Poor
Chimney Ck. P.T. #2	Chimney Ck.	3.0/Good	G/Mod.	Mod.	Good
Chimney Ck. P.T. #3	Chimney Ck.	3.0/Good	G/Light	Mod.	Good
Chimney Ck. P.T. #3	Chimney Ck.	2.7/Fair	G/High	Major	Fair
Chimney Ck. P.T. #4	Chimney Ck.	3.0/Good	U/Light	Mod.	Good
Chimney Ck. P.T. #4	Chimney Ck.	3.7/Good	U/Light	Mod.	Excell.
Chimney Ck. P.T. #4	Chimney Ck.	2.7/Fair	U/Mod.	Major	Fair
Chimney Ck. P.T. #5	Chimney Ck.	3.0/Good	U/Light	Mod.	Good
Chimney Ck. P.T. #6	Chimney Ck.	3.0/Good	U/Light	Mod.	Good
Upper Chimney Ck.	Chimney Ck.	3.3/Good	U/Light	Mod.	Excell.
Upper Chimney Ck.	Chimney Ck.	3.7/Good	U/Light	Light	Excell.
Upper Chimney Ck.	Chimney Ck.	2.0/Fair	U/Light	Severe	Fair

[1]Riparian Site Function Rating
[2]Whether the stream was grazed and the amount of vegetative use by animals
[3]Streambank Soil Alteration Rating
[4]Vegetative Bank Protection Rating

Table 5-Data from a dBase III printout of inventory data including stream reaches in three watersheds

Data manipulation within the dBase III program permits us to easily quantify the extent and type of riparian systems in this area. With the vegetation classification data in particular, we are able to describe the riparian systems under our management in ways that were not possible in the past. For example, we know now that the "riparian scrub" formation is dominant on public lands in the Kern River watershed with smaller amounts of "riparian forest," "riparian marshland," and "riparian strand lands" present. By contrast, riparian areas on public lands in the Kaweah River watershed are almost entirely riparian forests. For each reach, comparisons between parameters such as "percent vegetative use by animals" and the riparian site function rating provide an indication of impacts from grazing.

This inventory method and the analysis of the data in a dBase program have provided us a great amount of new information in a relatively brief period of time. The emphasis on collection of vegetative and morphological information has been an effective method of assessing the effects of livestock grazing.

We recommend that this method be used in other areas in this district where this type of data is lacking. For public lands in the Kern and Kaweah River watersheds, it has documented baseline characteristics and conditions. A good baseline inventory is needed to decide where management practices should be changed and where projects should be implemented. With such data we can make better decisions on where projects should be implemented when the funds become available. The results of this inventory provide the data needed to establish management objectives and to monitor our progress toward meeting them. In addition, we have data that can be used as a starting point to assess what the appropriate levels of livestock grazing should be on these reaches.

Finally, the records can be easily maintained and amended on the dBase III program. We have strongly justified the need for monitoring selected stream reaches. Maintaining an up-to-date inventory and monitoring critical reaches are required by the Federal Land Policy and Management Act of October 21, 1976 (43 U.S.C. 1701), the Public Rangelands Improvement Act of October 25, 1978 (92 Stat. 1803) and the Bureau's riparian area management policy. This procedure provides the method to meet these mandates and to ultimately improve the condition of riparian areas in the Bakersfield District.

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THE FALLACY OF STRUCTURES AND THE FORTITUDE OF VEGETATION [1]

Wayne Elmore and Robert L. Beschta[2]

Abstract: Given time and proper management conditions, degraded rangeland streams can often produce by natural means the same results that we expect from streambank stabilization and fisheries enhancement structures. Advantages of using vegetation and natural recovery processes include: 1) costs are likely to be lower and 2) a wide range of benefits can accrue to a recovered stream. Structures tend to lock a stream channel in place whereas vegetation allows incremental changes in channel characteristics as flow and sediment loads vary. Healthy riparian vegetation can replace itself in perpetuity, providing a resiliency which keeps banks adjusted to channels — even shifting ones. Improved management of streamside vegetation, not structural additions to channels, offers the most promise for developing valuable and productive riparian systems.

State of the Art

A wealth of information on stream management is being presented in workshops and technical journals. Sometimes we call it habitat improvement, sometimes stream enhancement, and sometimes just stream structures. This information indicates that we have the capability to analyze, compute, design and construct projects on streams ranging in size from first to sixth order. These projects are accompanied by reporting procedures that allow us to document materials, cost per project, and "projected" benefits. Publications like "A Streambank Stabilization and Management Guide" (Commonwealth of Pennsylvania 1986) and the USDA Forest Service "Wildlife and Fisheries Habitat Improvement Handbook" (Payne and Copes 1986) take us through projects step by step. They identify project timing, size, materials and installation instructions in an attempt to ensure a successful effort. Some publications describe advantages, disadvantages, and apparent effectiveness of various structural modifications to stream channels. Diagrams and pictures provide additional information of what a structure will look like and how it is intended to operate within the stream system.

What Structures Do

There are various reasons for installing stream structures. In arid regions, the most common reason is probably for channel stability, followed by fisheries restoration and habitat enhancement. The main goal is usually to minimize channel changes or attempt to create specific habitat features. A "stable" structure is typically considered to be indicative of a successful project. Some structures are known to aid in the deposition of sediment, slow bedload transport, store water, and retard bank erosion. Their construction has also been reported to increase fish habitat for rearing and spawning, although rigorous evaluations and monitoring of increases in biological productivity are uncommon. Even so, it is often assumed by many biologists that we have an adequate understanding of how structures can be used to modify streams and fish habitat.

Telling the Stream vs the Stream Telling Us

The characteristics of naturally functioning stream systems can provide a basis for evaluating the relative success or failure of structural additions to streams. Figure IA provides a cross-sectional view of a degraded stream system. In this example the stream has cut down through previously deposited alluvium. As a result, the channel and associated vegetation have changed dramatically.

Species typical of wetland conditions have largely disappeared and the channel continues to erode laterally. There is little subsurface storage of water and the stream is characterized by intermittent flow.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; University of California, Davis.

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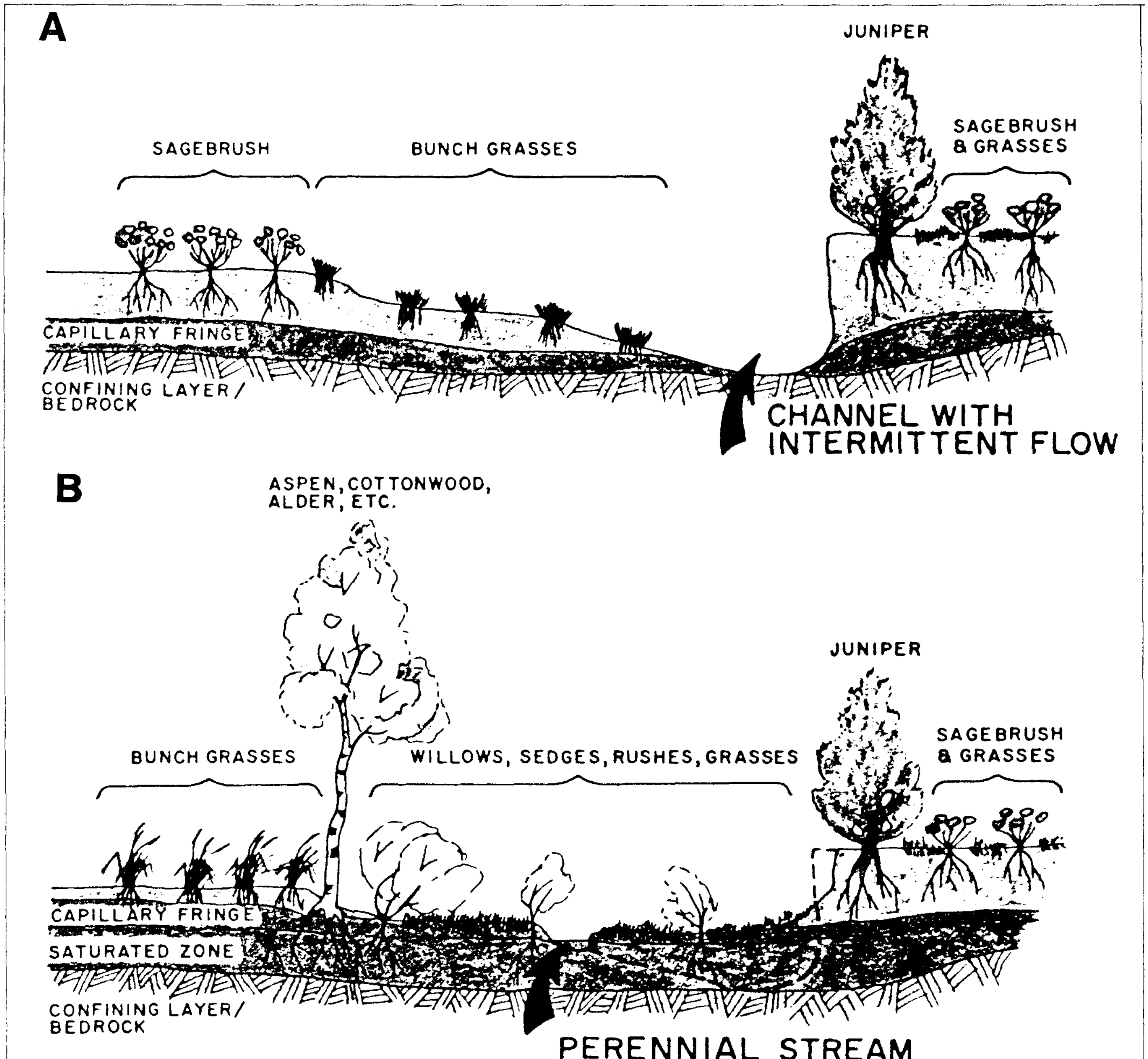

(A) Degraded riparian area

- *Little vegetation to protect and stabilize banks, little shading*
- *Lowered saturated zone, reduced subsurface storage of water*
- *Little or no summer streamflow*
- *Warm water in summer and icing in winter*
- *Poor habitat for fish and other aquatic organisms in summer or winter*
- *Low forage production and quality*
- *Low diversity of wildlife habitat*

(B) Recovered riparian area

- *Vegetation and roots protect and stabilize banks, improve shading*
- *Elevated saturated zone, increased subsurface storage of water*
- *Increased summer streamflow*
- *Cooler water in summer, reduced ice effects in winter*
- *Improved habitat for fish and other aquatic organisms*
- *High forage production and quality*
- *High diversity of wildlife habitat*

Figure 1 — General characteristics and functions of riparian areas associated with rangeland streams.

In contrast, Figure 1B illustrates a previously eroded channel that supports a diversity of riparian vegetation and has undergone recovery. The vegetation provides relative stability to streambanks and causes deposition of sediment; over time the channel has undergone aggradation. Such aggradation is often a natural consequence of allowing streamside vegetation (which may have been modified by historical grazing, logging, agriculture, or other management practices) the opportunity to again function and exert its influence on flow conditions and the characteristics of the channel. A consequence of this aggradation process is that the water table will similarly rise. In some cases, a formerly intermittent stream may flow perennially. For stream systems draining rangeland watersheds in the western United States, a change in grazing strategies is typically necessary to allow the recovery process to begin.

Often, we fail to address the real problem associated with a degraded stream system, i.e., the management of streamside vegetation. We forget about the role that such vegetation plays in influencing stream dynamics and channel morphology. If most streams are currently in a degraded state due to historical management practices that have heavily impacted riparian vegetation, doesn't it seem likely that a change in management and improvement in vegetation may represent an important solution?

Where improvement of a degraded channel is desired, the selection of a structural approach is seemingly driven by a desire for instantaneous gratification. We are currently using a "fast-food" approach to stream management. A certain sized pool or spawning riffle is desired and the apparent solution is to construct a structure that might immediately provide such a channel feature. Even where structural additions to a channel may help the recovery of riparian vegetation, we rarely allow several years of recovery before identifying where the structures might do the most good. Structures are almost always added to streams that are in poor ecological condition. As a result we are "telling a stream" where it needs help instead of letting the "stream tell us" where it needs help (Elmore 1987).

Structures and Streams

Many proponents of improved riparian management have reconciled themselves to spending large amounts of money to correct riparian problems. Additional funds are needed to assist in changing of streamside management, protecting sensitive stream reaches, and for additional research to better understand the complexities and management capabilities of riparian systems. Spending large amounts of money to build instream structures (e.g., gabions, dikes, check dams, rip-rap, sills, etc.) or to structurally modify a channel with construction equipment (hydraulic excavators, backhoes, front-end loaders, etc.) will seldom provide a long-term solution to riparian problems and deficiencies. Furthermore, the construction of expensive structures allows managers to sidestep difficult management decisions (Elmore and Beschta 1987). Often, the structural "enhancement" of rangeland streams is viewed as the solution to inadequate riparian management. As a result, changes in management may not be forthcoming.

Alluvial streams undergo continual channel adjustments as flow and sediment loads vary. Incremental changes in channel morphology and streamside vegetation allow such streams to withstand the wide range of dynamic forces that occur as flows fluctuate rapidly during storm runoff and snowmelt flows. An important feature of alluvial streams is that their channels will continue to adjust, change, and sometimes shift location. However, by placing permanent structures in a channel, we are attempting to lock the stream into a relatively fixed location and condition. As a result, structures that are placed in a recovering stream system are often placed where they are not needed; many are ineffective.

In the rush to install expensive and often counterproductive fisheries enhancement structures, we have ignored what should be the primary management focus restoring streamside vegetation. Streamside vegetation can influence the character of a stream in a variety of ways: inputs of leaves and other plant parts as a source of energy for instream biota, shade from overstory plants, woody debris from tree species, streambank stability and cover from woody rooted species as well as sedge/grass/forb communities, and the biological processing and cycling of nutrients (Salo and Cundy 1987). Vegetation allows riparian areas to function in ways that structures cannot replicate.

The resiliency provided by riparian vegetation allows these ecosystems to withstand a variety of environmental conditions. Riparian vegetation, in contrast to structures, can maintain itself in perpetuity as new plants continually replace those that die. Whereas instream structures focus narrowly at attempting to improve fish habitat, diverse and healthy riparian plant communities provide a wide range of values related to water quality and quantity, wildlife, aesthetics, channel stability and fisheries. If we are truly after productive stream and riparian ecosystems, only vegetation provides hope of a long-term solution.

Structures and Economics

The alteration of stream channels by a wide variety of structural devices, in an attempt to enhance fish habitat or for other purposes, has gained increasing popularity in the last several years. And, based on the informa-tion presented at recent symposiums and workshops, we have become increasingly proficient at installing "stable" structures in many types of streams. However, are we judging the successes of our stream recovery enhance-ment program on the methods we use or on the results we achieve? Structures seemingly represent a quick fix and high-tech approach to degraded streams, but do they really work and are they cost effective? Bill Platts (Pers. Comm.) has indicated that structures in Big Creek (a stream with important fish habitat in northern Utah) have changed the stream into essentially a silty canal. Further, this condition now prevents the estab-lishment of willows. He is recommending the removal of instream structures along Big Creek to allow the stream to function more naturally. Based on observations in Big Creek and throughout the intermountain west, Platts has further concluded that "A dollar in stewardship is worth $10,000 in structures."

Experiences in eastern Oregon and elsewhere seem to echo Platt's concerns regarding the high economic costs associated with structural modifications of stream systems. In contrast, changes in management that will benefit streamside vegetation can often be incorporated within existing management planning and action programs at little additional cost. Not only may changes in management be less costly, such actions represent a real opportunity for long-term solutions to degraded channels and riparian areas throughout much of the western United States.

Vegetation recovery and responses to management, however, do require time. We cannot realistically expect all streams to recover immediately even with the most enlightened program of streamside management. However, if we want recovered riparian areas to become more prevalent in the future, we need to start today at changing our views of streamside management. We also need to reassess and reevaluate the role of structural modifications.

Conclusions

Our body requires healthy arteries and veins for nourishment. Similarly, our watersheds and streams need healthy riparian vegetation to function and provide a wide array of benefits. Now that we are able to diagnose and begin a healing process for many riparian maladies, there is little reason not to prescribe and implement treatments (Luscher Pers. Comm.). These treatments should focus on beginning the process of vegetation recovery through improved management of rangeland riparian areas; structural additions to streams are a much lower priority.

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EVIDENCE FOR AN ALTERNATIVE LANDSCAPE POTENTIAL IN CALIFORNIA ANNUAL RANGELANDS[1]

Richard J. King[2]

Abstract: The basic tenet of annual range management in California is that perennial grasses are unable to effectively compete with the naturalized alien annual species. Evidence from the field in northern California is not consistent with this thinking. An alternative view that perennial grasses are restricted in importance from overgrazing and excessive rest is presented. Implications for range productivity and stability in riparian zones and uplands are outlined from a rancher's perspective.

The goal of range managers over much of the world's grazing land is a diverse plant community dominated wherever possible by perennial plant species. Perennial vegetation including communities dominated by perennial species, with various contributions from annual species, is generally regarded as offering more stable and productive watersheds compared to sites dominated by annual species.

In California annual grassland, dominance by introduced and naturalized alien annual species has become widely accepted as the new vegetation potential. Management goals for conservation and sustained productivity have shifted to a strategy of maintaining adequate residues. Most scientists and range managers believe perennials are unable to effectively compete with the aggressive annual species.

This paper reports evidence from the field that potential for increasing perennial species still exists throughout northern California's annual rangelands. Implications for rangeland productivity and stability in riparian zones and uplands are outlined from a management perspective.

Evidence for Perennial Potential

Evidence from personal observation that perennials have considerable potential comes from areas protected from livestock grazing and areas grazed at various intensities by livestock.

Annual plant communities grazed by livestock often have a significant perennial component (fig. 1,2). Individual perennial plants are generally considered overgrazed when they are not given an opportunity to recover from defoliation. Overgrazed perennials die or exhibit reduced productivity and reproduction (fig. 1).

Roadsides and ungrazed pastures offer innumerable remnant, recovering and new stands of perennial grasses, perennial forbs, and woody species (fig. 1,3-8). Yet protection from livestock may be as detrimental to perennial grass as overgrazing. Excessive residues can accumulate within tufts and/or between plants and reduce productivity (fig. 6, 7, 9). Reproduction may suffer from reduced vigor and seed production, or an unsuitable germination or seedling microenvironment.

Management Implications

Ranchers are interested in the potential of perennials in riparian zones and uplands for a variety of reasons. Riparian zones often receive the most grazing pressure and animal impacts, yet provide critically important forage, cover, or water.

The productivity and stability of many annual rangeland riparian zones often is diminished when residue on attendant upland sites is the basis for management. It is common to find accelerated gully and streambank erosion on annual range even when recommended levels of residue remain. Annuals offer little resistance to the erosive energy of concentrated flows when compared with perennials (fig. 10). Perennials, including sedges, rushes, grasses, shrubs, and trees offer far greater protection in both riparian and upland sites (fig. 7).

Additionally, perennials offer other values. Managing toward perennial dominance is potentially advantageous from a manager's perspective for a wide array of reasons:

a. Increased forage quality and quantity
b. Longer green feed period and greater market flexibility
c. Reduced erosion and sediment damage
d. Improved soil structure, organic matter content, and nutrient cycles
e. Improved rainfall effectiveness and forage reliability
f. Greater diversity of potential ranch enterprises
g. Reduced feed and supplement needs; perennial hay possible
h. Reduced noxious plant and animal problems
i. Reduced conflicts with environmental interests
j. Improved water quality

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Summary and Conclusions

Field evidence throughout northern California annual rangelands suggests the potential of perennial grasses, perennial forbs, shrubs, and trees may be greater than generally believed. Overgrazing and/or excessive protection appear to be the primary factors restricting the importance of perennial grasses rather than an inability to compete with annuals.

The stability and productivity of riparian zones along water courses is often poorly protected by annual vegetation. Plant communities dominated by perennials could increase stability and productivity as well as provide numerous other benefits for rangeland resources and enterprises.

Figure 1 – Highly productive hardinggrass (*Phalaris Luberosa*) along roadside (March). Adjacent conventionally grazed pasture has a long-established stand which is persistent despite severe grazing. Road 303, Glenn County. Rainfall zone 18-20 inches.

Figure 2 –Grazed annual range dominated by needlegrass (*Stipa* sp.) near Flournoy, Tehama County. Rainfall zone 20-22 inches.

Figure 3 – Ungrazed riparian corridor. Channel lined with trees and shrubs. Dense creeping wildrye (*Elymus triticoides*) and scattered trees cover flood terrace. Corral Hollow Road, San Joaquin County. Rainfall zone 10–12 inches.

Figure 4 – Perennial grasses, perennial forbs, and young oaks along roadside and adjacent isolated grazed range where livestock access is restricted by banks of ephemeral stream. Vasco Road, Contra Costa County. Rainfall zone 12-14 inches.

Figure 5 – Young oaks established in needlegrass (*Stipa* sp.) dominated roadside yet absent from adjacent grazed pasture. Conn Valley Road, Napa County. Rainfall zone 22-26 inches.

Figure 6 – Ungrazed needlegrass (*Stipa* sp.) with individual plants hampered by accumulation of previous years' growth (May). Corral Hollow Road, San Joaquin County. Rainfall zone 10-12 inches.

Figure 7 – Roadside needlegrass (*Stipa* sp.) with individual plants hampered by accumulation of previous years' growth (January). Highway 99E, Tehama County. Rainfall zone 20-22 inches.

Figure 8 – Creeping wildrye (*Elymus triticoides*) dominating ungrazed roadside hill, sparse to absent in adjacent conventionally grazed annual range. Interstate 680 between Pleasanton and Fremont, Alameda County. Rainfall zone 18-20 inches.

Figure 9 – Field of mostly dead hardinggrass (*Phalaris tuberosa*) plants. Plants died from excessive litter buildup within individual plants when ungrazed for many years. Livermore, Alameda County. Rainfall zone 14 inches.

Figure 10 – Dense annual grassland community offers little resistance to erosive energy of overland flow (March). Johnson Road, Tehama County. Rainfall zone 20-22 inches.

USE OF SUPPLEMENTAL FEEDING LOCATIONS TO MANAGE CATTLE USE ON RIPARIAN AREAS OF HARDWOOD RANGELANDS[1]

Neil K. McDougald, William E. Frost, and Dennis E. Jones[2]

Abstract: Typical cattle use on two range units of hardwood rangeland (annual rangeland) at the San Joaquin Experimental Range, Madera County, California, left 50 percent of riparian area with less than optimum amounts of residual dry matter (RDM) for promoting seedling growth and soil protection. By relocating supplemental feeding sites away from water sources and into areas of high amounts of RDM, the impact of cattle on riparian areas was greatly reduced. In Range Unit 1, where supplemental feeding sites were relocated, only 1 percent of the riparian area was left with low amounts of RDM. In Range Unit 8, where feeding sites were left unchanged, over 50 percent of the riparian area was left with low amounts of RDM.

Hardwood rangelands (annual rangelands) are comprised of several different land classes which vary in the amount of forage produced, time of forage growth and species composition. Distribution of use by cattle on these rangelands is highly correlated with the amount of forage production of the different land classes (Wagnon 1967); that is, the greatest amount of cattle use occurs on the highest producing areas - the riparian areas.

On these rangelands the greater use of riparian areas by cattle results in lower amounts of residual dry matter (RDM) than on associated sites at the end of the grazing season (Frost and others 1988). Residual dry matter is the dry plant material left on the ground from the previous year's forage growth. Moderate amounts of RDM provide a favorable microenvironment for early seedling growth, soil protection, adequate soil organic matter and a source of low quality fall forage (Clawson and others 1982). Moderate levels of RDM for riparian areas on the San Joaquin Experimental Range have been determined to be 400 to 800 pounds per acre. During a recent 3-year supplemental feeding trial under typical feeding practices, one half of the riparian areas were consistently left with low amounts (less than 400 pounds per acre) of RDM while less productive areas were left with high amounts of RDM (McDougald and others 1987; Frost and others 1988). The low amounts of RDM do not provide the best microenvironment for seedling growth nor the best soil protection. A means of redistributing cattle use into less productive areas and away from riparian areas would provide more favorable conditions for forage production and soil protection than currently exist.

This paper reports a study to determine if the use of riparian areas, expressed in terms of RDM remaining in the fall could be affected by a livestock management practice.

Since past investigations found that relocation of salt blocks was ineffective in changing the distribution of cattle use (Wagnon 1967), we examined the relocation of the supplemental feeding areas into areas previously identified as consistently having high amounts of RDM.

Study Area

The San Joaquin Experimental Range is located 28 miles northeast of Fresno in Madera County, California, near the center of the state and in the heart of the granite soil section of the Sierra Nevada foothills. It supports annual plant/oak woodland type vegetation and is characterized by grassy, rolling hills with a scattering of trees and occasional dense stands of brush. It is in the lower part of the woodland zone between the treeless valley floor and the higher brush and timber belts. Seeds of most herbaceous plant species germinate with the first 0.5 to 1.0 inches of fall rain. The plants grow slowly during the winter and rapidly when warm temperatures return in March. Most of the herbaceous species reach maturity in April and are mostly dry by mid-May. The climate is Mediterranean, characterized by mild, rainy winters and hot, dry summers. Annual precipitation averages 19 inches, with extremes of 9 and 37 inches.

Range Units 1 and 8 were used during this trial. Both units are approximately 450 acres of which over 5 percent is considered riparian area:

	Range Unit 1	Range Unit 8
Riparian	6 1	7 1
Rolling, open	21 1	5 %
Rolling, rocky, brushy	73 %	63 %
Steep, rocky, brushy	0 %	25 %

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Methods

During a 3-year study (1982-85) of range cow supplementation, the amount of RDM remaining in the fall was measured and mapped for Range Units 1 and 8 at the San Joaquin Experimental Range (Frost and others 1988; Dunbar and others in press). This 3 year period identified a pattern of use for riparian areas in those units. These patterns were used as the baseline in determining the effect of relocating supplemental feeding locations on the distribution of cattle use.

Supplemental feeding sites were relocated in 1986-87 in Range Unit 1. They were placed in areas which, during the three year supplemental feeding trial, consistently had high amounts of RDM remaining in early October. Feeding locations were not changed in Range Unit 8 to provide a means of eliminating the effect of current years' weather and forage production as the cause of a shift in the distribution of cattle use. Annual precipitation and forage production were lower in 1986-87 than in the years involved in the supplemental feeding trial during which cattle use distribution was established (table 1). Use by cattle (expressed as Animal Unit Months or AUM's) was similar for all years:

	Range Unit 1	Range Unit 8
	(Use per year in AUM's)	
1982-85 average	449	469
1986-87	432	444

In early October RDM was mapped using categories of high, moderate and low (Clawson and others 1982):

Residual dry matter (pounds per acre)		
Low	Moderate	High
<400	400 - 800	>800

Table 1— Average forage production and precipitation at the San Joaquin Experimental Range, California.

Year	Production (lbs/ac)	Date of germinating rain 1	Total precipitation
1982-83	3,630	Sept. 26	37.4
1983-84	1,824	Oct. 1	16.3
1984-85	1,690	Oct. 17	13.6
1986-87	968	Sept. 28	11.9
54 year ave.	2,316	Oct. 27	19.0

Amounts of RDM were determined by the Comparative Yield Method (Haydock and Shaw 1975) and visual estimation. The acreages within each RDM class were mapped, measured and expressed as percentages of total riparian area. These percentages were examined to determine if the change in supplemental feeding locations in Range Unit 1 produced a change in the use of riparian areas within that unit.

Results and Discussion

Traditional supplemental feeding locations in Range Units 1 and 8 resulted in approximately 50 percent of the riparian areas being left with low amounts of RDM in early October (McDougald and others 1987)(table 2). These feeding locations were generally located in close proximity to water sources and salt locations. Cattle use in Range Unit 8 during 1986-87 followed the same general pattern as during the baseline period. During this trial and the baseline period about 55 percent of the riparian area was left with low amounts of RDM, while approximately 30 and 15 percent was left with moderate and high RDM levels, respectively (table 2).

In Range Unit 1, relocating the supplemental feeding sites into areas which consistently had high amounts of RDM remaining in the fall resulted in a dramatic change in RDM levels in riparian areas. The percentage of total riparian area with low amounts of RDM was reduced from 48 percent in the 3 year baseline period to only 1 percent during this trial (table 2). The percentage of area with moderate RDM levels was also reduced from 39 percent to 27 percent while the percentage of area with high RDM amounts was increased from 13 percent to 72 percent (table 2).

These results, obtained in a year of below average forage production, indicate that cattle use can be manipulated through the location of supplemental feeding sites. By moving supplemental feeding locations away from water sources and into areas where high amounts of RDM remain, the impact of cattle on riparian areas in hardwood rangelands can be greatly reduced.

Table 2— Percentage of riparian area within RDM classes in early October.

Year and Unit	Low	Moderate	High
1982-85 Range Unit 1	48	39	13
Range Unit 8	59	29	12
1986-87 Range Unit 1	1	27	72
Range Unit 8	54	33	13

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CLARK CANYON (MONO COUNTY) RIPARIAN DEMONSTRATION AREA[1]

John W. Key and Mark A. Gish[2]

Abstract: The Clark Canyon riparian demonstration area was established in 1984 within the East Walker River subbasin of Mono County, California. Destabilization of the meadow sections of the stream and the upper stream reaches contributed to an increase of suspended sediments, turbidity, and stream channel widening in the lower stream reaches where a viable population of rainbow trout is found. Several different treatments have been implemented to (1) restore meadow riparian areas to high levels of productivity, (2) stabilize active erosion and gully development (headcutting), (3) improve aquatic habitat from poor to good condition, and (4) improve wildlife cover and downstream fish habitat. These treatments include changes in grazing management practices and the construction of several types of instream structures.

In 1984, the Bishop Resource Area of the Bureau of Land Management (BLM) established the Clark Canyon erosion control project. This project implemented several different treatments to restore riparian meadow areas and to stabilize active erosion and gully development. Riparian meadow areas are unique and among the most productive and important ecosystems on the public lands. They display a greater diversity of plant and wildlife species and vegetation structure than adjoining ecosystems (Bureau of Land Management 1987). Riparian meadows are narrow, highly productive plant communities located along streams. These meadows are usually dominated by grasses and grass-like plants with shrubs often as a major vegetative component. Livestock preference on riparian meadows has been reported as a major influence on overall grazing distribution on mountain rangeland (Gillen and others 1985, Platts 1986). Livestock are attracted to these areas for water, shade, and vegetation that remains green after upland forage has dried out.

Riparian watershed values include water table recharge, soil erosion reduction, flood water control, and sediment and nutrient collection (Thomas 1986). Surface flooding and elevated water tables have been reported as having a definite influence on plant vigor of certain shrub species (Ganskopp 1986). This erosion control project has become a successful example of riparian area management using the Coordinated Resource Management and Planning (CRMP) process and serves as a demonstration area for several different techniques for riparian area rehabilitation.

The Clark Canyon Riparian Demonstration Area

The Clark Canyon Riparian Demonstration Area is located about 5 kilometers east of the town of Bridgeport, Mono County, California. The climate of the area is cold and semi-arid. Annual precipitation ranges from 20 to 40 centimeters and occurs mainly as snow in the winter. The elevation is 2200 to 2260 meters. The soils on the canyon bottom are formed in mixed stratified alluvium. They are dark colored, deep, moderately fine textured and poorly to somewhat poorly drained along the drainage bottoms; and dark colored, deep, moderately coarse to fine textured, and well drained along the drain ways and side slopes. Soils on the canyon sides are rocky and shallow to moderately deep, with moderately coarse textures over moderately fine textured subsoils.

Clark Canyon Creek covers a total of 6.4 stream kilometers within the East Walker River subbasin. It is a perennial stream which receives much of its flow from subsurface water as it flows through the canyon. Stream flow is fairly constant through the summer months, and at the junction with Aurora Canyon Creek it is as cool or cooler than the upper reaches. In 1979 an intensive stream survey recorded an average stream width of 0.9 meters and an average stream depth of 3 centimeters and a discharge rate of 0.0057 cubic meters per second (cms). Constituent water analysis from stream samples taken at the time of the 1979 stream survey revealed undesirably high levels of iron (Fe) and manganese (Mn). Also, heavy algal growth was reported in the meadow sections of the stream, attributed to livestock trailing and heavy grazing use. An increase in suspended sediments (turbidity) was also reported in the lower stream reaches where a viable rainbow trout population occurs.

The four major vegetation types in Clark Canyon (Barbour and Major 1977, Ratliff 1985) are:

The **montane meadow vegetation type** is located on the moister alluvial sites. The ecological grouping of major meadow species in the riparian demonstration

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area is as follows:

Scientific Name (Munz and Keck 1973, Messick 1982)	Common Name
Primary Meadow Species	
Carex lanuginosa	Woolly Sedge
C. nebraskensis	Nebraska Sedge
C. rostrata	Beaked Sedge
Deschampsia caespitosa	Baltic Rush
Secondary Meadow Species	
Aster adscendens	Long-leaf Aster
Eleocharis pauciflora	Common spikerush
Hesperochiron californicus	Centaur
Hordeum brachyantherum	Meadow Barley
Muhlenbergia asperifolia	Alkali Muhly
M. richardsonis	Mat Muhly
Poa cusickii	Cusick Bluegrass
P. nevadensis	Nevada Bluegrass
Ranunculus cymbalaria	Desert Buttercup
Senecio hydrophilus	Swamp Groundsel
Invader Meadow Species	
Iris missouriensis	Western Iris

This meadow type is dominated by Nebraska sedge, Common spikerush, and bluegrasses. Vegetative cover is more than 85 percent and vegetative production is high. The riparian meadow vegetation is found in stringers along the creek. Several small bogs with peat moss (*Sphagnum fimbriatum*) are found at major spring sources of Clark Canyon Creek within the project area.

The **Great Basin sagebrush vegetation type** is located on the drier alluvial sites. Vegetative cover was inventoried at about 30 percent and vegetative production was low. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) *is* the dominant species with 35 to 90 percent composition.

The **pinyon-juniper vegetation type** is located in shallow, moderately coarse textured soils on the stony canyon sides and the rocky uplands surrounding Clark Canyon. One leaf pinyon pine (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) dominate this vegetative type.

The **deciduous woodland vegetation type** is located along perennial streams in the canyon. It is dominated by a dense growth of narrow-leaved willow (*Salix exigua*) and arroyo willow (*S. lasiolepis*). These willows are accompanied by a large undergrowth of wood rose (*Rosa woodsii*) and, where willows adjoin a meadow, squaw current (*Ribes cereum*) is found.

Erosion Control and Rehabilitation

The 1979 intensive stream survey of Clark Canyon rated aquatic habit at from fair to poor condition. Nonmeadow riparian areas rated poor due to the heavy livestock damage. Streambanks were badly trampled and denuded of vegetation; willows and other streamside vegetation were severely hedged. Riparian meadow areas were on a downward trend with streambanks being impacted by heavy live-stock use. This condition was causing the elimination of natural overhanging banks and concomitant widening of the stream. The stream profile was changing to wide, shallow, and saucer shaped; water was becoming warmer due to les s shade. Erosion problems were evident with active gullying at the upper reaches of the perennial flow. Shallow gullying was occurring throughout the riparian meadow areas and large headcuts (active erosion and gully development) were rapidly lowering the water table in two of the moist meadows along the stream by draining them.

Plans to rehabilitate the riparian areas in Clark Canyon were started in 1982. A combination of several treatments including grazing management were proposed to (1) restore meadow riparian areas to high levels of productivity, (2) stabilize headcutting, (3) improve aquatic habitat from poor to good condition, and (4) improve wildlife cover and downstream fish habitat. Representatives from the Bureau of Land Management, Forest Service, and California Department of Fish and Game visited the area and assisted with the preliminary plan development to repair stream channel damage caused by livestock grazing. The complete erosion control project included improved grazing management and the construction of gully control structures. Improved grazing management would restrict grazing until gully development has been stabilized. The gully control structures were designed to fill gullies, elevate water tables, and control further erosion until natural vegetation becomes vigorous enough to become permanent.

A series of instream structures were planned for construction to control active erosion and gullying (Key 1987). Two major headcuts were planned to be stabilized to control further cutting. The upper 2.4 kilometers of Clark Canyon were divided into different stations and site-specific recommendations developed for each station. The watershed erosion control project consisted of two large wire mesh structures, three small gabion basket structures, three single fence rock-check dams, four double fence rock-check dams, and one loose rock headcut treatment.

In 1984 the project was started at the headwaters of Clark Canyon Creek with the goal of contouring the steep side slopes for natural revegetation, raising the water table in the riparian meadow portions, and preventing further degradation of the remaining riparian meadows.

The two large wire mesh structures were constructed in 1984 near the head-waters of the stream, where the gullying was the most severe (fig. 1). These two structures were lined with an erosion filter fabric to trap fine soil particles behind the structures (fig. 2).

Figure 1 — Site of large wire mesh structure, Clark Canyon, California, June 22, 1983.

Figure 2 — Large wire mesh structure covered with an erosion control filter fabric, Clark Canyon, California, July 24, 1984.

The three smaller gabion basket structures were constructed in 1984 in shallow gullies in the meadow area. Initially, they were not lined with erosion control filter fabric (fig. 3). In 1985, the upper gabion basket was modified and lined with erosion control filter fabric to improve its effectiveness (fig. 4).

The three single fence rock-check dams were installed in October 1985 with hand labor, erosion control filter fabric, woven wire fence, and metal fence posts (fig. 5). These small instream structures have been very successful (fig. 6) in elevating the water table and controlling further erosion.

The four double fence rock-check dams were installed in 1986 and 1987, and have proven to be successful in both controlling further erosion and elevating the water table. Proper spacing between structures depends upon the gradient of the gully and stream. The minimum interval used had the crest of one structure level with the apron of the structure above it. Key locations for the structures are immediately below a junction of two or more small gullies, at narrow points of the gully, and at points where the gully is not eroding rapidly.

The loose rock headcut treatment was implemented in 1986. The head wall was cut back so rock could be placed easily under the sod crest. Foundation rock was placed at the toe of the loose rock rip-rap to ensure that the rip-rap would not slide away from the headcut. Rock was carefully placed and hammered into the head wall soil to ensure close contact. Rip-rap was built under the lip of the sod crest and over the foundation rock to form an apron. Flat wedge shaped rock was used and hammered into and under the sod crest. Water was allowed to flow over the sod crest across the rock rip-rap, across the apron, and downstream in the stream channel.

Coordinated Resource Management and Planning

Because of the involvement of both public and private land in the project, Coordinated Resource Management and Planning (CRMP) was used to prepare a resource plan for the public land grazing allotments and associated private lands. CRMP is a resource planning process used to address resource problems, based upon a philosophy that resource conflicts can best be solved at the local level by direct communication among all interested groups and individuals. It is based on the premise that people who meet together voluntarily will find common ground as they interact with one another and have a chance to observe resource problems firsthand on the ground (Nevada Coordinated Resource Management and Planning Task Group 1983).

Initiating action in the Clark Canyon area was complicated by the fact that Clark Canyon was an unfenced grazing allotment boundary between two different grazing allotments (Aurora Canyon and Travertine Hills). As a result, two CRMP activities were started—one for each grazing allotment. Major issues to be resolved specific to Clark Canyon were (1) evidence of accelerated erosion in Clark Canyon, (2) poor vegetation conditions in meadows and other riparian areas in Clark Canyon, and (3) livestock grazing use conflicts caused by using Clark Canyon as the grazing allotment boundary between two grazing allotments and the impact of historic livestock trailing through Clark Canyon.

In order to resolve livestock grazing impacts in Clark Canyon, BLM personnel from the Bishop Resource Area in January 1984 consulted with the livestock permittees affected by the plan. Concerns focused on availability of water and forage for livestock, livestock trailing through the canyon, and livestock drift between the Travertine Hills and Aurora Canyon allotments.

Written consensus was reached for the following:

Fencing and Livestock Water—Two fence projects were implemented to create watering gaps for livestock. The upstream water gap fence was constructed between the exclosures surrounding the two large wire mesh structures. These exclosures were constructed to protect the recovering streambanks from livestock trampling. Approximately 36 meters of stream between the exclosures were left accessible for livestock watering. The second water gap fence was constructed approximately 0.8 kilometers downstream near the public-private land boundary. This fence controls cattle drift along an easily accessible portion of Clark Canyon and provides a water gap at a commonly used draw west of the creek. It also provides a means to confine cattle within the 0.8 kilometer intensive management area. Both fences are inspected and maintained annually by BLM personnel.

Livestock Trailing—Sheep trailing through the intensive management area was continued with the stipulation that no bedding, grazing, or watering occur, and that all allotment boundary gates are kept closed. One sheep permittee on a neighboring allotment traditionally trails two bands of sheep through the project area during the first week of June on the way to his allotment and in mid-October on his return to his home ranch. The sheep permittee in the Travertine Hills allotment does not use Clark Canyon for trailing. Cattle trailing through the project area is not authorized.

Figure 3 - Unlined gabion basket structure, Clark Canyon, California, July 28, 1984.

Figure 4 - Same gabion basket structure as in Figure 3 after modification and lining, Clark Canyon, California, July 17, 1986.

Figure 5 — Installation of single fence rock-check dam, Clark Canyon, California, October 10, 1985.

Figure 6 — Single fence rock-check dam, Clark Canyon, California, August 4, 1987.

Stocking Level–The grazing capacity within the intensive management area was determined by calculating the animal-unit months (AUM) based upon the 1980 forage inventory. Twenty AUM were determined available for annual use during the period of June 15 through October 31. The AUM authorized allows only a few cattle to use the area season long or not at all. The normal use by each permittee is as follows:

	AUM	Season of Use
Travertine Hills cattle permittee:	10 cows	6/16 - 8/15
Aurora Canyon cattle permittee:	6 cows	6/16 - 9/30

The cattle numbers are generally pairs (the cow and her calf). The grazing plan allows the Travertine Hills permittee to use the area for two consecutive seasons of use followed by three consecutive seasons of use by the Aurora Canyon permittee.

Utilization levels at season's end approach the high end of the moderate class, for herbaceous vegetation, using the Key Forage Plant Method. The moderate class is described as: "The rangeland appears entirely covered uniformly as natural features and facilities will allow. From 15 to 25 percent of the number of current seed stalks of key herbaceous species remain intact. No more than 10 percent of the number of herbaceous forage plants are utilized."

Monitoring

The following methods were used to monitor the success of the erosion control project: trend and photo plots, stream profile and sediment deposition, stream stability indicators, and weather.

A total of four trend plots were established within the project area to monitor grazing impacts–one inside the two exclosures and two outside the exclosures (one upstream of the second large wire mesh structure and one downstream of the second large wire mesh structure). Each plot was 0.9 meters by 0.9 meters square and was placed on the streambank close to the water's edge. The plot locations were also selected on the basis of having some existing vegetation in place as opposed to purely bare ground. The methodology used was the Photo Plot Method which involves taking an overhead photo of the plot and a panoramic photo of the background from a located photo point marker. Plot readings involve determining species identification, the number of mature plants or seedlings by species, and estimating the number of 1/16 units per square foot (0.0929 square meters) each plant species and litter occupies within each plot (table 1). These data are then multiplied by a factor for plot size to determine plot totals.

Plots 2 and 3 were permanently obliterated by deposited sediments after spring runoff in 1986 and were not reestablished. Plot 4 was partially obliterated in 1987.

An initial stream profile utilizing sag tape transects was conducted at the time the two large wire mesh structures were constructed. A total of 10 sag tape transects (fig. 7) were made annually since 1984 to document changes in stream profile and sediment deposition collection behind each of the two large wire mesh structures. The transects followed procedures described by Ray and Megahan (1979).

Stream stability indicators were evaluated initially in 1984 at the two large wire mesh structures and on an annual basis since that time. The results of this rating is used in conjunction with the stream profile and sediment deposition measurements and revegetation monitoring to determine stream condition and trend. Weather information collected at the Bodie State Park is used to evaluate the influence of annual weather patterns on the other components being monitored. Results of all the monitoring studies are evaluated each fall to determine progress towards stated objectives.

Table 1. Three years of vegetation monitoring data

	1985	1986	1988
Plot 1 (Inside Upper Exclosure)			
Percent Composition	95.4	96.0	73.1
Percent Cover	3.7	33.4	60.8
Number of Seedings	7.0	7.0	0
Percent Litter	0.2	1.4	22.4
Plot 2 (Outside Upper Exclosure)			
Percent Composition	87.7	Obl.	Obl.
Percent Cover	0.5		
Number of Seedings	24.0		
Percent Litter	0.1		
Plot 3 (Inside Lower Exclosure)			
Percent Composition	53.1	Obl.	Obl.
Percent Cover	7.9		
Number of Seedings	3.0		
Percent Litter	7.0		
Plot 4 (Outside Lower Exclosure)			
Percent Composition	94.6	95.3	Obl.
Percent Cover	16.5	17.6	
Number of Seedings	7.0	26.0	
Percent Litter	0.9	1.3	

Figure 7 – Sag tape transect, Clark Canyon, California, July 17, 1986.

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SOUTHWESTERN WOODY RIPARIAN VEGETATION AND SUCCESSION: AN EVOLUTIONARY APPROACH[1]

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Abstract: Interrelationships between flooding and climax woody vegetation in riparian ecosystems of the desert Southwest are discussed. The lack of succession in woody desert upland and desert riparian plant communities results from opposite stresses, the former from aridity, the latter from flooding. Today's "wet riparian big five" are northern tree species of hydroriparian and mesoriparian (wet riparian) ecosystems; remnants of the Arcto-Tertiary Geoflora. The "dry riparian big five" are tree or subtree constituents of xeroriparian ecosystems occurring as Madro-Tertiary remnants at the northern extremes of their ranges. Human activities have interrupted normal flood regimes of Southwest rivers, resulting in desertification and endangering native riverine ecosystems.

Woody Riparian Vegetation

Trees and shrubs are major components of riparian ecosystems. Their elevated woody structure forms the characteristic landscape feature which visually distinguishes riparian ecosystems from their surroundings, especially in the Southwest deserts. It is also this structure which provides habitat for the highest concentrations of birds in North America; provides shade for recreationists, fish, and cattle; and forms the biomass of the basic trophic level in these productive riparian ecosystems (Johnson and Carothers 1982).

Changes in the diagnostic vegetative structure of a given riparian ecosystem is an early warning of broader problems. Closer examination invariably shows triggering processes—soil erosion or deposition, dewatering of the system resulting in the changing of perennial or intermittent streams to ephemeral watercourses, and other signs of riparian and aquatic degradation.

In order to better interpret and understand the full implications of such historic and continuing changes one must understand the driving forces of riparian ecosystems. The interrelationships of flooding, succession (or lack thereof) and different woody plant regimes—Arcto-Tertiary vs. Madro-Tertiary Geofloras—need to be fully understood.

Riparian Big Five

Lowe (1961, 1964) developed the concept of the riparian "big-five" in reference to five widespread riparian trees in the Arizona lowlands: cottonwood (*Populus fremontii*), willow (*Salix bonplandiana*) and others, e.g. (*S. gooddingii*), sycamore (*Platanus racemosa wrightii*), ash (*Fraxinus velutina*), and walnut (*Juglans microcarpa major*). Other riparian species of the desert Southwest show more limited geographic and elevational distributions (fig. 1). These or closely related species also occur throughout the California and Southwest desert lowlands in general (table 1).

Table 1 — Lowe's (1961, 1964) "wet riparian big five" or Arcto-Tertiary Geoflora riparian species of the desert Southwest with California (Holstein 1984) and eastern United States analogs (Little 1980).

Common Name	Southwest	California	Eastern United States
Ash	*Fraxinus velutina* [*F. v.* subsp. *pennsylvanica*]	*F. latifolia*	*F. pennsylvanica*
Cottonwood	*Populus fremontii*	*P. f.*	*P. sargetii*
	[*P. deltoides* & subsp. *P. palmeri, P. wislizenii*]		*P. d.*
Sycamore	*Platanus racemosa* var. *wrightii*	*P. racemosa*	*P. occidentalis*
Walnut	*Juglans microcarpa* var. *major*	*J. hindsii*	*J. nigra*
Willow	*Salix goodingii* [*S. nigra* subsp. *goodingii*]	*S. g.*	*S. n.*

[1]Presented at the California Riparian Systems Symposium; September 22-24, 1988; Davis, California.

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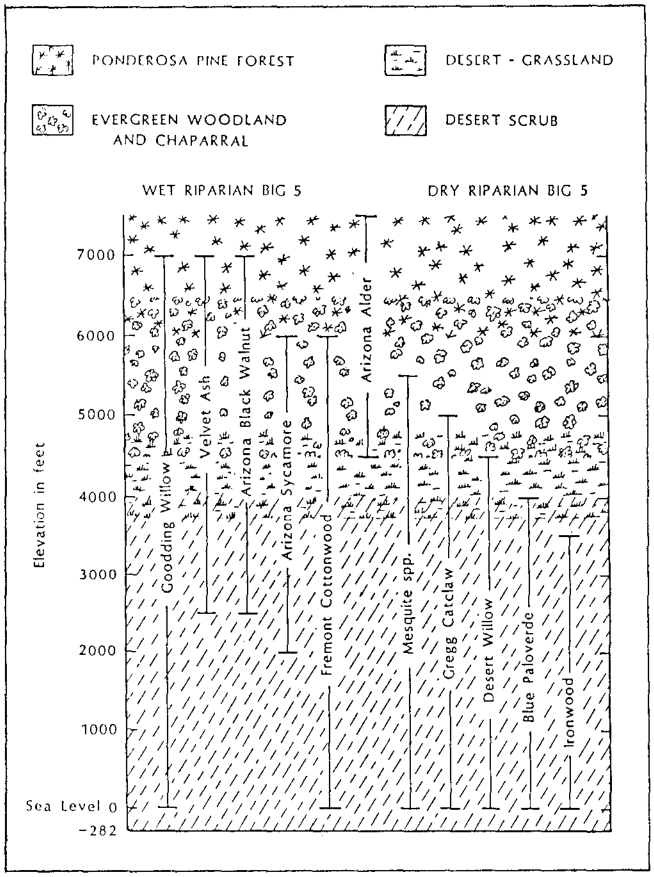

Figure 1 – Elevational and ecological amplitudes (spans) for the "wet riparian big five" and "dry riparian big five" in the desert Southwest. Other species, e.g. Arizona alder (*Alnus oblongifolia*) were excluded from these categories by Lowe (1961, 1964) and Johnson and Lowe (1985) due to their narrow amplitudes (after Benson and Darrow 1981; Kearney and Peebles 1969; Little 1980).

These generally occur as dominant woody species of hydroriparian (perennial) and mesoriparian (intermittent) ecosystems (Johnson and Lowe 1985) along lowland watercourses. A more technical paleobotanical term is "Arcto-Tertiary riparian big five." Using the same criteria for xeroriparian systems along desert washes Johnson and Lowe (1985) listed the "dry riparian big four" – mesquite (*Prosopis* spp.), catclaw acacia (*Acacia greggii*), ironwood (*Olneya tesota*), and blue paloverde (*Cercidium floridum*); we here add a fifth species, desert willow (*Chilopsis linearis*), to complete the "dry-tropic riparian big five." These five species occur in the Lower Colorado subdivision of the Sonoran Desert of southern California. As with the "wet riparian big five," these or closely related species are widely distributed in the Southwest deserts. The one exception is Olneya, which is widespread throughout the Sonoran Desert of the United States and Mexico but is too frost-tender to live in either of the colder Mohave or Chihuahuan deserts. Carothers and others (1974) were the first to quantify the importance of the wet riparian big five to avian populations. Parallel wildlife importance has been recently discussed for xeroriparian ecosystems, of which the dry riparian big five are major components (Johnson and Haight 1985).

Plant Succession

Plant succession is the replacement of a plant community on a given site by other plant communities on the same site over a period of time, usually occurring in a predictable order. Although European botanists were the first to record the processes, two mid-western botanists, Fredrick E. Clements (1916) and his student, J.E. Weaver (Weaver and Clements 1938), further developed the concept while working in the eastern United States. Odum (1969) identified three general characteristics of plant succession. It is an orderly, predictable process with one natural community modifying the environment and thereby allowing for the establishment of subsequent communities (seres). This culminates in a stabilized, energy-optimizing ecosystem (climax community).

Absence of Desert Riparian and Upland Succession

The development of plant communities in Southwest deserts differs markedly in several ways from that in classical, mesic vegetation. Clementsian succession, so well studied and documented in the eastern United States, does not occur either in desert upland or riparian communities. This was discussed at length by Lowe (1959) and for upland systems first pointed out by Shreve (1951) who wrote:

> "It is not possible to use the term 'climax' with reference to desert vegetation ...If a particular community is destroyed without change in the soil, the earliest stage in the return of vegetation will be the appearance of young plants of the former dominants. Not only do the same species reappear at the outset, but their first individuals ultimately constitute the restored community."

Shreve (1951) did not differentiate between upland and riparian habitats in his writings about desert vegetation. Lowe (1964) was the first to specifically address riparian succession in the Southwest, finding a lack of succession for Southwest desert riparian ecosystems where cottonwoods and willows are both "pioneer" and "climax" riparian species (in Clementsian terms). Further, the same individual plant is both a pioneer and a member of the climax vegetation.

Although succession does not occur in either riparian or upland ecosystems of the desert Southwest two different, opposite stresses are involved. In riparian ecosystems flooding ("too much" water) is the driving function behind plant community development. In upland systems aridity ("too little" water) limits community development, excluding succession.

Interestingly, Lowe (1964) also points out the lack of succession in a high elevation spruce-fir forest in northern Arizona. Here the stressful environment results from water occurring only as ice much of the year, thus being unavailable for uptake by plants. Consequently plant communities at high elevation and/or high latitude may demonstrate some of the same xeric characteristics of desert upland plant communities, including abbreviated or non-existent successional stages.

In a paper on "riparian succession" Campbell and Green (1968) suggested "mosaics of various seral stages" but did not demonstrate succession for Southwest riparian vegetation. They stated, "The channel vegetation probably never reaches a climax hierarchy due to periodic flood disturbances such as erosion, inundation, and deposition."

Reichenbacher (1984) likewise discussed riparian succession in the Southwest without substantiating it. He also considered the establishment of different riparian species under different physical conditions at different microsites as successional—stating, "On the convex bank early seres are initiated by seedling establishment while mature vegetation on the concave bank is undercut." Rather than succession, he was discussing the aforementioned vegetational mosaic mentioned by Campbell and Green (1968) characteristic of riparian vegetation. This patchiness in riparian vegetation is largely a result of shifting channels and abandoned meanders. Riparian communities are composed of species as they occur along a moisture gradient. Reichenbacher (1984) and Campbell and Green (1968) actually made a better case for the continuum concept, a concept especially discussed by Whittaker (1975). A continuum is "a gradient of environmental characteristics or of change in the composition of communities" (Ricklefs 1979). This concept postulates that plant communities are composed of a collection of species, each with a specific gradient and coexisting not because of biological affinities for one another but because of common environmental needs. The continuum concept has been discussed for other areas; e.g. for riverine aquatic ecosystems and their physical and biological parameters as expressed by headwater to mouth gradients (Vannote and others 1980). Similarly, riparian continua have been discussed along drier to wetter moisture gradients both for headwater to mouth (intrariparian) and upland to deepwater (transriparian) gradients (Johnson and Lowe 1985).

Mechanisms preventing either riparian or upland succession in the southwest have not been thoroughly examined, but for riparian ecosystems there are contributing factors. Competition is an important factor in plant succession (Odum 1971; Ricklefs 1979). Shreve (1951) pointed out that in the southwestern deserts the struggle is with the environment rather than inter- or intraspecific competition with other plants, and "the frequency on the desert of extensive communities which are simple in composition is not due to the poverty of the perennial flora so much as to the severity of the physical conditions."

Compared to desert upland systems, Southwest riparian ecosystems are much more mesic and thus might be expected to show a closer similarity to eastern deciduous hardwood forests in respect to competition and succession. This, however, is not the case. The different plant communities occurring along a river that are interpreted by some as different seral stages occur side by side in different physical habitats. For example, mesquite bosques often occur on higher terraces or alluvial fans while adjacent floodplain bottomlands are vegetated by cottonwood-willow forests. Mesquites, because of their long tap roots, can secure water from deeper water tables than cottonwoods and willows. Therefore, because of differing abilities to obtain water, the two communities occur side by side at the same time rather than one community following the other on same site.

Two related processes to consider in the lack of riparian succession in the Southwest are catastrophic floods and the long period of time required for successional stages (seres) to evolve into a climax community. Our examination of historic photos show flooding as a major reason for riparian plant communities in the Southwest not reaching more than 100 years in age before being greatly disrupted or destroyed. These photos, taken at chronological intervals along southwest rivers, show groves of mature cottonwoods and mesquite bosques at different sites along a river from one decade to the next. Periodic floods scour the substratum and destroy attendant groves at a given locality. Subsiding flood waters then create conditions for a seedbed, allowing germination of a new stand of young cottonwoods either in the same spot or elsewhere (Brady and others 1985). Thus, the relatively short intervals between catastrophic floods in the Southwest deserts does not allow sufficient time for succession. Factors that have changed flow regimes along southwest lowland streams, greatly affecting development of riparian plant communities, are discussed later under *floods*.

Although individual sandbars, terraces, or riparian plants may be short-lived, the riparian ecosystem is stable. The most pertinent statement in literature is by Lowe (1964:62):

> The southwestern riparian woodland formation is characterized by a complex of trees, and their plant and animal associates, restricted to the major drainageways that transgress the landscape of desert upward into forest. It is incorrect to regard this biotic formation as merely a temporary unstable, seral community. It is an evolutionary entity with an enduring stability equivalent to that of the landscape drainageways which form its physical habitat. That is, it is a distinctive climax biotic community.

Desertification of Southwest Riparian Ecosystems

Many historically recorded Southwest perennial and intermittent streams are now ephemeral watercourses. Analyses of factors involved in the disastrous conversions of these watercourses have been conducted by investigators such as Hastings (1959), Hastings and Turner (1965), Cooke and Reeves (1976), Dobyns (1981), and Betancourt and Turner (1988). In many cases there has been an almost total loss of both the aquatic and riparian resources that originally attracted European settlers to these linear desert oases.

Before the North American import of Old World cattle and the invention of the steel plow, most of the soils of the United States were largely covered by vegetation. The root-filled sod served as a sponge, allowing water to run off slowly toward drainages and clean water to percolate into the watertable. Runoff water from the uplands was partially cleansed by riparian processing (biological and physico-chemical processes of riparian ecosystems) before entering branching, meandering networks of drainages and flowing slowly downstream. When floods overtopped the riverbanks, rich alluvial soils were deposited, increasing the fertility and productivity of riparian ecosystems. Today these channels are carrying increased volumes of debris and silt-laden water from tributaries that have been greatly altered by humans, e.g. storm drains and gullies, from uplands denuded of absorptive vegetation and topsoil through misuse of the land by livestock and humans. Many of these channels have been heavily silted-in or, more often at lower desert elevations, have become incised and denuded, allowing increasingly serious environmental degradation (Betencourt 1988; Cooke and Reeves 1976; Dobyns 1981; Rea 1983; and Turner 1988). Other human activities that have interfered with flow regimes, especially water storage and diversion projects, are discussed by Johnson and Carothers (1982). Overgrazing and consequent desertification has also greatly affected natural riparian community development (Brown and others. 1977; Dobyns 1981; Glinski 1977; Johnson and Simpson 1988; Reichenbacker 1984). Without concentrated efforts to reverse many of these disastrous, often unnecessary, activities, desertification of riparian and aquatic ecosystems of the Southwest will irreversibly proceed, thereby destroying some of our most valuable natural resources.

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RELATIVE NATURE OF WETLANDS: RIPARIAN AND VEGETATIONAL CONSIDERATIONS [1]

Peter S. Bennett, Michael R. Kunzmann, and R. Roy Johnson[2]

Abstract: Riparian ecosystems have been divided into three basic types; hydroriparian, mesoriparian, and xeroriparian associated in the desert lowlands with perennial, intermittent, and ephemeral water respectively. Floral species associated with these ecosystems can be divided into four categories; obligate, preferential, facultative, and nonriparian. Additionally, various site characteristics such as (1) latitude, (2) elevation, (3) soil, (4) slope, (5) exposure, (6) water periodicity, and (7) water chemistry, create a complex matrix of terms with each one needing delineation. Few of these parameters can be readily measured in the field. We examine the classifying of vegetation according to the species presence (actual or potential) and the evolutionary/developmental history of vegetational communities and implications in wetland and riparian land classification.

Most scientists believe that they have a workable definition of "wetlands" and "riparian" in an ecological context. Writers of laws and regulations have this same confidence. Resource managers and administrators also believe they have equally usable definitions. For each term, one can find dozens of definitions in dictionaries, manuals, textbooks, and other sources. Some of these definitions are similar, others are very different. EPA regulations (40 CFR Section 230.3) state "... areas that are inundated or saturated with surface or ground water at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" are wetlands. Under idealized conditions, these common sense, commonly held views are adequate to the task of definition. Each person defining these terms uses concepts appropriate to their own particular situation and background.

At best each definition generally applies to a local, regional, or particular ecosystem situation. However, application of these local concepts presents severe problems when these definitions are applied at a national scale. Johnson and Carothers (1982), Lowe and others (1986), Johnson and others (in press) and Kunzmann and others (in press) present information demonstrating that there are generally significant structural and functional differences between eastern and western wetlands. These differences are particularly pronounced when comparing wetlands and riparian lands of the desert Southwest to the more mesic East. Even though eastern derived definitions have generally prevailed for national programs, more than half of the nation's wetlands and riparian lands are in the more arid West.

Discussion

Johnson and others (1984a) introduced the "xeroriparian," "mesoriparian," and "hydroriparian" ecosystem descriptors to reflect ecological differences, especially for ecosystems associated with ephemeral, intermittent, and perennial waters in the Southwest deserts. Floral species associated with these three ecosystems can be divided into four categories (the 4-Category System): obligate, preferential, facultative and nonriparian (Johnson and others 1984a). There is no classification system, let alone rules and regulations, that address the combination of these seven entities. The current regulations and the proposed seven day test for wetland inundation (40 CFR Section 230.3 and EPA Wetland Identification and Delineation Manual) strictly applied in the west, would include only the wettest environments and exclude many of the periodic (ephemeral and perhaps intermittent) western wetlands and riparian lands (Lowe and others 1986).

By using these seven descriptors (three riparian and four floral) we are talking about wetland/riparian land ecosystem expression interpreted from "the top down" including botanical, hydrologic and soil parameters. However, plants are the ultimate synthesizers of environmental information, and vegetation composition alone may be considered the key to (1) latitude, (2) elevation, (3) soils, (4) slope, (5) exposure, (6) water periodicity, (7) water chemistry, (8) evapotranspiration rate and many other factors.

Wetland/riparian land classification and delineation is best accomplished by examination of factors that are always present and measurable. For example, consider the situation at Wilcox Playa, a large lakebed in the Chihuahuan Desert grassland of Southeastern Arizona. The playa surface is quite barren, with salty soils at its lowest elevation, becoming occupied by various salt-tolerant plants at its periphery and finally by mesquite

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subtrees up-slope. The lower elevation playa surface is intermittently flooded by a thin sheet of water, and buried to a depth of more than a meter at least every century. Mostly its surface is dry. If we are to follow the Environmental Protection Agency's 7 day saturation criteria to classify or map the extent of wetlands on the playa, we would have to observe the extent and persistence of the pool after each rain. But this does not draw the line for the 100 year (1 meter + depth) event. While it is true that soil saturation can often be judged by soil characteristics, the relationship of the 7 day saturation rule to soil characteristics has not been well established. In fact, 7 days of inundation, or other defined intervals, may or may not support "a prevalence of vegetation typically adopted for life in saturated soil conditions" (quotes from 40 CFR Section 230.3). Where the substratum is composed of coarse sand or cobbles typical hydric soil characteristics are not present. Other problems include judging soil saturation in unusual western situations, e.g. where the fine textured playa surface lies beneath a layer of shifting wind-blown sand. Additional problems include determining the bases for classifying wetlands/riparian lands where permanent water lies well below the soil surface but still within reach of phreatophytic species, such as the mesquites found at Wilcox Playa.

Many similar problems can arise regarding classification by using criteria, e.g. hydrologic regimes, that are not always present and visible. There is a strong similarity in visual contract between riparian ecosystems and those of the desert uplands of the Southwest, whether mesoriparian hydroriparian, or xeroriparian (Johnson and others 1984a). Many of the latter might not be delineated as wetlands under classification systems such as Cowardin and others. (1979) or U.S. Army Corps of Engineers and E.P.A. Guidelines. However, these xeroriparian plant communities are generally characterized by a higher visible differentiation from the vegetation of adjacent uplands, even than most riparian ecosystems, e.g. the visual differences between bottomland hardwoods along running streams and deciduous hardwood forests of the eastern U.S.

In addition to the visual contract between xeroriparian ecosystems and adjacent uplands, xeroriparian communities are generally composed of measurably different biotas from those of adjacent communities. Thus biotic components differentially utilize xeroriparian ecosystems whether classifiers considers them wetlands or not. Johnson and others (1984a) determined that vegetational differences do occur between difference or occur between different order washes as well as between uplands and xero-riparian lands. The preferential use of xeroriparian habitats compared to desert upland habitats has been quantified for birds. Johnson and Haight (1985, 1988) found up to 10 times (or greater) the number of individuals and species of birds along desert washes in comparison to adjacent uplands in the Chihuahuan and three subdivisions of the Sonoran Desert.

We propose addition of a visual comparison component to the wetland/riparian land definition; that vegetated wetlands/riparian lands be defined as "those whose vegetation is dominated by obligate, preferential or facultative wetland/riparian plants whose species occurrence, or woody plant density, or stature differ by more than 25 percent (an arbitrary figure) compared to the surrounding non-wetland communities." After additional analysis the 25 percentage difference may be modified to a more realistic figure if necessary to reflect the actual vegetation pattern. Now classification can be based on something that is visible and measurable at any time.

The requirement that vegetation be composed of wetland/riparian plants would prevent misclassification of areas where effective soil moisture differences in upland situations result in vastly different vegetation types, e.g. along ridge-lines, where slope/aspect control available moisture and vegetational differences greater than 25 percent are commonplace, between north and south facing slopes, for example. In general, the 25 (or whatever) percent rule would apply to wetland/riparian obligate or preferential species. It is not true, however, for facultative species, e.g. in the desert Southwest. Foothills paloverde (*Cercidium microphyllum*) is a widely distributed, diagnostic upland species in the Arizona Upland Series (Brown and others 1979). It grows on rocky hillsides with saguaro (*Cereus giganteus*), desert ironwood (*Olneya tesota*), mesquite (*Prosopis* spp.), and triangleleaf bursage (*Ambrosia deltoidea*) along the eastern and northern limits of the Sonoran Desert (annual precipitation 7-13 in.). Near Yuma, Arizona, (annual precipitation approximately 3 inches) these species still occur together but are strictly confined to washes where they behave as obligate xeroriparian riparian species. Redbud (*Cercis occidentalis*), an eastern upland species, typically occurs along water courses in the arid west. In xeric environments creosotebush (*Larrea tridentata*) grows to a stature of a meter or less and plants are spatially separated by 2 meters or more. Yet along 1st or 2nd order desert washes (Johnson and others 1984b) it occurs as a xeroriparian plant with individuals occasionally 3 to 4 meters tall and separated by less than a meter.

Our proposed 25 percent difference in species composition, woody plant density, or plant height, would correctly classify each of these examples above as wetlands/riparian lands in relation to their surrounding communities.

Conclusions

These wetland/riparian land classification and identification difficulties will continue so long as ecologists persist in differentiating between uplands and wetlands/riparian lands on bases other than plant species growing in the natural communities. A paloverde-triangleleaf bursage community should be classified as such regardless of where it is growing. Differentiation into a "wetland" category should be in relation to surrounding ecosystems. Although on the surface this proposal seems inapplicable to legal absolutes, its ecological flexibility allows the definition to be adopted to varying local conditions and/or habitats.

Until a scientific consensus is reached about the classification and demarcation of wetlands/riparian lands, we suggest that the legal system depend more heavily on the opinions of expert wetland/riparian ecologists, than on the rule-making ability of attorneys and administrators.

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THE RIPARIANNESS OF A DESERT HERPETOFAUNA[1]

Charles H. Lowe[2]

Abstract: Within the Mojave, Sonoran, and Chihuahuan Desert subdivisions of the North American Desert in the U.S., more than half of 143 total amphibian and reptilian species perform as riparian and/or wetland taxa. For the reptiles, but not the amphibians, there is a significant inverse relationship between riparianness (obligate through preferential and facultative to nonriparian) and desertness. In addition to the nondesert species (N=36) present, there are two evolutionary kinds of desert species in the herpetofauna: true desert species (N–20), and desert-included species (N=87); the former are obligate specialists, the latter are facultative generalists. Quantitative aspects of desertness, riparianness, species richness, nondesert taxa and others are examined.

A large part of the herpetofauna of North America is located extensively and abundantly in riparian habitats. No other terrestrial vertebrate group is a better indicator of the biological health of riparian ecosystems. Within the "warm deserts" of the Southwest United States more than half of the total amphibian and reptilian species perform as riparian and/or wetland taxa.

Riparian taxa are obligate, preferential, or facultative components of riparian ecosystems. Thus including the nonriparian condition, four levels of riparianness (R), or riparian dependency, are recognized (Dick-Peddie and Hubbard 1977, Johnson, and others 1987). Moreover, for deserts, in addition to the distinction between desert species and nondesert species, there is a clear distinction between two evolutionary kinds of desert species: true desert species and desert-included species. True desert species are obligate specialists in the real sense that they have evolved within desert environments, while the desert- included species tend to be facultative generalists that include desert environments in their much wider and often widely extensive ecological and geographical distributions. Thus including the nondesert condition, three levels of desertness (D) are recognized (Lowe 1968; and others, 1986):

Desertness		Riparianness	
Nondesert	(ND)	Obligate	(RO)
Desert	(D)	Preferential	(RP)
Desert-Included	(DI)	Facultative	(RF)
Obligate Desert	(DT)	Nonriparian	(NR)

The North American Desert.–There are four major subdivisions in the North American Desert of Shreve (1942, 1951): Chihuahuan Desert, Sonoran Desert, Mojave Desert, Great Basin Desert. Creosotebush *(Larrea divaricata) is* one of the abundant dominants absent from the Great Basin Desert, sometimes referred to as a "cold desert." 'The three major subdivisions in which creosotebush is among the major dominants are referred to here and elsewhere as "warm deserts." These are the Chihuahuan, Sonora, and Mojave Deserts.

In this preliminary report the data for the areas of these three major desert subdivisions that occur in the U.S. sector are extracted from a database that includes the amphibians and reptiles from the larger area of all four subdivisions of the North American Desert. Thus the present report contains in addition to all of the Mojave Desert, only those parts of the Chihuahuan Desert and the Sonoran Desert that lie north of the U.S.A.–Mexico international boundary; most of the geographic area of the Chihuahuan and Sonoran Deserts lie in Mexico. In the present work–involving less than the entire North American Desert herpetofauna–the database involves a total of 12 potential R on D combinations for a total of 143 taxa requiring direct field observation; that yields a potential number greater than 1700 for determinations. There are certain combinations for R and D that are "invalid" or "error" combinations, a subject treated in a longer (subsequent) report on this subject for the North American Desert herpetofauna inclusive of the United States and Mexico.

The Semidesert Grassland.–In the international borderlands of the study area, the North American desert-grassland, or semidesert grassland, lies adjacent to the warm deserts. It is sometimes not understood that the desert-grassland is grassland, not desert. Present deserts evolved out of grasslands and scrublands during the late Tertiary (Axelrod, 1950, 1958, 1979). Throughout the desert areas of the world, biologists make a correct distinction between the desert proper, i.e., desertscrub and its adjoining grassland, steppe, or scrubland. In our Southwest, the Holocene dry-tropic grasslands, called desert-grassland (Shreve 1917) or semidesert grassland (Little, 1950), obviously represent grassland environments. While the present quantitative analysis has been cognizant of desert environment versus nondesert environment, and of desert species versus nondesert species, the difficult cases of the mosaics and ecotones of desertscrub versus semidesert grassland, especially in the Chihuahuan Desert arena, provide a particularly difficult challenge for ecologic and biogeographic analysis.

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There is a recent regional tendency to use the synonym semidesert grassland, recommended by the U.S. Forest Service. The synonym desert- grassland also continues to be used, as it has been for most of this century.

Recent Reports.–During recent years there has been a sharp increase in field research directed to amphibian and reptilian populations in Southwest riparian ecosystems. [In the manuscript editing process, a brief review of these papers was eliminated by the Station editors to "reduce non-relevant reference listings."]

Methods

The areas in the North American Desert for the present analysis, i.e., the study area, lie outside of the Great Basin Desert. Specifically they are the parts of the Mojave, Sonoran, and Chihuahuan Deserts that lie in the six United States of California, Nevada, Utah, Arizona, New Mexico, and Texas. The scheduled degree of desertness (desert to nondesert) and riparianness (obligate to nonriparian) was determined for each amphibian and reptilian taxon in the study area. These ecological determinations for the taxa are provided from direct field observations, mostly those of the author in the southwestern United States and northern Mexico. Over several years colleagues have been generous in both verifying and extending the database for some of the species in and between both California and Texas, which are the longitudinally limiting U.S. states in the desert coverage reported. These field experts are Robert L. Bezy, George L. Bradley, Charles J. Cole, F. R. Gehlbach, S. F. Hale, Peter A. Holm, Howard E. Lawler, Brent E. Martin, Hugh K. McCrystal, Philip C. Rosen, C. R. Schwalbe, Robert C. Stebbins, Thomas R. Van Devender, John W. Wright, and Richard G. Zweifel.

It is worth noting in this connection that there are two sources of commonly used information that are inadequate for this type of fauna- wide ecological analysis. These are the field guides for, and the museum specimens of, the amphibians and reptiles. These two sources often have been abused as substitutes for lack of worker-knowledge in ecological and biogeographical investigations requiring ecological input for reports in both the primary and nonprimary literature. The obvious reason that field guides in particular cannot provide the detailed ecological information required is the fact that the modern field guides and similar books were never intended for this type of service and obviously are not designed for providing it. Among the several existing field guides for amphibians and reptiles in North America, with regard to treatment of the natural biotic communities in which the species live as well as in its illustration and other excellence, by far the best in the West is by Stebbins (1985).

Because in both theory and practice riparianlands (characterized in important part by imported water) fall within the broader concept of "wetlands," there is some current confusion in their application to plant and animal taxa occurring on natural western landscapes. Part of the problem lies in the often strong and confusing seasonal periodicity of both in-situ water (wetlands) and imported water (riparianlands) in desert environments. Table 1 indicates an expected concordance in the concepts and thus the schedules for wetland species status (developed in the eastern U.S.) and riparian species status. This schedule from obligate riparian to nonriparian (Table 1) was used in the present investigation.

The regression model (Fig. 1) employed for the testing reported here for the herpetofauna involves a streamlining of riparian and wetland terminology. For example, the spadefoot toads (genus *Scaphiopus*) perform as both obligate wetland and obligate riparian corridor species (WO/RO) in arid and semiarid environments. In the present study such are scored with a single value for OBLIGATE, whether the taxon is primarily or wholly RO or WO, or RO/WO or WO/RO. Moreover, for further simplification as in modeling, RO is used to represent the obligate position on the riparian/wetland ordinate. An essential notation is that a taxon whether plant or animal is an obligate riparian one when it is directly dependent on the riparian system during any phase of its life cycle.

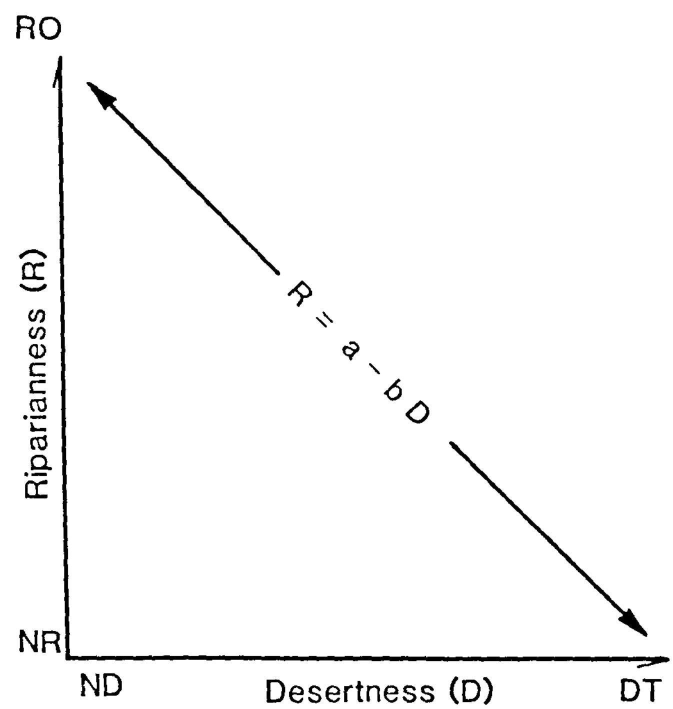

Figure 1– Inverse relationship of riparianness on desertness in a desert herpetofauna. Equations in Table 4.

Table 1 — Comparative schedules for riparian land and wetland plant species. Wetland schedule after Reed (1986). Riparian schedule modified after Dick-Peddie and Hubbard (1977), and Johnson and others (1987). Frequencies follow wetlands convention (see Reed 1986).

Riparianlands Species Status	Frequency (%)	Wetlands Species Status
Obligate Riparian (RO)[1]	>99	Obligate (OBL)
Capable of natural establishment only in the riparian environment		Always found in wetlands under natural (not planted) conditions; may persist in nonwetlands if planted there by man or in wetlands that have been drained, filled, or otherwise transformed into nonwetlands
Preferential Riparian (RP)[2]	99-67	Facultative Wetland (FACW)
More frequently in the riparian environment than in the adjoining upland		Usually found in wetlands; occasionally found in nonwetlands
Facultative (RF)[2]	66-33	Facultative (FAC)
Subequally in the riparian environment and the adjoining upland.		Sometimes found in wetlands; also occurs in nonwetlands
Nonriparian (NR)[2] = Upland	<33	Facultative Upland (FACU)
Upland taxon, present or absent in the riparian environment		Seldom found in wetlands and usually occurs in nonwetlands

1. Frequency of occurrence--in wetland/riparian versus nonwetland/nonriparian--across the entire distribution of the species.

2. Potentially obligate riparian (RO) locally, as in driest sector of species distribution.

Results and Discussion

Table 2 indicates the extent and species richness of the herpetofauna. In the total of 143 species in the study area, reptiles outnumber amphibians approximately 4 to 1. Species of lizards and snakes are present in subequal numbers. Separately, the lizards and the snakes each outnumber the turtles by 5 to 1. With lizards and snakes taken collectively (Squamata), the squamate-turtle ratio is approximately 10 to 1.

The North American Desert herpetofauna is, of course, somewhat richer than indicated in Table 2, which represents a smaller total desert area. The final form and content of this table and Tables 3 and 4 await finalization regarding desertness and riparianness for certain taxa, and the actual evolutionary (species) status of others that remain unsettled. For example, to what extent are the genera Gambelia (Leopard Lizards) and Uma (Fringe-toed Lizards) polytypic? Gambelia is treated here as a monotypic genus, and Uma as a polytypic genus with one species in the Mohave-Sonoran desert arena. The introduced error swing between maximum splitting and maximum lumping is about 2%. While none of the few remaining systematic and ecologic decisions referred to above will affect significantly the overall conclusions drawn from the data set, all of them are of much interest for the completeness as well as correctness of the data set.

	N	%
Amphibia		
Salamanders	2	7.4
Frogs and Toads	25	92.6
Total Amphibians	27	100.0
Amphibian % of Herpetofauna		18.9
Reptilia		
Turtles	11	9.5
Lizards	54	46.5
Snakes	51	44.0
Total Reptiles.	116	100.0
Reptilian % of Herpetofauna		81.1
Total Herpetofauna	143	100.0

Table 2 – Number (N) and percent of totals for species in the combined herpetofauna within the Mohave, Sonoran, and Chihuahuan subdivisions in the United States sector of the North American Desert.

Tables 3 and 4 indicate the degree of desertness in the herpetofauna and its correlation with riparianness. The data for the reptiles (Table 4) fit the regression model (Fig. 1) that predicts an inverse relationship between desertness (X) and riparianness (Y). Ultimate adaptations underlying the strong negative correlations seen in Ta-

	DT (N)	DI (N)	ND (N)
Amphibia (N = 27)			
Salamanders	0	1	1
Frogs	1	17	7
species sums	1	18	8
% of total 27	3.7%	66.7%	29.6%
desert vs. nondesert		70%	30%
Reptilia (N = 116)			
Turtles	1	1	9
Lizards	11	34	9
Snakes	7	34	10
species sums	19	69	28
% of total 116	16.4%	59.5%	24.1%
desert vs. nondesert		76%	24%
Herpetofauna (N = 143)			
species sums	20	87	36
% of total 143	14.0%	60.8%	25.2%
desert vs. nondesert		75%	25%

Table 3 — Number (N) and percent of totals for true desert (obligated desert) species (DT), desert-included (facultative desert) species (DI), and non-desert species(ND). See Table 1.

taxa (species)	df	regression equation	r	P
all reptiles	114	R = 3.566 - 0.962 D	-0.763	<.001
turtles	9	R = 4.130 - 1.174 D	-0.938	<.001
lizards	52	R = 3.270 - 0.814 D	-0.677	<.001
snakes	49	R = 3.487 - 0.958 D	-0.744	<.001
lizards and snakes	103	R = 3.362 - 0.875 D	-0.707	<.001

Table 4 — Regression equations for riparianness (R) on desertness (D) for reptilian groups collectively within the Mohave, Sonoran, and Chihuahuan sub-divisions of the U.S. sector of the North American Desert. See Fig. 1.

ble 4 are the taxa-specific water balance ratios and the reptilian amniotic egg. Within the boundaries set by those constraints, trophic and other energy-behavioral adaptations drive the habitat-selection exhibited.

The data for amphibians do not fit the inverse R on D model for reptiles. Amphibians as a group in a desert environment are (entirely to essentially) obligate, and thus the degree of riparianness (Y) is for the most part statistically independent of degree of desertness (X). As indicated in Fig. 2, the R on D regression coefficients for amphibian taxa in desert environments are predicted to be not significantly different from zero ($b \approx 0$). In natural habitats wherever they are, the primary reproductive wedlock of the anamniotic amphibians to water and water-wetness is overriding.

Summary and Conclusions

Desertness.–Nondesert species, and desert species of two evolutionary types, characterize the desert herpetofauna. The two kinds of desert species are (1) true desert species which are obligate specialists, and (2) desert-included species which are facultative generalists; the two are non-equivalent desert species.

In a herpetofaunal total of 143 species in the North American Desert study area, a respectable 25% (25.2) are nondesert species (ND). In the 75% (74.8) that are desert species (D), 61% are desert-included species (DI), and 14% are true (obligate) desert species (DT)–a small but not unexpectedly small percentage of true desert species in the North American Desert.

Riparianness.–The descriptor Riparian is used in this report as a generic term inclusive of both the riparian and the more purely wetland situations; riparian (and wetland) species are either obligate, preferential, or facultative, and the nonriparian species are upland species.

Approximately 40% (41.2) of the 143 total species in the herpetofauna are nonriparian (NR). Nearly 60% (58.8) are riparian and/or wetland species and exhibit various degrees of compensation for moisture, with more than half of the 60% (37.1%) restricted to the obligate riparian (RO) and/or obligate wetland (WO) ecological position.

Relative Species Richness.–There are approximately 4 reptilian species to every 1 amphibian species in the North American "warm desert" ecosystems investigated. Similarly , turtles are outdistanced about 5 to 1 by both the lizards and the snakes. The lizards and snakes are virtually equal in species richness.

Reptiles.–A total of 116 reptilian species comprise approximately 80% (81.1) of the total herpetofauna in the 3-desert study area. A combined 105 species of lizards and snakes comprise 90% (90.5) of the reptilian species in the study area, with approximately half of the 90% contributed by each systematic group–46.5% lizards, 44.0% snakes. Turtle species (N = 11) comprise the remaining approximate 10% (9.5) of the reptilian total.

A strong inverse relationship between desertness (D) and riparianness (R) emerges for the three major reptilian groups in the North American Desert-turtles, (Fig. 2) lizards, and snakes. While this relationship was predicted from the model, the correlation is stronger than expected, especially when all groups are combined ($r=-0.763, P < .001$). In the ecological data on desertness (D) and riparianness (R) for lizards and snakes, a strong pattern similarity is seen for them in the desert area treated; the sums for the lizards and snakes are nearly identical, and neither the slopes nor the intercepts are significantly different.

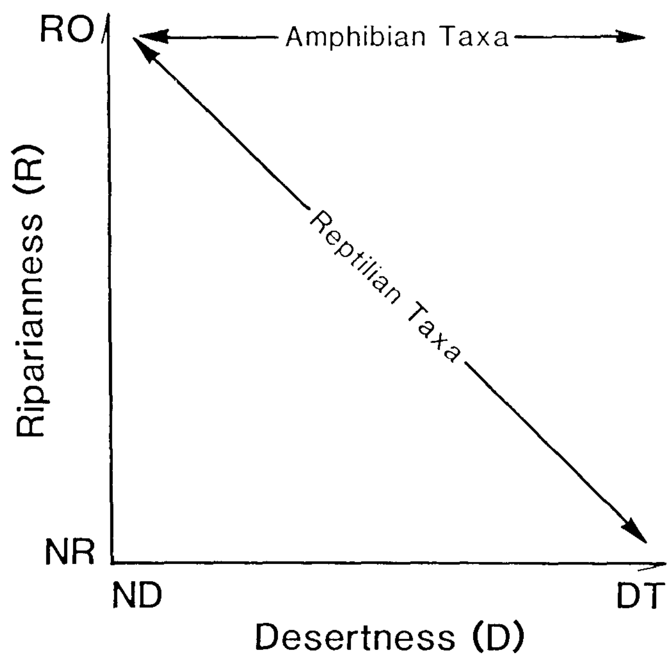

Figure 2. The relationship of riparianness and desertness in amphibian and reptilian taxa in the North American Desert herpetofauna.

Amphibians.–A total of 27 amphibian species comprise approximately 20% (18.9) of the herpetofauna of the desert study area. All but two of the 27 are frogs and toads. The other two are salamanders, the Tiger Salamander (*Ambystoma tigrinum*) which is a desert-included species, and the Desert Slender Salamander (*Batrachoseps aridus*) which is a nondesert species in the desert-edge.

Unlike the reptiles, amphibians as a group in the North American Desert do not exhibit an inverse relationship between desertness (D) and riparianness (R). The flat-curve model for amphibians predicts a regression coefficient not significantly different from zero for riparianness (NR-RO) independent of degree of desertness (ND-DT). In the theory underlying the model there is an anamniotic versus amniotic hypothesis for the amphibian R on D pattern distinction from that of reptiles. It is at least clear from the test thus far that (with the exception of Batrachoseps and Hylactophryne) the desert-arena amphibians in the North American Desert require reproductive surface water at sufficient depth .(> 1 cm) for a period > 10 days; they are the most clearly obligate riparian/wetland taxa in the desert herpetofauna and include both DI and DT desert species.

Nondesert (ND) Species.-Eight amphibians and 28 reptiles, for a total 36 species, make the 25.2% nondesert taxa. A few are man's introductions, some are post-climax relicts. Some nondesert native species in the North American Desert established originally on riparian river and stream corridors of transported water well into the desert arena-inter-biome water from sources and sheds often from outside the desert region as well as transported water from within its overall geographic limits. Today that water may be permanent, seasonally intermittent, or torrentially ephemeral. In some cases the nondesert native species within now-arid environments were present where they are, as resident populations, under more mesic environmental conditions that preceded the more recent establishment of current desertscrub environments. Moreover, earlier less-arid climate in general is beyond reasonable doubt associated in various degrees with both mechanisms- riparian corridors and in-situ residency.

Acknowledgements

Under methods are listed the names of many herptologists who have assisted me in the present work. I thank also R. Roy Johnson of the U.S. National Park Service who has been of able assistance in matters riparian and who is currently reporting on desert riparian systems for the U.S. Fish and Wildlife Service. The work has been supported by grants and contracts from the National Park Service, National Science Foundation, The Arizona Foundation, and University of Arizona Research Fund 302787.

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COYOTE CREEK (SAN DIEGO COUNTY) MANAGEMENT AND RESTORATION AT ANZA-BORREGO DESERT STATE PARK [1]

David H. Van Cleve, Lyann A. Comrack and Harold A. Wier[2]

Abstract: Coyote Creek, along with its associated watershed in Anza-Borrego Desert State Park, is an extremely rich riparian system in the Colorado Desert of California. It provides habitat for the least Bell's vireo (Vireo bellii pusillus), *is used as a critical summer watering site for the peninsular bighorn sheep* (Ovis canadensis cremnobates), *and was the site of major use and encampment by the Cahuilla Indians. Management activities have focused on maintaining or enhancing the integrity of the riparian system. Activities such as eliminating off-highway vehicle use and removing cattle with helicopters have been controversial, yet have demonstrated progress towards achieving the goals of protecting the riparian habitat, associated fauna, and cultural features of this Creek.*

Coyote Creek is the only reliably perennial creek in Anza-Borrego Desert State Park, San Diego County, California, and stretches 29 kilometers in length from the town of Anza to the edge of the Borrego sink near the town of Borrego Springs. Along its length are three distinct tracts of high quality riparian forest habitat known as Upper Willows, Middle Willows, and Lower Willows (the largest and most significant). These areas contain the following dominant plant species: narrow-leaf willow (*Salix exigua*), Fremont cottonwood (*Populus fremontii*), western sycamore (*Platanus racemosa*), arrowweed (*Tessaria sericea*), white alder *(Alnus rhombifolia),* mulefat (*Baccharis glutinosa*), honey mesquite (*Prosopis glandulosa*), and tamarisk (*Tamarix ramosissima*). Occasionally, fan palms (*Washinglonia filifera*) occur (Wier and Jones, 1986).

One of the most significant residents of this area is the state threatened peninsular bighorn sheep. Approximately 150 bighorn rely on this drainage for food, water, breeding grounds, and cover. Sensitive bird species in Coyote Canyon include the state and federally endangered least Bell's vireo, black- crowned night-heron, green-backed heron, common yellowthroat, American kestrel, yellow-breasted chat, black-tailed gnatcatcher, blue grosbeak, downy woodpecker, willow flycatcher, yellow warbler, prairie falcon, red-shouldered hawk, and black-shouldered kite (Remsen, 1978; Tate, 1981)

This region was also important to the Native American inhabitants. The Cahuilla Indians lived throughout and used the Coyote Creek area, as evidenced by the presence of 27 archeological sites in the Lower Willows area alone. These sites include 18 major aboriginal villages and smaller encampments. Also included are bedrock mortars, bedrock metates (milling slicks), and rock art sites. Undoubtedly, the availability of food, water, and shade made this area attractive to these early inhabitants. This area is also historically significant, since it was the route traversed by the Juan Bautista de Anza expedition in 1774-75 (Sampson, 1987).

Much of the upland area surrounding the creek is still relatively inaccessible to humans. In fact, all but the existing routes of travel were classified as state wilderness in 1981 by the State Park and Recreation Commission. The "oasis" quality of the actual riverine system is extremely attractive to humans and animals. It is this same attractiveness which has led to its colonization and use by undesirable species.

Threats

Despite its status as part of a state park, its relative inaccessibility, and the wilderness designation of much of the surrounding landscape, the Coyote Creek area suffers from numerous threats to its ecological health and its value as a refuge to humans and sensitive fauna. These threats include the impacts of humans on the natural, cultural, and esthetic features (primarily through the effects of off-highway vehicles and archeological pothunters), and the effects of alien species on native flora and fauna.

Off-Highway Vehicles

Until March 1988, all vehicles were allowed to traverse the 29 kilometer route of Coyote Canyon from Borrego Springs to Anza, including the riverine routes. Although much of this jeep trail was located in upland areas, it passed directly through the three most significant riparian forests of Coyote Creek: Upper, Middle, and Lower Willows. Vehicular use in the last 40 years has changed

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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dramatically in this area. Originally used by jeeps and trucks as a route for sightseeing and nature enjoyment, Coyote Creek had, by the early 1980's, become the playground and speedway for motorcycles and All-Terrain Cycles (ATC). It was evident that the impacts of approximately 1000 vehicles on the riparian system during busy weekends were becoming intolerable. The Department of Parks and Recreation (Department) reevaluated its management practices towards off-highway vehicles because of the destruction of riparian habitat, suspected direct destruction of the nests of sensitive avifauna, deterioration of water quality, uncovering of archeological sites along with associated vandalism and theft, increased soil and bank erosion, the transformation of the area from a quiet sightseeing area to a noisy playground and other concerns (M. Jorgensen, 1987).

Studies also showed that the peninsular bighorn sheep avoided the riverine area during periods of vehicular activity. During those periods of the year when air temperatures are above 35 degrees C, sheep require frequent access to watering sites. Their avoidance of the creek during peak vehicular activity caused stress in the sheep (P. Jorgensen, 1974). This study led directly to the implementation, in 1975, of an annual seasonal closure (June 15 – September 15) of the entire Coyote Canyon watershed to all persons and vehicles.

In July 1985, funding was secured to take the first step towards providing Lower Willows with permanent protection. Several alternatives were considered. These included extending the seasonal closure forward to March 15 to provide protection for the least Bell's vireo and other sensitive species during the breeding season, and implementing a permit process to limit the amount of traffic in the area. The alternative selected was a plan which proposed relocating the jeep trail out of the riparian forest into a xeric side canyon. Since this proposal provided resource protection and continued to allow vehicular access to the area, the Department felt that its project was fairly benign. The off-highway vehicle enthusiasts were incensed, however, and fought the proposal at every level possible. The proposal was heard by the State Park and Recreation Commission, which voted unanimously in favor of it and the concomitant proposal to classify the Lower Willows area as state wilderness.

The San Diego Off-Road Coalition filed suit against the Department for not meeting the provisions of the California Environmental Quality Act (CEQA) for this project. After a lengthy process, the suit was adjudicated in favor of the Department in June, 1987. Construction of the bypass route was finalized in March, 1988, and opened to the public soon thereafter. This route now provides permanent protection to Lower Willows from the direct and indirect impacts of regular vehicular traffic. Horse and foot traffic is still allowed in Lower Willows except during the annual seasonal closure.

The other major action of the Department designed to lessen the impacts of motorized traffic on riparian resources of the area has been the issuance of a ban on all vehicles, except those which are street-legal, throughout the entire park. This ban, effective September 1, 1987, has effectively reduced the total number and type of vehicles accessing the Coyote Canyon area. Dirt bikes, all-terrain cycles, and many dune buggies may no longer be operated in Anza-Borrego Desert State Park. Although street-legal jeeps, trucks, and motorcycles still have impacts on the riparian forests of Middle and Upper Willows, these impacts have been greatly reduced. The types of vehicles and recreationists utilizing the area are now involved in slow-moving sightseeing instead of high-speed equipment testing. The physical and esthetic changes have become quite evident even in the short time since the institution of the ban; the traffic corridors have been filling in with thick stands of willow and tamarisk which provide additional avian habitat, and the scouring effect of rainstorms has eliminated many of the more obvious vehicle tracks. This regrowth was set back temporarily in May 1988 because of a wildfire in Lower Willows.

This ban was also opposed vigorously by off-highway vehicle enthusiasts and groups in the proposal stage. Large letter-writing campaigns and strong political pressures were brought to bear upon the Department. It even became a major issue in the confirmation hearings of the new director of the Department. The proposal to ban off-highway vehicles was heard separately before the State Park and Recreation Commission, which again voted unanimously in its favor. At the time of this writing, the ban is in effect, and it is expected to remain so.

Threats to Least Bell's Vireo

Various researchers have described the population status of the least Bell's vireo in California (U.S. Fish and Wildlife Service, 1986). Anza-Borrego Desert State Park provides extremely high quality desert breeding habitat for this species, with Lower Willows as an important population center.

An intensive survey for least Bell's vireo was conducted in the park during 1986. A total of 32 territorial male vireos was found distributed in seven localities in the northern portion of the park. This figure is somewhat higher than estimates from past surveys, but is probably a reflection of more thorough and intensive field work rather than a population gain. Of this total, 9 were located in Lower Willows, representing 28 percent of the total territorial males in the local desert population. Nesting success (percent of nests that produced vireo fledglings) was 54 percent, consistent with results found by researchers in coastal localities. Brown-headed cowbirds were prevalent in riparian habitat throughout the park. Cowbird nest parasitism was implicated as a significant factor reducing vireo productivity; at least 80 percent of the nests in Lower Willows had been parasitized (Wier and Jones, 1986). Future expansion of the least Bell's vireo into seemingly suitable habitat in Middle and Upper Willows will be dependent on the reduction of the cowbird parasitism threat.

The Department began a vigorous cowbird reduction program in 1986 in an attempt to reduce significantly the local cowbird population. Six traps were built and set in Lower Willows, Riviera Farms (a private horse ranch), and the park's own Horse Camp. A total of 56 cowbirds was trapped, removed, and killed in the park in 1986. The dead cowbirds were frozen and donated to the San Diego Natural History Museum for use as study skins. The trapping results were somewhat disappointing, but can probably be attributed to a late start date that year (May 12th). The cowbird trapping program has continued through 1988 in Lower Willows. 170 cowbirds have been trapped and removed during the first part of this year's breeding season (Griffith and Griffith, 1988). The Department plans to continue the trapping program for several more years. The program will be improved as knowledge of cowbird dispersal patterns in Coyote Canyon increases.

Tamarisk Eradication

Tamarisk is a well documented problem species in the Southwest (Kerpez and Smith, 1987). As a phreatophyte, it evapotranspires tremendous amounts of water into the atmosphere. The result of this evapotranspiration is a reduction in the amount of water available for wildlife and for native riparian and waterhole plant species. Tamarisk tends to form dense, monotypic stands, outcompeting native vegetation. It is also less preferred as wildlife habitat than native riparian species. Tamarisk is pervasive in the Coyote Canyon drainage with several severe infestation areas.

During May 1988, approximately 150 acres of riparian vegetation were burned in Lower Willows due to an escaped campfire. Two weeks after the burn, tamarisk had vigorously resprouted from underground rootstalks. Seedling establishment was also noted. The Department's response was to send workers into Lower Willows to cut and chemically treat the tamarisk. A park-wide tamarisk eradication program has been conducted since 1983, but had focused on remote springs and drainages where infestation has not been as severe. Past removal work included cutting the specimen with chainsaw or loppers, and immediately applying the herbicidal agent Garlon-4 to the cut stump. Results have been encouraging. Following two successive seasons of removal work, a mortality rate of 95 percent on treated tamarisk has been achieved. Garlon-4, produced by Dow Chemical, is brushed or sprayed on the tamarisk stump immediately after the stem has been severed. Tamarisk resprouting has been minimal with the use of this chemical. Also, Garlon-4 is not a restricted pesticide, which makes it easier to obtain and use than other, more powerful, herbicides (Comrack, 1987). Techniques developed by park staff will be used on the Lower Willows tamarisk infestation problem in order to reduce the negative impacts of this weed on the riparian system. The fire consumed portions of riparian habitat used for nesting purposes by the least Bell's vireo. What direct effect the fire had on this population of vireos is unknown. Five territorial males have been noted in Lower Willows after the fire. We suspect that vireos may colonize nearby but previously unoccupied habitat at Middle or Upper Willows. Further surveys will be required to confirm this possible relocation.

Another unfortunate side effect of the fire was its removal of the duff and litter layer in Lower Willows. Since this area had been used extensively by the Cahuilla Indians, the surface evidence of their occupation became very evident after the fire. Park rangers made an arrest for vandalism of a Cahuilla grave site, which included the possession of the remains of human cremation.

Feral Cattle

Livestock can cause many types of resource damage in riparian systems. They may compete with native wildlife species for food and water, destroy the riparian corridor through overgrazing, pollute surface water flows, compact soil, and increase erosion of streambanks. Additionally, domestic livestock carry contagious diseases which are deadly to the peninsular bighorn sheep (Jessup, no date). The presence of an increasingly large population of feral cattle in the backcountry of Anza-Borrego Desert State Park has long threatened the resource integrity of Coyote Canyon. Although grazing leases were canceled in 1971, remnant herds multiplied prolifically in the absence of any natural predators. Also, numbers of cattle increased from the illegal entry of branded cattle onto park property from neighboring ranches. Past efforts to rope, herd, and/or trap the cattle resulted in failure.

An attempt was made in 1985 to introduce a bill in the State Legislature which would allow the Department to shoot feral cattle within the boundaries of the state park. This proposal met intense opposition from the California Department of Food and Agriculture and both the State and County Cattlemen's Associations.

In the only avenue left unexplored, the Department initiated an aerial animal capture program, utilizing the professional services of Skydance Operations, Inc., of Minden, Nevada. Skydance provided a Hughes 500D helicopter especially equipped for aerial animal capture, pilot, net-gun operator, and other support staff in order to capture and transport the cattle successfully. Removal efforts were concentrated in Coyote Canyon due to the significance of its resource values and because past cattle damage to the drainage had been most severe.

The field operation was broken into four phases as described below:

Phase 1: A continuous supply of alfalfa was placed in key locations in Coyote Canyon a few weeks before the airlift operation began. Establishment of the feeding stations served to lure the animals into predetermined target range.

Phase 2: Early morning reconnaissance flights served to locate large concentrations of cattle. During the actual animal capture, the pilot used the helicopter to herd the targeted bovine into the open. The animal was then captured with a net fired from a gun designed to be used from a helicopter hovering about 4 meters from the target. After firing, the 5 by 5 meter net settled onto and entangled the targeted animal. Captured cattle were hobbled with heavy leather straps, hoisted by hook to the helicopter, and flown out to holding pens erected in the park's Horse Camp.

Phase 3: Ground crews subdued and untethered the cattle after they were unhooked from the helicopter. Veterinarians working independently from the Bighorn Research Institute in Palm Desert, California, collected blood samples and nasal swabs from each animal for diseases analysis. Cattle were then released to await transport.

Phase 4: Through an arrangement with the Bureau of Livestock Identification, truckloads of cattle were taken from the Horse Camp to the town of Brawley. Animals were held for 14 days to determine ownership status. All unclaimed cattle were then sold at auction.

The feral cattle removal operation began March 31, 1987 and continued through December 18 of that year. A total of 111 cattle were captured from Coyote Canyon and nearby Buck Ridge (M. Jorgensen, 1988). Although any animal capture operation poses some risk to the animals involved, all personnel and cattle escaped injury during transport. Disease analysis of blood and nasal discharge samples taken from the cattle was conducted independently by the Bighorn Research Institute. Preliminary results indicate that cattle have been exposed to many of the viruses which have decimated bighorn populations, including Para-Influenza III, Blue Tongue, Bovine Viral Diarrhea, Bovine Respiratory Synicital Disease, and Epizootic Hemorrhagic Disease (DeForge, 1987). It is hoped that this cattle removal program will help ensure the long-term health of the Coyote Canyon bighorn population.

In an effort to prevent further ingress of feral cattle into the park now that most existing animals had been removed, a fencing project was conducted in 1987. Approximately 13 miles of barbed-wire fencing were constructed at a cost of $194,000 on the western boundary of the park. Sites were selected which did not conflict with bighorn habitat and which were suspected to be major cattle ingress routes (M. Jorgensen, 1988).

Conclusions

The Department of Parks and Recreation has taken several important steps to identify and correct threats to the natural, cultural, and esthetic resources of Coyote Creek in Anza-Borrego Desert State Park. It is continuing to assess the populations of least Bell's vireo, peninsular bighorn sheep, and other sensitive species through contracts and volunteer programs. The Department is also continuing to monitor the success of the cowbird removal program through a contract and the success of the tamarisk removal and the Off-Highway Vehicle ban through studies conducted by park staff. It is vital that these monitoring efforts continue on a regular basis; they are expected to continue for several years. Even though these steps have been controversial at a variety of levels, they have been in concert with the legal mandates of the department and in conjunction with Departmental goals in the field of resource management. It is essential that established processes and laws be adhered to at each and every step. Too often, projects are stopped or delayed, not on their respective merits, but rather because the established process was not followed. In order to carry out resource management projects successfully, identification of and adherence to the process is an essential step of implementation.

Acknowledgements

We thank Anza-Borrego Desert State Park Naturalist Mark C. Jorgensen for contribution of field work, leadership, and coordination on all of these projects.

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SESSION D: RIPARIAN SYSTEMS AND FOREST MANAGEMENT

Forest streams create unique conditions along their margins, and even though a distinctive vegetation may not be present, managers have recognized the need to minimize disturbances in streamside corridors. Early management emphasis was on controlling sediment delivery and maintaining conditions that would support fisheries. The wider role that streamside vegetation plays in the ecosystem of forested basins and their streams is only now being fully appreciated. Many advances have occurred since the 1981 California Riparian Systems Conference.

Two papers link forest management practices in and near the riparian zone with water temperatures and physical structure of the channel as it is affected by coarse woody debris. Another paper deals with the status of an unusual forest understory element, the Pacific yew. The final papers deal with management of riparian systems in watersheds where decomposed granitic soils and landslides exert significant influences.

The papers in this session emphasize the high priority that riparian systems are starting to receive in forest management.

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PREDICTING STREAM TEMPERATURE AFTER RIPARIAN VEGETATION REMOVAL [1]

Bruce J. McGurk[2]

Abstract: Removal of stream channel shading during timber harvest operations may raise the stream temperature and adversely affect desirable aquatic populations. Field work in California at one clearcut and one mature fir site demonstrated diurnal water temperature cycles and provided data to evaluate two stream temperature prediction techniques. Larger diurnal temperature fluctuations were observed in the water flowing through the clearcut than in the undisturbed area above the clearcut site. The mature fir forest also had a large diurnal water temperature variation. A 5.6°C temperature rise was observed through a 380-m clearcut that exposed the stream channel, and Brown's equation predicted a change of 6.1°C. A regression model underpredicted the maximum observed temperature by just under 2°C at the clearcut site. A technique that includes the effect of shade recovery after timber harvest is suggested for use during long-range harvest planning.

Forest management can affect water quality and aquatic life, and riparian areas are both sensitive and easily disturbed. Streamside forest canopy removal allows direct sunlight to reach first- and second-order streams that were extensively shaded before timber harvest. Direct sunlight can increase stream temperature, which effects fish and aquatic insect species composition and growth (Feller 1981). Temperature also affects water quality parameters such as dissolved oxygen and the waste assimilation capacity of a stream.

The effects of logging on stream temperature have been the subject of considerable research and numerous reviews (Brett 1956, Brown 1969, Patton 1973, Anderson and others 1976). Direct solar insolation was found to account for at least 90 percent of a stream's temperature change after clearcutting (Brown 1970). Salmon (*Oncorynchus* sp.), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) prosper in streams that are between 10° and 18°C, and if water temperatures exceed 24°C they may die, depending on acclimation temperatures, pH, and dissolved oxygen (Patton 1973). The replacement of these high-value, cold-water fish species by warm-water fish has been associated with timber harvest.

Early research determined that an important shading and sediment filtering role was played by the vegetation along channels, and this area was termed a buffer strip (Patton 1973). Management agencies have incorporated this concept by establishing special management areas along active stream channels that include the riparian zone and some amount of the adjoining hillslope. Limited.

harvesting may be allowed in these streamside management zones (SMZ), which may vary in width depending on hillslope angle. Although equipment entry into the SMZ is discouraged, the restrictions do not prevent the removal of shade-providing vegetation from riparian zones. In addition, the Pacific Southwest Region (California) of the Forest Service, U.S. Department of Agriculture, has established Best Management Practices (BMP), which state that no adverse temperature impacts should occur to streams during harvests. The actual effectiveness of SMZ restrictions and other BMPs is not known due to the lack of detailed or long-term monitoring.

Early efforts to predict stream temperature changes focused on predicting the maximum temperatures associated with peak summer conditions and low flows (Brown 1969). These early models were based on temperature changes caused by full exposure of the stream reach to the sun at the peak sun angle. By combining the site's latitude with field measurements such as stream temperature, channel width, depth, flow velocity, and an estimate of shading with estimates of potential cover reduction, likely temperature increases can be quantified. The estimated change in temperature, when added to the pre-harvest water temperature, provide an indication as to whether post-harvest temperatures might exceed the lethal limit for the resident fish.

Other modeling approaches include empirical models that are calibrated for one geographic region, or detailed simulation models that require extensive data pertaining to the reaches to be modeled (Schloss 1985, USDA Forest Serv. 1984). The Schloss model is typical of a regression model and was developed in western Oregon to predict maximum summer temperature based on elevation, distance above the main channel, stream order, and shading. The USDA model was developed by the Forest Service to simulate stream temperature

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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response to multiple alternative harvest areas in a basin. It is a physical, energy budget-based algorithm, and has a time step that can range from 15-minute to hourly or daily intervals. Both direct and indirect (diffuse) shading is incorporated, as is stream aspect, topographic shading, groundwater influx and temperature, and flow into and out of the reach. The stream network is represented by sequentially estimating the outflow water temperature in each reach and using that information as the inflow temperature in the next downstream reach. A significant advantage to this model is its ability to handle partial shade, but obtaining the copious input data requires considerable field work.

This paper reports on field work at two streams in California that evaluates Brown's stream temperature change prediction technique and an empirical equation developed in Oregon (Brown 1970, Schloss 1985). Both partial and complete riparian vegetation removal are analyzed. A modification of Beschta and Taylor's (1988) phased vegetation recovery system is proposed as part of a multireach accounting system for basins with multiple cutting areas.

Temperature Prediction

Model Selection

Model selection should be based on the size of the area of concern and on the intended use of the water temperature prediction. Because the typical forestry use is to assess the effect of timber harvest, grazing, recreation, or road construction on large land areas, the complex and data-hungry physical simulation models are inappropriate. Empirical (regression) models may be appropriate if one has been developed for the local area of interest. In most cases, however, a relatively simple model based on the physical processes relating stream surface exposure to sunlight is most appropriate.

Exposed Surface Models

Exposed surface models combine a few crucial types of field data with tabular data dependent on site location (Brown 1969). This type of model uses only physical constants and field measurements, so it is not an empirical, "calibrated" model. Changes in water temperature T(°C) increase directly in relation to new stream surface area A (m^2) that is exposed and insolation N (cal/cm^2-min), and inversely with streamflow Q (m^3/s):

$$\Delta T = \frac{AN}{Q} * .000167 \tag{1}$$

The coefficient contains the constants for the conversion of the flow, area, and insolation units to temperature.

Because this model predicts a change in temperature, pre-project temperatures should be measured wherever harvests are planned. Streams should be visited during California's low flow and peak heat times of July, August, and September. A simple pocket thermometer could yield representative data for several small basins with a moderate amount of effort, using measurements taken between noon and 1500 hours. Peak temperatures occur due to the interaction of declining streamflow and insolation, in spite of the decline of insolation after June 21.

The parameter A reflects the new channel area that will be exposed due to forest harvest, but topography, channel aspect, and harvest design also have a role in determining A, so subjective judgments may be needed. If 35 percent of the cover in a 100 m zone along the southside of a channel is to be removed, it may be reasonable to equate this to complete removal from about 30 m of channel.

Table 1 — Average values of net solar radiation absorbed by water surfaces in middle latitudes for a range of exposure times (cal/cm^2-min) (after List 1951, Brown 1974).

Water Travel	Latitude (degrees)		
Time (hours)	35	40	45
2	1.30	1.28	1.22
4	1.25	1.22	1.17
6	1.19	1.14	1.11
8	1.09	1.06	1.00

Solar loading N is dependent on season, latitude, and the length of time that the water is in an exposed area. California's National Forests range from 34° to 42° latitude, so N values for the appropriate latitudes have been estimated (table 1). N values could be reduced by about 1 percent for each week after July 1 to account for the seasonal decrease in insolation, but such minor adjustments are probably not warranted due to the inherent errors in area and discharge estimates. The travel times for the 160 m to 400 m openings typical of National Forest System operations and stream gradients are between 1 and 2 hours, so the N values for 2 hour travel times in table 1 should be used for most small streams.

The final requirement for equation 1 is discharge volume, and small mountain streams are difficult to gauge accurately due to shallow depths, turbulence, and side-pool areas. If a small current meter is available, measurement of cross-sectional areas and water velocities can provide reasonably accurate results. Alternately, dye or floating objects such as oranges can be used but accuracy will suffer. If objects such as sticks are used, the velocity should be multiplied by 0.8 to correct for the vertical velocity profile of the stream. Cross-sections should be selected to minimize stagnant water pools near the stream's edge or discharge can be overestimated by 50 to 100 percent.

Empirical Prediction

Empirical equations can be developed by regressing stream temperature on basin, cover, and stream characteristics (Schloss 1985):

$$T = 11.9 - 0.0013E + 0.206L + 0.676R + 1.814(S/50 + 1) \quad (2)$$

where:
T = maximum summer stream temperature (°C)
E = midbasin elevation (m)
L = distance from junction of next higher-order stream (km)
R = stream order
S = shade percentage (percent)
Standard deviation = ±1.7°C.

Equation 2 was calibrated for forested basins in western Oregon that were below 610 m elevation. Unlike equation 1, this technique predicts maximum temperature rather than temperature change. The stream order and channel distance factors are measured on US Geological Survey 7.5° quadrangle maps. The channel length is the distance from the area of interest to that stream's juncture with the "main" channel. The shade code is the percentage of channel that has less than "complete" shade within 1600 m upstream from the point of interest.

Site Descriptions and Field Methods

McGill Creek

A clearcut site was identified 3 km north of Iron Canyon Reservoir along McGill Creek at an elevation of 915 m (figure 1). Iron Canyon Reservoir is in the Shasta National Forest and is 61 km northeast of Redding, California. McGill Creek is a south-draining second-order stream, with a slope of 3.5 percent, that passes through an 8-ha clearcut. The timber operator removed nearly all of the timber on both sides of the stream, and the slash disposal burn got out of control and destroyed most of the remaining near-stream vegetation. These actions produced a 380-m section of stream that had almost no shading.

Field instrumentation consisted of water temperature, air temperature insolation, humidity, and wind instruments. Ten water temperature probes were placed in the unshaded channel, one probe was 70 m upstream of the cut, and probes were placed 35 m and 90 m downstream of the clearcut area. Except for a hygrothermograph and rainfall collector, all readings were collected electronically at 15-minute intervals. The site was monitored for 48 hours between August 31 and September 2, 1983. Approximately 1.3 cm of rain fell during the afternoon and evening of August 31, but September 1 and 2 were warm with clear skies. Peak air temperatures were 29°C on September 1 and 32°C on September 2. The average discharge during the study interval was 18 l/s (0.6 ft^3/s).

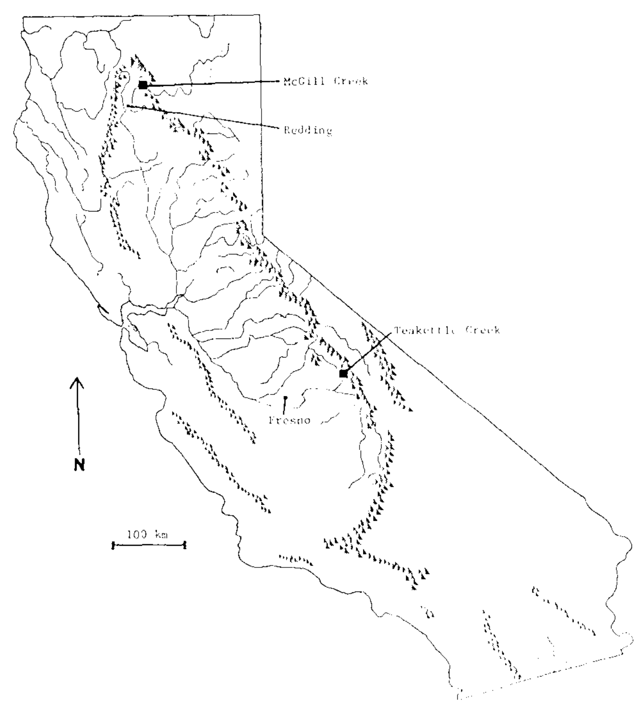

Figure 1—California map pinpointing McGill Creek clearcut site and Teakettle Creek mature fir site where field tests took place.

Table 2 - Average water temperatures and meteorological data for McGill Creek near Redding, and for Teakettle Creek near Fresno, California.

Date	Time	Entry Water Temp.(°C)	Exit Water Temp.(°C)	Temp Diff (°C)	Air Temp. (°C)	Insolation (°C)	Windspeed (cal/cm²-min)
McGill Creek							
8/31	15-18	12.0	12.0	0.0	12.8	0.04	0.6
	18-24	11.8	10.7	-1.1	10.3	.0	.3
9/01	0-6	11.6	11.2	-0.4	9.4	-.01	.1
	6-9	11.5	11.6	0.1	10.0	.06	.1
	9-12	11.7	13.9	2.2	15.9	.65	.5
	12-15	12.2	16.7	4.5	20.6	.82	.7
	15-18	12.1	15.6	3.5	16.9	.21	.7
	18-24	11.6	12.2	0.6	7.0	-.05	.4
9/02	0-6	11.0	10.9	-0.1	5.2	.0	.6
	6-9	10.8	10.8	0.0	8.2	.02	.6
	9-12	11.3	14.1	2.8	22.9	.82	.6
	12-15	12.3	17.4	5.1	27.0	.89	.8
Teakettle Creek							
8/26	15-18	11.1	10.6	-0.5	13.8	0.01	0.5
	18-24	9.0	8.9	-0.1	6.8	.0	.8
8/27	0-6	7.5	7.4	-0.1	5.1	.0	.8
	6-9	7.1	7.0	-0.1	9.3	.02	.8
	9-12	9.5	9.2	-0.3	24.4	.69	.4
	12-15	12.0	11.3	-0.7	22.3	.38	.5
	15-18	11.3	10.8	-0.5	14.6	.0	.4
	18-24	9.2	9.0	-0.2	7.4	.0	.0
8/28	0-6	7.8	7.6	-0.2	5.8	.0	.0
	6-9	7.5	7.4	-0.1	9.1	.01	.0
	9-12	9.7	9.4	-0.3	23.4	.70	.5
	12-15	12.0	11.3	-0.7	21.2	.32	.3

Teakettle Creek

The Teakettle site is on the Sierra National Forest at an elevation of 2100 m. It is in the Teakettle Experimental Forest, on the southeast flank of Patterson Mountain and 66 km east of Fresno, California. Teakettle Creek is a southeast-facing, second-order drainage with a slope of 8 percent that passes through senescent red fir. Although some clearings exist due to the presence of 10 m by 40 m wet meadows, the combination of extensive shrub growth and the 50- to 80-m fir trees exclude most direct exposure from sunlight. A shading survey produced an estimate of 80 percent canopy cover.

The field instrumentation at Teakettle was similar to that used at McGill Creek. Approximately 380 m of stream channel was monitored with 11 water temperature probes, and the other instruments were sited along the stream channel. Peak air temperatures were 27°C on August 27 and 25°C on August 28, 1983. The average discharge during the study was 39 1/s (1.3 ft^3/s).

Measurement Accuracy

All thermistor probes were calibrated by measuring their resistances in three baths of known temperature that spanned the expected measurement interval. The agitated water baths were measured using a precision thermometer accurate to ±0.1°C. A separate polynomial equation was developed for each probe.

Replicate stream temperatures were measured by placing two probes within 2 cm of each other at a single random spot at both McGill and Teakettle Creeks. The mean difference around the replicates and the confidence limits around the difference between any two probes were as follows:

	Mean difference (°C)	95 Pct. Confidence interval (°C)
McGill		0.16 ± 0.3
Teakettle		0.20 ± 0.4

Based on these confidence intervals, observed water temperature values that differ by less than 0.8°C must be considered to be the same.

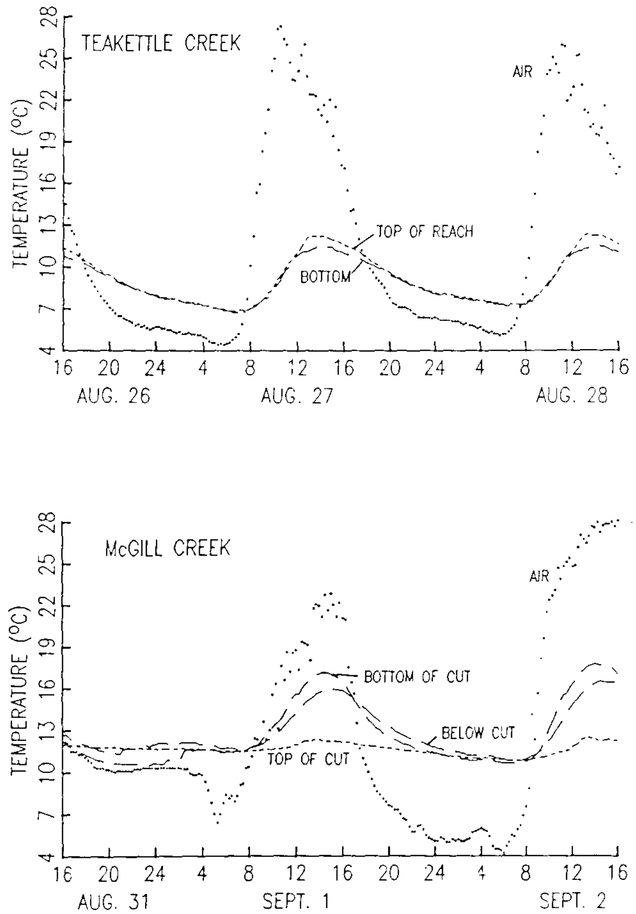

Figure 2–Recorded diurnal water temperature at the two field test sites, August 31 – September 2, 1983.

Results and Discussion

The diurnal water temperature at the two sites share a similar pattern, but there are important differences (figure 2). The air temperatures at both sites peaked at between 24°C and 28°C. The McGill Creek water temperature was 17°C on September 1 and 18°C on September 2, but Teakettle water temperatures peaked at 12°C on both August 27 and 28.

Although both sites produced a sine-shaped temperature pattern, the amplitude varied at the two sites. At McGill Creek, one can hypothesize that the diurnal variation of temperature would be very small in the natural system. Sensors 65 m above and at the upper margin of the clearcut show very small diurnal variations (figure 2). This small variation is due at least in part to the dense shade provided by the willow and alder that choked the channel upstream of the clearcut area. The mature fir forest at Teakettle Creek provided the channel with only 80 percent cover, and the overstory was much higher than at McGill. Teakettle Creek's water temperature is lower than the "natural" case at McGill, a situation that may be due in part to the 1100 m elevation difference. The higher variability at Teakettle may be due to the upstream springs that supply the stream. At McGill, side seeps were common along the channel, and their presence would add to the diurnal variation due the shallow, marshy flow that was exposed to the sun.

Average insolation, windspeed, and air and water temperatures illustrate some of the differences between the sites (table 2). The difference between the 3-hour average water temperature entering and leaving the clearcut was about 5°C at McGill, but the stream actually lost heat in the measured reach at Teakettle. The open site had both larger daytime energy inputs and larger nighttime energy losses due to the lack of a canopy. The total allwave flux was 790 cal/cm^2 at McGill and 383 cal/cm^2 at Teakettle. Windspeeds at the two sites were roughly equivalent, but little wind movement would have been possible in the natural channel areas above the clearcut at McGill due to the dense vegetation close to the water surface. The canopy at Teakettle, however, is much higher, allowing typical diurnal wind patterns.

Exposed Surface Water Temperature Prediction

The McGill Creek site was well suited to Brown's (1970) model for predicting temperature. Channel area was calculated using an average width estimated by measurements at six locations along the channel. In addition to the 1.9-m width along the 380 m of channel, there were also eight small pools that had been constructed for gradient control and to allow sediment to settle. The pools added 111 m^2 to the 483 m^2 of channel surface area, so the estimate of the total exposed area was 594 m^2. McGill Creek is at 41° latitude and the water travel time was about 1 hour (velocity = 0.1 m/s, so the N factor (equation 1, table 1 for 2 hours) equals 1.27. The average discharge, as measured by both current meter and dye velocity/cross-section measurements was 0.019 m^3/s. The calculated temperature change was 6.6°C, and the observed water temperature increase through the cut area was 5.0°C on September 1 and 5.4°C on September 2.

Both the calculated and observed temperatures are estimates that include measurement errors. For equation 1, the area term may have about a 25 percent error, the insolation error may be 20 percent, and the discharge error may be 50 percent. The combined effect of these errors suggests that the predicted value of 6.6 °C is the "best guess" in a range of predicted temperature increase that extends from 3°C to 20°C. Some decrease in the error band may be obtainable with extreme diligence during data collection. The errors associated with the probe measurements are discussed above.

Part of the difference between the predicted and observed values could be due to the decreased solar strength in early September as compared to the peak strength associated with the June 21 summer solstice. Peak insolation at the Central Sierra Snow Laboratory, near Soda Springs, California, declined by 8 percent during that interval. Assuming that the same pattern is followed at McGill Creek, the decreased solar input accounts for 0.5°C, dropping the predicted change for the actual measurement period to 6.1°C. The remaining difference could be due to the shrubby vegetation along the channel, ground water inflow, or errors in the stream area or discharge measurements.

Equation 1 is sensitive to errors in discharge estimation, especially on small streams with low total flows. If the 0.019 m^3/s value is varied by ±10 percent, the initial predicted temperature change (6.1°C) changes to 5.6°C or 6.8°C. Typical current meters are accurate to approximately ±5 percent (USDI Bur. Reclam. 1975), and errors as large as 50 percent are likely in small channels due to lateral turbulence and shallow depths.

The largest 3-hour average insolation values in table 2 for McGill Creek are 35 percent less than a solar loading value of 1.26 estimated for a site at 41° latitude from table 1. The instantaneous net allwave values measured at McGill Creek peaked at 1.1 cal/cm^2-min. If the tabular value is reduced by the 8 percent seasonal factor, the value becomes 1.16 cal/cm^2-min, a value that is only 0.06 cal/cm^2-min different than the observed value.

The Teakettle Creek site is not as well suited for the application of Brown's technique as was McGill Creek. Although no new channel area had been exposed due to harvesting, the 80 percent canopy cover implies that 20 percent of the stream is exposed to insolation. The channel survey yielded an average width estimate of 3.3 m and a length of 380 m, so there is 1254 m^2 of surface area and 251 m^2 of the total is exposed. The insolation value for a 2-hour travel time at 37° latitude, corrected by the 8 percent seasonal factor, is 1.19 cal/cm^2-min. The observed discharge was 0.037 m^3/s, so the predicted temperature increase was 1.4°C. The field results show a top-to-bottom temperature decrease of almost 1°C on both days. Due to the measurement and prediction error factors mentioned above, there is no difference between estimated and observed values, but the divergence is interesting. The decreasing water temperature is counterintuitive in that no large open areas above the measurement site were present from which the stream was recovering. Further, the water temperature at the top of the reach was already rather low for the peak summer heat period.

The diurnal variations at the two sites were markedly different. The Teakettle site had diurnal variations of 4°C, but the undisturbed portion of the McGill site had diurnal variations of 1.2°C. This difference may be due to the lack of low shrub cover at Teakettle versus very dense willow and alder at McGill Creek. The water temperature at Teakettle declined markedly during the night, and this pattern was not seen at McGill in spite of similar air temperatures.

Empirical Temperature Prediction

McGill Creek's elevation is 915 m (E), it is a second order stream (R), and the site is 2.4 km (L) from Iron Canyon Reservoir. The 380 m of clearcut area produces an S value of 24 percent because the remainder of the channel was shaded. It is likely that there would be less overall effect if the clearcut area was split into two portions at either end of the 1600 m effective distance, but this method lumps all partial or unshaded areas into a single ratio. Equation 2 predicts a summer maximum temperature of 15.3 °C. Compared with observed maxima of 17°C and 18°C, the predicted values are surprisingly close.

As a second test at McGill Creek, a prediction can be made for the undisturbed area above the clearcut. The shading factor becomes zero and the channel length changes to 2.5 km. The predicted maximum water temperature is 14.4°C , and the observed maximum was less than 12°C.

Teakettle Creek is at 2100 m elevation, is a first-order stream, and the site is 3 km from the Kings River. Using a shade factor of 20 percent, the predicted summer maximum was 13°C with a standard deviation of 1.7°C. The observed maximum water temperature was 12.3°C, not significantly different than the predicted value. Because Teakettle is further from Oregon and higher than McGill, plus has no real clearcut areas, the correspondence between the observed and predicted temperatures is surprising.

Although these three cases are not an adequate evaluation of Schloss' equation, they do show both the promise and the danger associated with an empirical approach. An equation that was calibrated for a geographic area could be very useful and reasonably accurate. Indiscriminant use, however, could conceal problem situations that deserve closer attention.

Heat Loss

Elevated water temperature may decrease once the heat input disappears. At McGill Creek, a sensor was located 130 m below the clearing. After the Creek flowed under the dense canopy cover for this distance, the peak temperature listed above and shown in figure 2 decreased by 1 or 1.5°C. Heat was lost to the streambed or to the air, but it is not known if this rate of heat loss continued or if the water returned to its original temperature at some downstream point. Many streams lose heat and return to their elevation-, flow-, and groundwater-influenced base temperature within 1.6 km of their exit from a disturbed area (Schloss 1985).

Multiple Harvest Areas

Although one harvest may have only a small effect on stream temperature, multiple harvests within a few years might produce a "cumulative effect" on downstream temperature. For an Oregon watershed following clearcut harvesting, little shade recovery occurred within 5 years after stream banks were cut, but a linear and total recovery occurred during the subsequent 15 years (Beschta and Taylor 1988).

Although some stream temperature models have multicut, multiyear capability, the data requirements preclude their use on basins with miles of channels and numerous subbasins (USDA For. Serv. 1984). A tabular recovery analysis for basins could aid the harvest planning by explicitly incorporating shade recovery information (table 3). The table incorporates a 20-year vegetation growth cycle, and the procedure uses an index that varies from 1 (full effect) to 0 (no effect) to represent the loss of shading due to harvest if any canopy cover is removed from the riparian zone. After 20 years, the index returns to zero as stream shading recovers. In table 3, harvest E occurred near 1960, A occurred near 1965, and B and D occurred near 1970. The column labeled "Total" is the sum of the horizontal coefficients, but the value that should be considered to be a cumulative effect threshold is unknown. If the average riparian timber removal is 50 percent along the associated 300 m of channel and five harvests occurred within a 5-year period, a value of five in the "Total" column might represent 750 m of clearcut stream channel.

The incorporation of this technique during the harvest plan could provide a feedback system such that predicted increases in estimated stream temperatures would increasingly restrict the removal of shading vegetation. A monitoring plan that proceeded concurrently with the harvest would provide valuable information on temperature effects.

Table 3 - Shade recovery calendar for aiding the scheduling of timber harvests within a basin (after Beschta and Taylor 1988).

Harvest Year[1]	Harvest Event									
	A	B	C	D	E	F	G	H	I	Total
1960	1	-	-	-	1	-	-	-	-	2.0
65	1	1	-	1	.6	-	-	-	-	3.6
70	.6	1	-	1	.3	-	-	-	-	2.9
75	.3	.6	-	.6	0	1	-	-	-	2.5
80	0	.3	-	.3	-	1	1	-	-	2.6
85	-	0	1	0	-	.6	1	1	-	3.6
90	-	-	1	-	-	.3	.6	1	1	3.9
95	-	-	.6	-	-	0	.3	.6	1	2.5
2000	-	-	.3	-	-	-	0	.3	.6	1.2
05	-	-	0	-	-	-	-	0	.3	0.3
10	-	-	-	-	-	-	-	-	0	-

[1] Assign harvests to nearest 5-year date.

Conclusions

The exposed surface area model (Brown 1970) for predicting stream temperature may be a good choice for land managers because it requires a minimum of field data that are relatively simple to obtain. If a sufficient data base exists within a region or can be collected over time, an empirical model will simplify maximum temperature prediction associated with shade removal.

Field data from both a clearcut and a mature fir site were used. A predicted temperature change of 6.1°C compared well with an observed change of 5.4°C at a 380 m clearcut site. The prediction equation is sensitive to streamflow, a factor that is known to be difficult to measure with less than at least ±5 percent error. The 80 percent-shaded Teakettle site yielded a predicted increase of 1.4°C compared to an observed decrease of almost 1°C.

Results from the empirical model were 2°C lower than the observed water temperatures in the clearcut portion of McGill Creek and 2°C higher than the undisturbed area (Schloss 1985). The regression model's prediction nearly matched the fir site's water temperature of 12°C. If data were collected for several areas of California and used to calibrate a model with similar structure, greater consistency might be achieved. This type of model has the advantage of requiring no additional field data once the coefficients are estimated.

A shade recovery accounting system was proposed for use during the National Forest System harvest planning process. The system assumes channel cover is regained in 20 years and offers the planner a way to avoid overscheduling harvests in a basin and producing an adverse cumulative temperature effect.

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COARSE WOODY DEBRIS ECOLOGY IN A SECOND-GROWTH SEQUOIA SEMPERVIRENS FOREST STREAM[1]

Matthew D. O'Connor and Robert R. Ziemer[2]

Abstract: Coarse woody debris (CWD) contributes to high quality habitat for anadromous fish. CWD volume, species, and input mechanisms was inventoried in North Fork Caspar Creek to assess rates of accumulation and dominant sources of CWD in a 100-year-old second-growth redwood (Sequoia sempervirens) *forest. CWD accumulation in the active stream channel and in pools was studied to identify linkages between the forest and fish habitat. CWD accumulates more slowly in the active stream channel than on the surrounding forest floor. Of CWD in the active channel, 59 percent is associated with pools, and 26 percent is in debris jams. CWD associated with pools had greater mean length, diameter, and volume than CWD not associated with pools. The majority of CWD is Douglas-fir* (Pseudotsuga menziesii) *and grand fir* (Abies grandis). *CWD entered the stream primarily through bank erosion and windthrow. The estimated rate of accumulation of CWD in and near the stream was 5.3 m*^{3}. *Selective addition of CWD to stream channels to compensate for reduced inputs following timber harvest could maintain or enhance fish habitat.*

Coarse woody debris (CWD) greater than 10 cm diameter in streams contributes to high quality habitat for anadromous fish (Bisson and others 1987). Management options for anadromous fish in north-coastal California could be expanded through analyses of CWD ecology.

The abundance of CWD in streams flowing through old-growth redwood (*S. sempervirens*) has been documented (Keller and others in press). Input processes, accumulation rates, and dynamics of CWD have been studied in the Pacific Northwest (Lienkaemper and Swanson 1987).

This paper reports a study that estimated CWD abundance and its relative proportions in the riparian zone and in the channel of a stream following through second-growth *S. sempervirens*. Data for CWD input mechanisms, tree species, and numbers of CWD pieces were also collected.

Study Area

The 508-ha North Fork Caspar Creek (Caspar Creek) watershed, in the Jackson Demonstration State Forest, Mendocino County, California (fig. 1), was clearcut and burned 90 to 100 years ago. A splash dam was constructed in the upper one-third of the watershed, and was periodically breached to transport cut logs. Native runs of steelhead trout (*Salmo gardnerii gardnerii*) and coho salmon (*Oncorhynchus kisutch*) utilize the full length of Caspar Creek below the splash dam site.

The Caspar Creek watershed is underlain by Franciscan graywacke sandstone. Slopes are steep and mantled with deep soils in which large rotational landslides are common. The stream is in an inner gorge 10 to 20 m deep. Bedrock is exposed locally. Alluvial terraces, 1 to 2 m above the channel, form the 15- to 25-m-wide valley floor. The channel gradient averages 2.0 percent in the study reach.

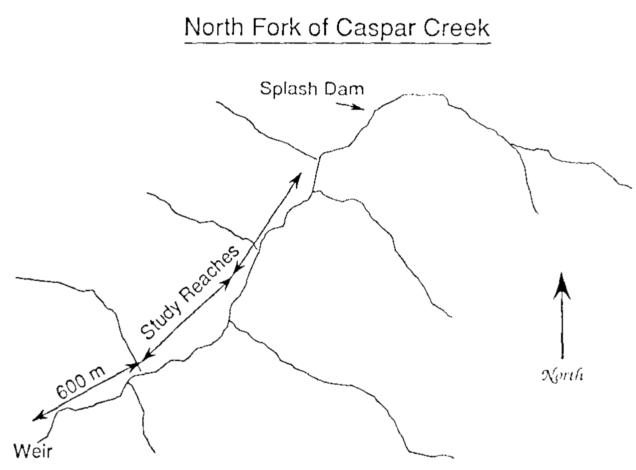

Figure 1 — Caspar Creek Experimental Watershed

[1] Presented at the California Riparian Systems Conference, September 22-24, 1988; Davis, California.

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At the lower end of the study reach, the mean annual flood occurs between November and May at about 0.5 m flow depth, with a discharge of about 3.1 m^3 flow depth of 1 m (discharge 8.5 m^3/sec) would be expected once every 25 years at this location in the watershed. During late summer, the minimum streamflow averages about 0.001 m^3/s.

Methods

CWD Volume

The volume of CWD was estimated in three zones defined as follows:

Classification	*Description*
Effective zone	Within the active channel, up to 0.5 m above the water surface or the channel bed.
Potential zone	Suspended 0.5 m or more above the channel, extending laterally 1 m beyond the vertical channel bank.
Valley floor	Stream channel and terraces; lateral boundary is steep slope

These classifications are hierarchical. The effective zone lies below, is smaller than, and exclusive of the potential zone; the valley floor includes both the effective and potential zones (fig. 2).

Our definitions of effective and potential CWD are similar to those used by Swanson and others (1984) and partition CWD into present and future supplies. Functionally, effective zone CWD was that in contact with the water column during the mean annual flood. Potential zone CWD was that transferable to the effective zone by breakage or bank erosion.

CWD volume in the potential and effective zones was estimated by measuring lengths and end diameters of CWD pieces with a stadia rod and log calipers in random sample plots. The 1850-m study reach was divided into 185 plots 10 m long and three 600-m sub-reaches (figs. 1 and 2a). To ensure even distribution of sampling, 20 plots were selected from each sub-reach. Portions of CWD pieces outside the plot were ignored. Plot size varied with channel width; the area within each plot was estimated as the product of length (10 m) and the mean of 3 active channel width measurements. CWD volume was calculated as for a cylinder. Ratio estimators (Cochran 1977) were used to estimate total CWD volume in each zone.

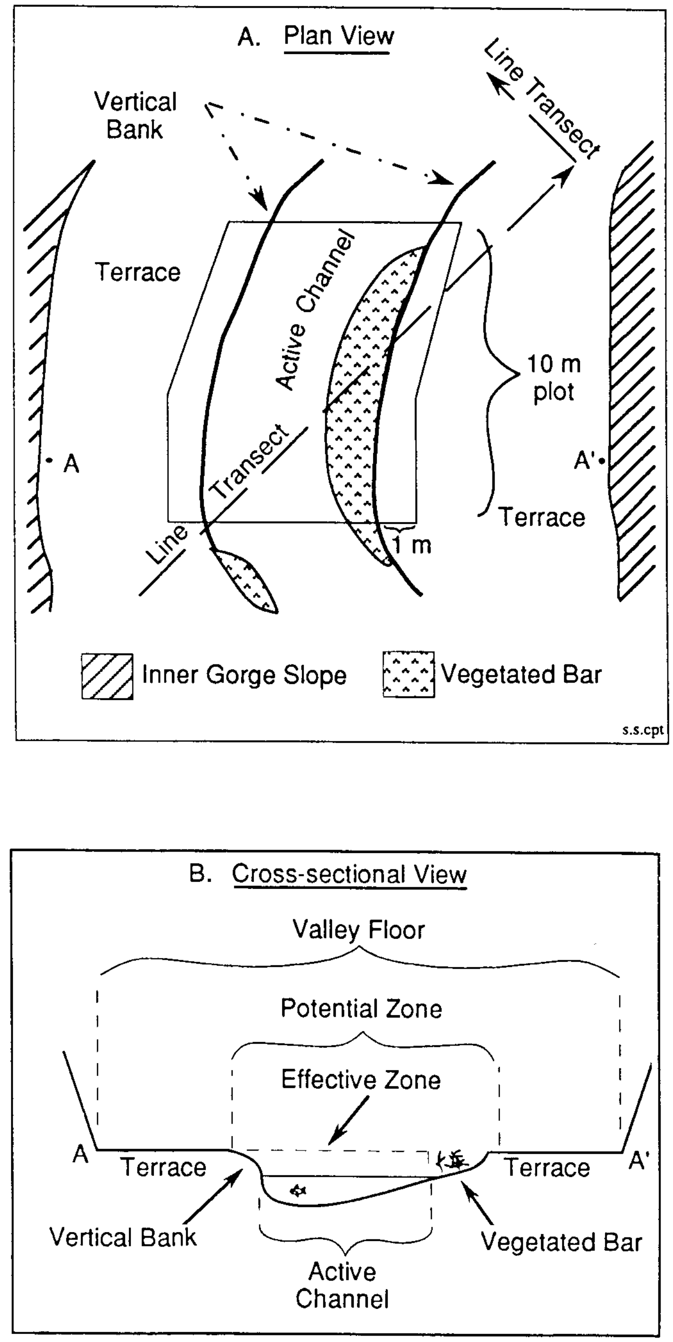

Figure 2 – Plan and cross-section views of sampling zones in Caspar Creek, California. (a) Plan View: Relationship of geomorphic features to sample plot and line-transect. Lateral plot boundary parallels streambank at a distance of 1 m. (b) Effective zone width determined by active channel. Effective zone contained in potential zone; potential zone contained in valley floor.

The line transect technique (Van Wagner 1968) was used to estimate quantities of CWD on the valley floor. Random transects extended 50 m diagonally across the valley floor in a "zig-zag" pattern (fig. 2a,b). CWD volume per unit area of valley floor was estimated as:

$$V = ((\pi)^2 / 8L * \sum (d)^2$$

where L was the transect length (50 m) and d was diameter of CWD in meters.

Base-flow fish habitat was inventoried by Decker and Lisle (work ongoing, unpublished data for June 1987) using the habitat classification scheme of Bisson and others (1982) modified for use in northern California. Pools were classified according to the cause of formation, e.g., scour around a rootwad, deflection by bedrock outcrop. CWD that affected inventoried pools ("associated" became a subset of effective zone CWD. CWD that created a scour zone that aided pool formation, or was in a pool, or appeared to be in the water column above a pool during the average annual flood was classified as "pool-associated."

CWD in the effective zone was also classified according to whether it was part of a woody debris jam, defined as aggregations of at least three CWD pieces. Whether CWD pieces appeared to have been mobilized by streamflows was also noted.

CWD Species

Tree species from which CWD originated was recorded. Because of the difficulty of distinguishing *Abies grandis* from *Pseudotsuga menziesii,* these were lumped together as "fir." *S. sempervirens* was the only other species found in substantial quantity. A third category of "other" species included known species with minor representation and CWD for which the species could not be determined.

CWD Sources

Six sources of CWD were identified: (1) bank erosion, (2) windthrow, (3) logging debris, (4) wind fragmentation, (5) landslide, or (6) unknown. Bank erosion included rootwads or trees with attached rootwads which collapsed from the banks into the channel. Windthrow was defined as tree falls with attached rootwads originating from the valley floor and adjacent slopes. (Tree falls attributed to bank erosion, simply because of the trees' proximity to the stream, might have been caused by wind.) Logging debris included pieces with cut ends, burn scars, or milled edges, such as bridge parts and railroad ties. Wind fragmentation included pieces broken from a snag. Landslide CWD was defined as tree falls with rootwads in landslide deposits. The unknown category was used when no input mechanism could be identified.

Results

CWD Volume and Density

We estimate that 1180 m^3 of CWD lies on the valley floor in the 1850-m study reach (table 1), 37 percent (437 m3) of which is in either the potential zone (25 percent) or the effective zone (12 percent). Seven percent of CWD in the study area was pool-associated.

Table 1- Coarse woody debris volume and density at Caspar Creek, California.

	Total +S.E. (m^3)	Area (ha)	Density (m^3/ha)
Valley Floor	1180 ± 182	3.03	389
Potential + Effective	437 ± 41	1.29	339
Potential	294 ± 34	1.29	228
Effective	143 ± 16	0.82	174
Pool-Associated	84 ± 14		
Debris Jams			
Effective	57 ± 20		
Pool-Associated	38 ± 8		

CWD accumulates in the combined potential and effective zones at the same rate that it accumulates on the valley floor. CWD density on the valley floor was 389 m^3/ha, and in the combined potential and effective zones, 339 m^3/ha (table 1). The 95 percent confidence interval of the difference includes 0 (50 + 133 m^3/ha).

CWD accumulates in the effective zone at a slower rate than on the valley floor. CWD density in the effective zone was 174 m^3/ha. The 95 percent confidence interval of the difference in density between the effective zone and the valley floor did not include 0 (215 + 124 m^3/ha). In the effective zone, 59 percent of the CWD volume was pool-associated.

CWD Species

Differences in species composition were statistically significant (95 percent confidence level) for the combined data from the potential and effective zones, where fir was more abundant than redwood, and redwood was more abundant than other CWD. Despite limited statistical evidence, we are confident that fir-derived CWD is about two times more abundant than redwood—both volume and number of pieces—and that other species are insignificant for practical purposes (fig. 3). We attribute the lack of statistical evidence to the estimators used, the high frequency of null data in sample plots, and the inability to identify species of rotted pieces.

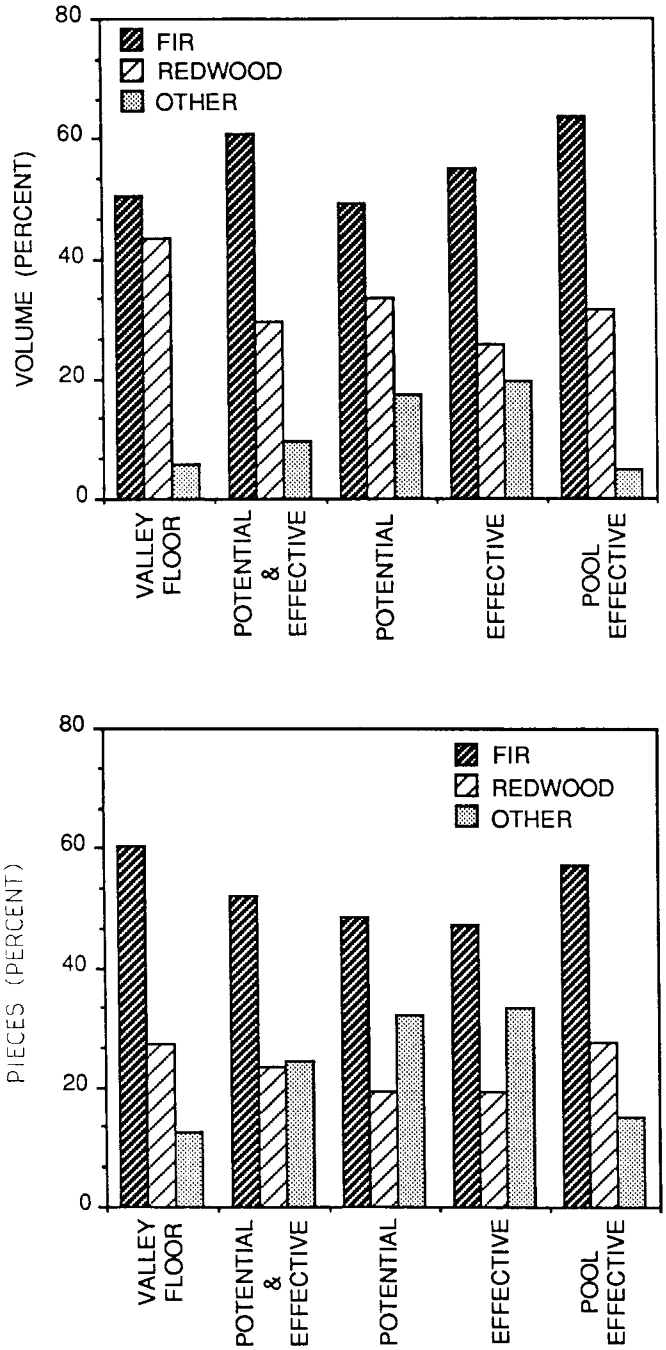

Figure 3 - Coarse woody debris species as percentage of sample volume (a) and pieces (b) at Caspar Creek, California.

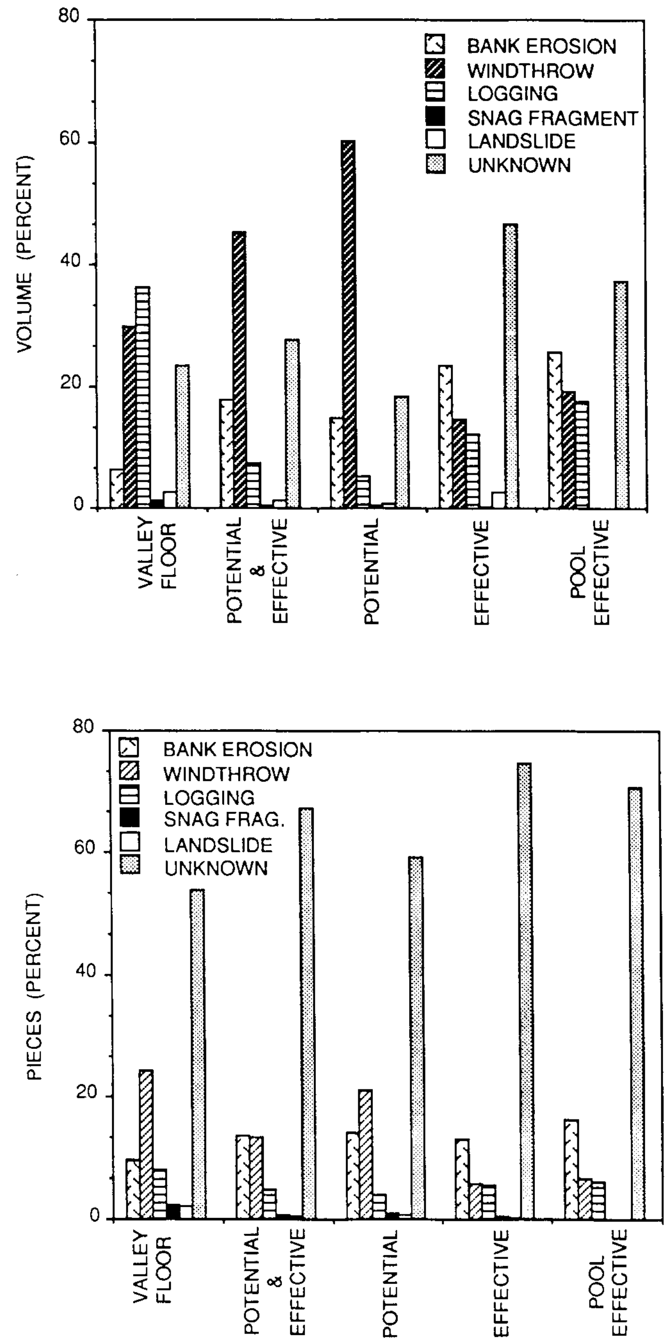

Figure 4 - Coarse woody debris as a percentage of sample volume (a) and pieces (b) at Caspar Creek, California.

CWD Sources

The high proportion of CWD volume and number of pieces classified as "unknown" (fig. 4) were due to the long time since some of the trees fell, and the tendency of fallen trees to be fragmented and transported by the stream. Because of this tendency, differences between sources were not statistically significant.

Despite these classification problems, most CWD volume in the potential zone (60 percent) was windthrown fir. Many fallen trees uprooted from the lower slopes of the inner gorge criss-crossed the valley floor and were suspended above the stream channel.

The high percentage of CWD from logging found on the valley floor (36 percent of volume), came from a few large diameter redwood pieces. Only 8 percent of the pieces on the valley floor were logging remnants.

In the effective zone and its pool-associated component, windthrow and logging contributed approximately equal proportions of CWD. Bank erosion contributed about as many pieces of CWD as windthrow and logging combined.

Debris jams, which develop after CWD input, are of equal or greater importance than direct input processes (windthrow and bank erosion) as pool-associated debris. Debris jams accounted for 27 percent of the volume and 56 percent of the pieces of pool-associated CWD.

Diameter and length affected the likelihood of CWD being associated with pools and being transported by the stream. Mean length, mean diameter, and mean volume of CWD was significantly greater, at the 95 percent level of confidence, when associated with pools than when it was not. The mean volume of CWD associated with pools was 0.17 m^3 compared with 0.07 m^3 for CWD not associated with pools.

Mobile CWD had significantly smaller mean values of length, diameter, and volume than non-mobile CWD. The mean volume of mobile CWD was 0.06 m^3, compared with 0.16 m^3 for non-mobile CWD.

Discussion And Conclusions

CWD Density

The mean density of CWD in Caspar Creek, 339 m^3/ha (combined potential and effective zones), is less than that for many streams in old-growth redwood forest. Mean CWD for 12 sample reaches in Redwood National Park were reported by Keller and others (in press) to be 1590 m^3/ha. The densities ranged from 240 m^3/ha to 4500 m^3/ha. The CWD density we measured in Caspar Creek is comparable to that for *P. menziesii* old-growth forest streams in the Klamath Mountains–mean of 282 m^3/ha and range from 10 m^3/ha to 1200 m^3/ha for 11 sample reaches (Harmon and others 1986).

CWD Ecology

The distribution of CWD can be visualized as follows: of each 10 m^3 of CWD within the limits of the valley floor, about 2.5 m^3 are in the potential zone, 1.2 m^3 are in the effective zone, and 6.3 m^3 are lying on that portion of the valley floor outside of these two zones. Within the effective zone, 0.7 m^3 of CWD are associated with pools. We attribute this distribution in large part to the dimensions of the stream channel and the mechanics of tree fall. Because the channel lies within vertical streambanks 1 to 2 m high, many trees fall across the channel and remain suspended above it. Trees falling from greater horizontal distances are less likely to be suspended above the channel because their upper trunks shatter or are not supported by the opposite bank. Tree trunks broken into lengths less than or equal to the width of the channel (4 to 5 m) are more likely to enter the effective zone. Trees falling parallel to the channel have a better chance of entering the effective zone because they do not have support points on both banks. Trees succumbing to bank erosion are likely to enter the effective zone.

CWD entering the effective zone tends to become pool-associated in these situations: when the piece is massive and is situated such that a pool is formed by scour, if the piece becomes lodged in a debris jam which in turn causes bed-scour and pool formation, or if the piece happens to fall directly into an existing pool. Circumstances in which CWD is associated with pools are limited due to the precise placement required to form pools.

The predominance of CWD from *A. grandis* and *P. menziesii* reflects successional dynamics of the redwood forest ecosystem. Windthrow, disease, and competition have thinned these species from this 100-year-old second-growth forest. The "climax" species, *S. sempervirens,* is less common as CWD and is particularly uncommon as windthrow.

The dominant CWD sources (input mechanisms) are windthrow and bank erosion. Windthrow is the dominant source for the potential zone, much of which originates from adjacent slopes. This is consistent with data for Oregon streams, where 90 percent of CWD originated within 30 m of the stream (McDade 1987). Bank erosion is the most common source of effective zone CWD. Logging debris, mostly in the form of redwood rootwads, is a valuable and stable structural element of the channel, but is a limited resource at Caspar Creek.

Debris jams are major components of the pool-associated class of CWD. Debris jams associated with pools typically are located at channel constrictions, sharp bends, or obstructions (e.g., redwood stumps, boulders). Much CWD in debris jams is small enough to be floated during floods.

CWD in the effective zone–which is likely to contribute to fish habitat–originates from both far and near the channel and from both the old-growth forest and its successor. Both stable and mobile pieces are associated with pools, which are thought to be the most valuable habitat. Considering the complexity of CWD ecology, one basis for managing CWD is maintaining or increasing the abundance of CWD and the diversity of sources, sizes, and positions.

Rate of CWD Accumulation

Logging techniques at the turn of the century left little debris in the stream channel at Caspar Creek. Subtracting logging debris from CWD volume, and dividing by 60 years (the first 30 years of regrowth is assumed to have contributed little CWD), yields estimates of annual accumulation rates as follows:

Potential & Effective Combined	5.3 m^3/ha/yr
Potential	3.5 m^3/ha/yr
Effective	2.7 m^3/ha/yr
Pool-Associated	1.6 m^3/ha/yr

For a 100 m reach 5 m wide, the addition each year of one log 4 m long and 0.3 m in diameter would be equivalent to the accumulation rate for the potential and effective zones combined. These estimates could guide efforts to deliberately add CWD to similar streams that are deficient in fish habitat. Professional judgement would be required to determine the appropriate methods and locations needing additional CWD. During logging, unmerchantable logs might be deliberately placed in desired locations. Such additions could be distributed among potential and effective zones to provide an even supply of CWD to the stream over time. Alternatively, if streamside bufferstrips do not preserve an adequate natural source area for CWD, deliberate additions of CWD to the stream might be made in proportion to the expected contribution lost from the source area over the duration of the cutting cycle (e.g., 50 years). Silvicultural methods could also be developed to optimize the supply of natural CWD (Rainville and others 1985).

Bilby (1984) and Swanson and others (1984) suggested that massive CWD is more stable and better suited to provide desired fish habitat. We found, however, that CWD in debris jams often contributed to pool habitat, indicating that mobile (smaller) CWD is also beneficial.

Acknowledgments

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PACIFIC YEW: A FACULTATIVE RIPARIAN CONIFER WITH AN UNCERTAIN FUTURE[1]

Stanley Scher and Bert Schwarzschild [2]

Abstract: Increasing demands for Pacific yew bark, a source of an anticancer agent, have generated interest in defining the yew resource and in exploring strategies to conserve this species. The distribution, riparian requirements and ecosystem functions of yew populations in coastal and inland forests of northern California are outlined and alternative approaches to conserving this resource are identified. Efforts to obtain additional information on genetic diversity of yew populations and to insure careful management of the species are essential for the protection of this resource.

Yews represent a genetic resource at risk. At least three species–the English yew (*T. baccata*), Florida yew (*Taxus floridana),* and Pacific yew (*T. brevifolia*)–have evolved an unique assemblage of characteristics that confer upon these trees and shrubs unprecedented vulnerability. The English yew, native to Europe, north Africa and parts of the Middle East, was valued for centuries as a strategic resource. The Florida yew, restricted to bluffs and ravines on the eastern bank of the Apalachicola River in northern Florida (Sargent 1961), is classified as a rare and endangered conifer (Barnes 1983). Now the survival of Pacific yew populations in western states may be threatened by the discovery that yew bark is an important source of an antitumor drug.

The yew has the longest tradition as a protected tree. In the 15th century, English yew populations were severely depleted; their fine-grained elastic wood was valued for archery bows. Laws mandating protection of this species date from 1423, (Szafer, W. 1965, cited in Bialobok, 1975). In many parts of central Europe and the Transcaucasus, the English yew remains a rare and vanishing conifer (Karczmarczuk 1986; Safarov 1986).

New demands for the yew have recently emerged. Although it has not been listed as an endangered species, environmentalists have expressed concern that populations of Pacific yew in California and other Western states may also suffer depletion (Booth 1987). Yew bark is currently the chief source of taxol–a diterpenoid antitumor agent (Suffness; Douros 1979; Wani and others 1971). The National Cancer Institute in cooperation with the USDA Forest Service have contracted for the selective harvesting of the Pacific yew in California, Oregon and Washington. In 1988, 60,000 pounds of bark were harvested from 12,000 trees in western Oregon; another harvest of the same magnitude is scheduled for 1989 (C. Bolsinger, personal communication).

This paper briefly outlines the current status of the Pacific yew as a facultative component of riparian forest communities in northern California and other Western states, and addresses questions that bear on possible strategies to conserve the yew resource without intervening with ongoing cancer research.

Pacific Yew as a Riparian Resource

In the Coast Range, on the inland forests of the Klamath and Cascade ranges, and the northern Sierra Nevada of California, the Pacific yew grows as scattered individuals and small groups of trees on or near stream banks and river margins, canyon bottoms and wet shaded ravines, and other moist habitats (Crawford and Johnson 1985; Griffin and Critchfield 1972; Jimerson 1988). Forest inventory data show that this tree is distributed from 100m in the coastal redwood to 1300m in the mixed conifer forests of the central and northern Sierra Nevada. At higher elevations, the Pacific yew may occupy less moist sites on north and east slopes. In the northern part of its range, this facultative riparian species utilizes a variety of moist habitats; however, as it approaches the southern limit of its range, the yew population tends to be more restricted and more obligate in meeting its riparian requirements (Jimerson 1988; F. Johnson, personal communication).

Yews are slow-growing, long-lived, and shade tolerant (Minore 1979). In northwestern California, they form an understory layer in association with coast redwood, Douglas-fir, tanoak, bigleaf maple, vine maple, other hardwoods, and conifers (Jimerson 1988). The dense yew subcanopy provides shading; thus, it contributes to maintaining temperature control along tributaries of small streams for juvenile salmon and steelhead (Jimerson 1988). Yews provide cover and serve as an important food source for browsing deer and other ungulates (Pierce 1984; Pierce and Peek 1984). Several

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[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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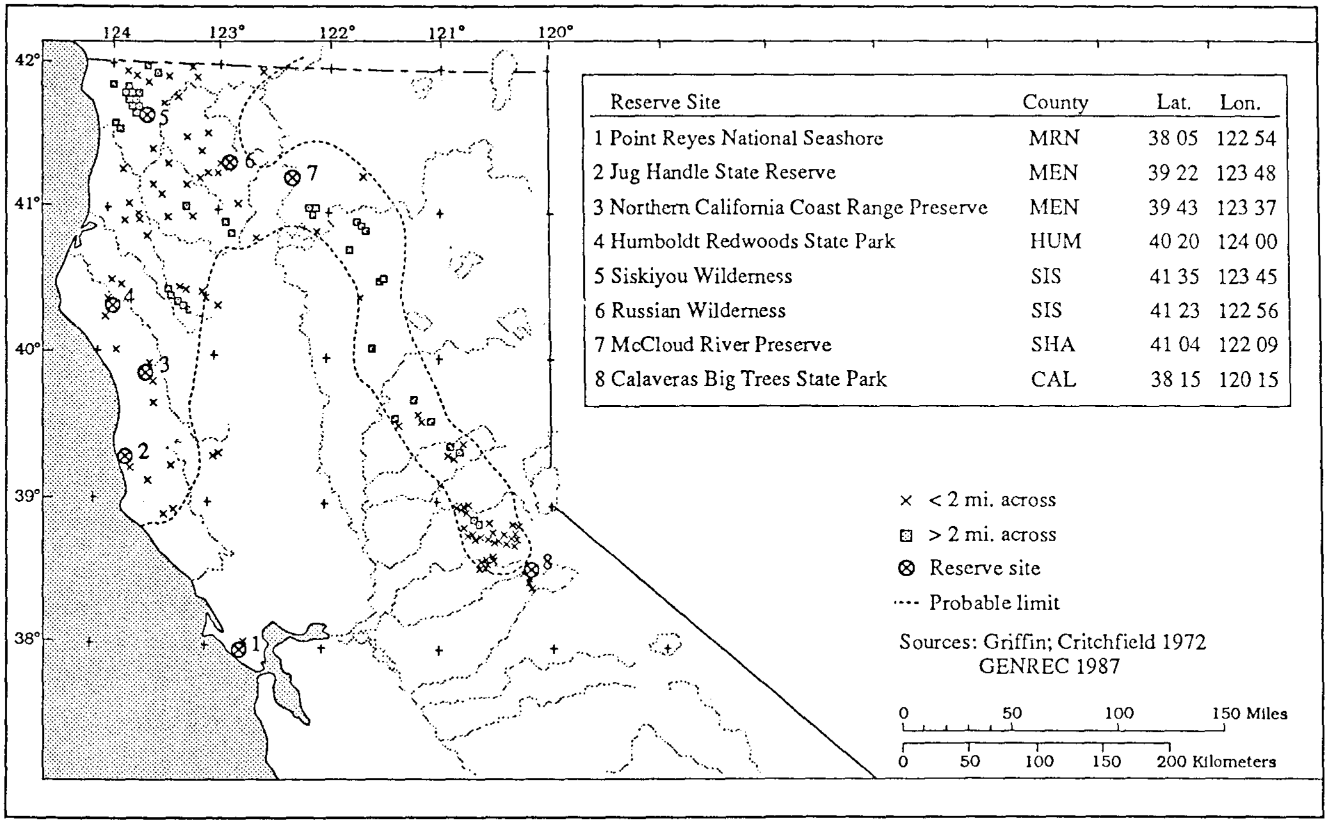

Figure 1 – Distribution of Pacific Yew (*Taxes brevifolia* Nutt.) and location of designated reserve sites containing *T. brevolia* in northern California.

groups of birds–thrushes, blackbirds, waxwings and nuthatches–are reported to feed on the fleshy aril and help to disseminate seeds of the yew (Bartkowiak 1975; Sudworth 1967).

The Need for Further Studies

Until recently, the Pacific yew was not considered commercially important; accordingly, virtually no information is available on yew population structure, or how yew trees produce taxol. Many questions need to be addressed, such as: How does the annual growth rate compare with the cutting (harvesting) rate? Studies are needed to provide baseline data on the amount and patterns of genetic variation in the species. Three cultivars of Pacific yew have been reported–Erecta, Nana and Nuttallii (Taylor and Taylor 1982). The extensive range of this species–from northern California to southern Alaska–suggests that geographic races have evolved. A range-wide study of isozymes and other measures of biodiversity would provide additional data on genetic variation. This information is essential for silvicultural management, for studies of variation in taxol, and for conservation of the species.

Conserving the Resource

Gene resources can be preserved *in situ*–in reserves, or *ex situ*–in seed banks or arboreta (Ledig 1986). Five major natural reserve programs have been established in California. Among the most ambitious are the University of California Natural Reserve System and the USDA Forest Service Research Natural Area program (Ford and Norris 1988). Although Pacific yew is not identified as a target element in established reserves, several contain significant populations of this species (GENREC 1987; Hood 1975-1980) (fig. 1).

In outlining the scope of gene conservation for forest trees, Ledig (1988) has underscored the need to establish larger areas–genetic resource management units

(GRMUs)–to protect coevolved gene complexes. He argues that existing reserves are inadequate; their small size increases the probability of extinction. GRMUs differ from strict reserves; logging can continue, but other forms of management promote genetic conservation. Ledig urges conservationists to evaluate existing reserve natural areas and persuade Federal and State land management agencies to establish GRMUs to fill the gaps. Yew populations need to be preserved in GRMUs now, to assure their future availability.

Identifying alternative strategies for producing taxol represents another approach to conserving the Pacific yew. Several methods are being considered: *in vitro* cell and tissue culture; stimulation of biosynthesis through precursor feeding; and isolation of genes for cloning and expression of taxol. Evidence for cell culture of Pacific yew has only recently been reported from two laboratories (Blume 1989). To date, none of the immediate precursors of taxol have been identified. We know of no studies on the isolation of genes controlling taxol biosynthesis and their expression.

Future use of forest genetic resources will be determined by current management strategies and practices. Failure to respond to this challenge could significantly reduce or eliminate the genetic diversity upon which natural selection acts (California Gene Resources Program 1982). One of the victims of that neglect could be the Pacific yew.

Summary and Recommendations

The current status of the Pacific yew (*Taxus brevifolia* Nutt.) as a facultative riparian component of the subcanopy in mixed conifer forests of northern California and other Western States was briefly outlined. Current demands for yew bark as a source of taxol–a diterpenoid antitumor agent–call attention to the need for additional information on this valuable resource. If clinical research trials with taxol are successful, then pressures to increase the harvesting rate of Pacific yew can be expected. Developing *in vitro* technologies for producing taxol represents one approach to conserving Pacific yew populations. In addition, range-wide studies of the genetic architecture are essential to provide baseline data for silvicultural management, for variation in taxol, and for conservation of the species. Efforts to identify and preserve a diversity of yew alleles and co-evolved gene complexes must be expanded. Clearly, Pacific yew is in a transitional phase between non-commercial status and commercial exploitation. Careful management of this species will be required to protect this valuable resource.

Conclusions

The discovery of taxol in yew bark poses a threat to yew populations and a challenge for humankind. We should expect to face such realities in the future as we identify and utilize genetic resources of other plant species. Strategies to both protect and manage the yew resource must be developed quickly if we are to preserve this valuable riparian species.

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RIPARIAN SYSTEMS AND FOREST MANAGEMENT—CHANGES IN HARVESTING TECHNIQUES AND THEIR EFFECTS ON DECOMPOSED GRANITIC SOILS[1]

John W. Bramhall[2]

Abstract: In the 1950s, timber on steep granitic terrain in Trinity County, California was harvested by using the logging techniques of the time. After Trinity Dam was built in the 1960s, it became evident these techniques were not suited to quality riparian habitat and healthy anadromous fisheries. Since adoption of the Z'berg-Nejedly Forest Practice Act in 1973, efforts have been expended to repair damage that has been done to riparian vegetation, and find forest practices compatible with granitic soils.

Early logging practices having a major effect on riparian ecosystems included skidding and hauling logs down the creekbeds, harvesting all merchantable trees in the riparian zone, and leaving slash and debris in the creekbeds. There are others, but these are the most identifiable.

California passed legislation to regulate forest practices on private land in 1945. A State Board of Forestry was also established at that time. California Forest Practice Rules, created from the legislation, were approved for administration in 1947 (Arvola 1976). Initially there were four foresters assigned to the program as the inspecting cadre. As expected, a few things fell through the cracks. Unfortunately no mention was made of riparian or stream protection zones in these early forest practice rules. By the mid-1960's rules were adopted to protect streams from overzealous construction, substantial diversion, excessive log jams or debris accumulation, and pollution deleterious to fish, plants, or bird life. But pesticides were not named specifically.

Contributing to the problem were the remaining attitudes of the earlier timber landowners. One example was the old "cut and get out" philosophy of cutting all of the possible timber in a tract and then moving on to new parcels in other states. Another attitude was exemplified in the belief that a piece of ground would recover soon after it is cut over if it were just left alone. This attitude was left over from operators who were familiar with timber operations in the East. There, where precipitation is plentiful, a piece of land will begin to come back to forest within 5 years if left undisturbed. here, in the arid West, this is not true as witnessed by the many brushfields scattered amongst our existing timberstands.

Effects of Early Logging

Early logging practices were not as regulated as today. Although California's forest practice regulations have always been the most stringent in the nation (Arvola 1976), they have evolved over the years. An example of the evolutionary process is contained in [paragraph 914(c) Logging Practices-Tractor Yarding] in the 1953 edition of the California Forest Practice Rules. Paragraph 914(c), titled "Logging Practices-Tractor Yarding," states in part, "Tractor roads shall be so constructed and left after logging that water flow thereon shall not contribute to undue or excessive erosion of the soils by gullying. Water breaks shall be installed at intervals of not more than three hundred (300) feet or at each natural water course where such courses are less than three hundred (300) feet, on all tractor roads having a gradient greater than ten percent; such water breaks are to be installed immediately following conclusion of use of tractor roads for logging and prior to removal of equipment (State of California 1953)." No mention is made of keeping equipment out of creekbeds. By 1988, the topic of waterbreaks has its own chapter-(Paragraph #934.60), and takes up more than two pages of the California Administrative Code (State of California 1988).

Silvicultural practices have evolved in a similar way. Earlier, there was concern about the adequate number of healthy seed trees left to restock the stand (State of California 1953). By 1988 Silvicultural Methods are covered in a separate article (Article #3), spanning ten pages (State of California 1988). No mention is made of clearcutting in the early rules. In 1988, clearcutting is discussed in great detail, including size, shape, width of buffer strips, and successive cutting within the buffers (State of California 1988).

Property taxes have also evolved over the years. Earlier, the property tax was levied on the assessed value of the land and the value of the timber. Once a tract of timber had been logged and 70 percent of the volume had been removed, the tract was taxed as

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"cutover timberland" for the next 40 years (State of California 1964).

This method of taxation tended to determine the selected silvicultural system, rather than have that decision based on solid silvicultural principles. In 1977, the State of California adopted a yield tax on forest land (State of California 1987) which taxes the value of the timber yield. Payment is made only at the time of harvest. Yield taxes separate the value of the land from the value of the timber. Land is taxed annually under the property tax while the tax on the timber value is deferred until harvest (Society of American Foresters 1984).

Recent Forest Practice Legislation

The Z'berg-Nejedly Forest Practice Act of 1973 and its amendments, are the most significant pieces of legislation affecting California's forest resources to date. The riparian resources, considered an integral part of the forest, are also included. In October 1983, new lake and watercourse classification and protection rules took effect. The new rules involved a major change in the procedures for classifying and protecting the waters of the State. Provisions of these rules include clear identification of watercourse and lake protection zones. The width of the protection zones varies with the stream classification and slope class of the adjacent land. There are also rules governing the amount of overstory and understory vegetation that must be left within the protection zone after timber operations (State of California 1983). Although water quality is the primary beneficiary of the watercourse and lake protection rules, the riparian ecosystem is also given major protection (State of California 1988).

The rules dealing with erosion control, logging roads and landings, and silvicultural methods, all indirectly enhance the riparian ecosystem. Erosion control serves to keep sediment out of streams and lakes, in addition to keeping soil on the hillside where it belongs. Roads and landings are to be located so that they give adequate protection to water quality and fish and wildlife habitat. Silvicultural methods limit the size of clearcuts and set standards for the use of shelterwood, seed tree, and selection systems; they therefore enhance the riparian ecosystem. These methods help provide or achieve built-in checks for proper forest land management in the form of erosion control, water infiltration enhancement, and maintenance of adjacent non-riparian habitat.

Effects on Granitic Soils

Back in the forties and fifties, logging practices previously described were the same on the granitic soils as those on all other soils. No thought was given to the impact logging operations might have on the granitics. It had not been discovered that granitics react differently to disturbance than do most other soils. The granitic soils are highly erosive. Once they are disturbed, they are extremely difficult to stabilize. Disturbing the stream channel and the adjacent vegetation with equipment for any purpose can cause damage to the riparian zone. This kind of damage in the granitics can be almost impossible to repair.

In 1976, the Soil Conservation Service became involved in an emergency erosion and sediment control program in the Grass Valley Creek Watershed (GVC) in Trinity County. GVC is a watershed having about 75 percent granitic soils. Most of the land in the watershed is commercial forest land. The physiography is characterized by steep mountain slopes and narrow valley floors. GVC was managed like other watersheds in the area, but it was different due to the granitic soils. The impact of disturbance started coming to the attention of local officials and residents after the Trinity Dam was constructed in 1963. The dam controlled the peak flows that had ravaged the Trinity River in the past. With the peak flows controlled, the annual spring floods no longer removed the sand deposits in the river. A very large sand bar developed below the mouth of Grass Valley Creek. The Trinity River Task Force, formed in 1973, determined by 1976 that the erosion occurring in GVC was the primary source of the sediment.

Part of the erosion control program in GVC has to deal with the riparian zone. The most effective practice appears to be the use of rock rip-rap on the outside bends. This practice is combined with willow plantings to make the project ecologically more sound. Treating streambanks is not the total solution to the problem. Erosion of the roads, landings, and skid trails also contributes to the deterioration of the ecological quality of the stream. Erosion control on these disturbed areas has consisted of the installation of waterbars at a closer than normal spacing; surfacing all permanent roads with rock; down drains and energy dissipaters installed at outlets of drainage ditches and culverts; stream crossings located to minimize disturbance of stream channels and stream flow; and seed, fertilizer, and mulch applied to all fill slopes.

Revision of the lake and watercourse classification and protection forest practice rules, adopted in 1983, has made it much easier to prevent additional degradation of the watercourse and lake protection zones (WLPZ).

This is true of all soil types, both granitics and others (State of California, 1983).

In April 1986, the California Department of Forestry and Fire Protection (CDF) formed a team to develop mitigation measures associated with timber harvesting on decomposed granitic soils in Grass Valley Creek. This team consisted of industrial and agency personnel which met for two days to examine soil erosion problems in decomposed granitic soils associated with timber harvesting. Also, the team was asked to upgrade mitigation measures which go beyond those already contained in the California Forest Practice rules for reducing, to the extent possible, soil erosion associated with timber harvesting on decomposed granitic soils. It drafted nine pages of mitigation measures. Those measures that affect the riparian zone, in this case identical to the WLPZ, are as follows:

1. No new roads will be constructed in the WLPZ unless such locations are explained and justified; and these locations will result in less hazard to the watercourse.

2. Fill slopes that contact stream flow will be armored with competent rock or alternative material that will provide equal or better protection; this shall include the approaches to removed temporary crossings.

3. Permanent culverts will not be used unless the road will be maintained at least annually. Culverts will be sized to a 50-year storm and oversized when streambed conditions indicate. Woody slash and debris must be cleared out for a minimum of 30 feet above the inlet to a culvert. Minimum permanent culvert size is 18 inches in diameter. Use a backhoe for culvert installations and removals except where other methods are justified. Decomposed granitic soils must be compacted in a moist condition when used as fill material around culverts.

4. Place logging slash from road right-of-way along the toe of all fill slopes.

5. Locate landings away from watercourses and outside the WLPZ unless otherwise explained, justified, and approved by the Director of CDF. Flag all watercourse protection zones (WPZ) and equipment exclusion zones (EEZ) prior to harvesting activities. WLPZ width shall be a minimum of 100 feet on all Class I and II watercourses.

6. Increase WPZ and EEZ widths (by at least 50 percent) as necessary to prevent erosion when the following conditions are present: (a) adjacent slopes exceed 50 percent; (b) areas of instability are present; (c) sparse vegetation exists or is projected either prior to or after the operation; (d) excessive natural or human-caused erosion is present; and (e) the watercourse or nearby downstream channels support fisheries.

8. Seed, straw, and fertilize all of the following areas of exposed soil within the WPZ: (a) road (unless rocked), landing, and skid trail running surfaces including sidecast; and (b) temporary crossing approaches. Use brow logs, where needed, to minimize sidecast within the WPZs.

The following recommended mitigation measures applying to permanent crossings follow:

1. Minimize excavation by using a backhoe when necessary.

2. Rip-rap inlets and/or install flared inlets.

3. Insofar as is practical, cross watercourses at right angles.

4. Install culverts at the natural channel grade, and control the direction discharge to the grade and center of the stream channel.

Temporary crossings had the following recommended mitigation measures:

1. Evaluate the use of metal pipe versus the use of a Humboldt crossing (made of wood) in the Timber Harvest Plan, and explain the reasons for the choice.

2. Cross drainages at right angles, minimize excavations and plan ahead for removal.

3. If a culvert is used, (a) use a backhoe, where practical, for installation and removal; (b) use culverts 18 inches or larger; and (c) use washed rock as fill material if available.

4. If a Humboldt crossing is used, (a) use sound logs just long enough to facilitate skidding or transporting logs, and maximize the number of logs to minimize the amount of fill; (b) when possible, install and remove logs with a front-end loader; (c) preattach chokers prior to installation, or provide for choker attachment upon removal when access restricts using a front-end loader; (d) minimize ground disturbance during installation and removal; (e) keep fill depth to a minimum; and (f) use brow logs on skid crossings where necessary.

In conclusion, great strides have been made in protection of riparian vegetation in the eighties. It would be naive to think that by winning a few battles, the war is won. Forty years ago many of the environmental blunders could be charged off to lack of awareness. This is not true any more. Today, all natural resource managers are aware of the impacts management operations have on the resource.

The challenge still before us is how to develop mitigation measures that protect the resource, and at the same time, are economically feasible for the operator.

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STABILIZATION OF LANDSLIDES FOR THE IMPROVEMENT OF AQUATIC HABITAT [1]

Michael J. Furniss[2]

Abstract: Chronic surface and mass erosion from recent landslides often prevents the recovery of productive stream habitats following initial mass failure events. Low-cost methods that can accelerate recovery and stabilization processes have been employed on numerous failed slopes in the Six Rivers National Forest in the northwest corner of California, with notable success. Two treatment methods, toe erosion control and revegetation have wide applicability in situations where funding is scarce.

There is often an important relationship between the condition of the soils in a watershed and the productivity of its riparian areas and streams. The maintenance and improvement of productive riparian systems is largely a consequence of good soil management. In the steep and erodible basins or northern coastal California that means maintaining the stability of slopes and the productivity of their soils.

The production of anadromous fish is being emphasized in the coastal streams and rivers on public lands managed by the Forest Service in northern California. In planning the enhancement of fish habitats, it is appropriate to evaluate watershed conditions and identify the factors that limit fish production.

On the North Coast of California, landslides are the most common habitat-degrading watershed problem. Large inputs of sediment from landslides often severely degrade or eliminate downstream fish habitat, and create unproductive islands in otherwise productive stream and riparian systems.

Large mass failure events are often followed by years of continued surface erosion and secondary mass failures, with each process worsening the other. Chronic sedimentation from subsequent erosion of failed slopes can prevent the natural recovery of downstream channels and riparian systems. It is suggested that such chronic, long-term sediment inputs are much more damaging, volume-for-volume, than catastrophic sediment inputs from mass failure events.

The willingness of land managers to attempt any landslide stabilization is often lacking, chiefly because the size of the features creates a perception of futility of anything but extremely expensive, large-scale engineering solutions. However, the cost of corrective measures is not always prohibitive, and high value fish and wildlife habitat can often be reclaimed without great expense or effort.

Landslide stabilization measures have been applied extensively to road and real estate development, and are well developed. Because of the urgency and high values at risk in these situations, very expensive measures are readily justified and usually include detailed evaluation and engineering designs. Vehicular access is usually feasible.

Where wildland water quality or fish habitat are the values at risk, the options for landslide stabilization are usually more limited because of: (1) a lack of perceived urgency and risk - no human life, access or improvements are threatened, (2) small amounts of available funding, often with higher priority projects competing, and (3) lack of vehicular access. Despite these limitations cost-beneficial options often do exist and may be an essential step in the reclamation of a stream reach or riparian system.

Some General Principles

There is a great variety of landslides that can occur in nature resulting from many combinations of causative factors acting on a great variety of landforms. No standard methods of control are universally applicable, but some generalizations about approaches can be made:

1. Corrective measures must be designed to act on the driving forces causing the slide or secondary erosion, or on the resisting forces tending to keep the hillslope stable. The specific factors causing the movement or risk of movement must be identified.
2. Corrective measures will either decrease the destabilizing forces or increase the resistance of the soil or slope to erosion.
3. The consequences of erosional impacts should be evaluated on the basis of the value of the resources threatened. A risk-value versus cost analysis should be done for each possible erosional process and contemplated corrective treatment.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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The risk is the probability or potential for a particular erosional or hydrologic event to occur. The value is the perceived worth of the resource or beneficial use that would be lost if the event occurred. The combination of risk and value defines the problem (Huffman and Bedrossain, 1979).

Corrective treatments will modify the risk and the attendant potential change in value. Comparing risk-value under various corrective treatments with the cost of corrective treatments facilitates rational decisions as to what to do, and forms a basis for assigning priorities to various processes and treatments.

4 Long-term, self-sustaining treatments that do not require maintenance are preferable to short-term treatments that depend on maintenance for success, particularly in poor access areas.

Types of corrective treatments that apply somewhat generally to landslides include:

1. Relocate the affected resource (road, stream).
2. Unload the head of the slope.
3. Load the toe of the slope.
4. Remove water from the slope.
5. Restrain or divert materials.
6. Protect landslide toe from stream erosion.
7. Control gully erosion.
8. Protect erodible surfaces.

These same general methods also apply to the prevention of landslides.

Detailed discussion of landslide processes and corrective measures can be found in several of the references (Bell 1964; Bradshaw and Chadwick 1980; Transportation Research Board 1978; California Department of Public works 1970; Federal Highway Administration 1978).

Site-specific measures are best developed when imagination and judgement are applied and the physical processes involved are understood.

Experience With Three Large Debris Slides On The Six Rivers National Forest

The Six Rivers National Forest has treated many landslides that impact anadromous fish habitat. Treatment of three very large slides with common erosional processes and similar resources at risk are described here.

The landslides are known as the Horse Linto, Rib, and Bigtoe Debris Slides. The Rib Debris Slide was initiated, and the Bigtoe and Horse Linto Debris Slides were greatly enlarged by the flood of 1964. The Horse Linto Debris Slide is within the Trinity River watershed and the Rib and Bigtoe Debris Slides are within the Smith River watershed.

Each slide had a mass failure volume of several million cubic yards, and each had ongoing severe surface erosion from the barren failure surfaces. The toe of each slide was rapidly being eroded by stream flows. This was a major driving force for ongoing and potential erosion from the slides.

Stream gravel sampling above and below each landslide showed substantial increases in both spawning gravel embeddedness and the proportion of fine sediment downstream of each slide, relative to gravels just upstream. Each slide was believed to be adversely affecting high-value habitat for king salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salrno gairdneri gairdneri*).

Each slide was treated in the early 1980's to control toe erosion, and was revegetated to control surface erosion. The objectives were to reduce sediment delivery to affected habitat, hasten the recovery of productive channel conditions, and accelerate the recovery of the soil and ecosystem productivity on the failed slopes.

The treatments are being monitored by annual visits for qualitative evaluation, annual photo points, evaluation of the embeddedness of downstream spawning gravels, and survey lines to track slope movement.

Control of Toe Erosion

Three different methods were used to control erosion at the toe of the slides that were being chronically destabilized by erosive river and stream flows: placement of a large prism of rock rip rap; excavation of a new channel with explosives with emplacement of tetrahedron-retard training fences, and; widening of the channel with heavy equipment.

On the Horse Linto Debris Slide, an energetic fifth-order stream (Horse Linto Creek) with a narrow channel and steep sideslopes was impinging on the toe of the slide at a sharp meander bend. The stream undercut the slide and promoted its instability, and an active gully system developed on the failure surface.

Placement of a prism of rock to protect the toe of the slide was judged to be the best treatment given the circumstances. The channel could not be relocated or modified to reduce the energy of the stream. Access to the toe by heavy equipment was easy to develop, and sufficient funds were available.

This treatment has been in place for five years and has been completely effective. There has been no toe erosion since the treatment. However, this treatment was quite expensive and this amount of funding is not usually available for such projects.

On the Rib Debris Slide, a smaller third-order stream (Idelwild Creek) was eroding the toe of the slide and causing a threat of additional large mass movements as well as ongoing sediment input to the stream from the erosion itself. Vehicular access to the toe of the slide was impractical.

A new channel was blasted using serial explosive charges to relocate the stream away from the toe of the slide, and a "retard" was constructed using a line of steel-rail tetrahedrons with cyclone fencing wired to their stream-side faces. This acted as a flow-obstructing energy dissipator, to retard flow velocity in the original channel and cause sediment deposition.

This treatment was completely effective. Seven years later, the retard caused extensive sediment deposition and debris accumulation preventing reoccupation of the original channel by the stream. The new channel carries all the flow well away from the toe of the slide. No visible toe erosion has occurred since the treatment.

On the Bigtoe Debris Slide, the upper Main Fork of the Smith River (sixth order) was impinging on the toe of the slide, causing ongoing piecemeal mass erosion and promoting surface erosion by removing backed-up sediments. An old rock source development widened the channel somewhat, but riparian vegetation was restricting the effective width of the channel.

The River flows are very energetic and funding was quite limited. Placement of rock rip rap would have been appropriate, but was too expensive.

Simple widening of the channel and removal of densely growing willows by bulldozer was employed, with emplacement of a small tetrahedron retard along part of the toe. The widened channel is about three times wider than the pre-treatment channel. This spreads high flows, reducing the level of peak flows and effectively reducing their energy. The retards consist of six-foot steel-rail tetrahedrons cabled together. These have accumulated floating woody debris that has increased their effectiveness in dissipating the erosive power of high flows.

After two years, it appears that this treatment is effective in substantially reducing but not eliminating toe erosion. The low cost and partial success of this treatment suggests that it is cost-effective where funding is insufficient for rip rap protection and access for heavy equipment exists or is inexpensive to develop.

Revegetation

Bare slide surfaces usually are inhospitable to plant growth due to very low nutrient capital and unstable surfaces. They tend to revegetate very slowly. Surface erosion of failure surfaces often removes enormous volumes of sediment before revegetation can stabilize the surfaces. We can accelerate the revegetation and stabilization process through planting and fertilization treatment.

Planting and fertilization of slide surfaces, if feasible, is almost always cost-effective. In some situations the newly-established vegetation will simply accompany sediment to the stream or slide toe in mass erosion events. However, the cost of planting and fertilizing is quite low and the long-term benefits are high. The risk of losing the treated areas to additional mass erosion is usually warranted.

Many bare and eroding slide surfaces have been planted and otherwise treated for revegetation on the Six Rivers National Forest. The results have been favorable in most places. Vegetative cover, root permeation of unstable soils, and ecosystem productivity have been increased many-fold through simple and inexpensive treatments.

While not all slide surfaces are accessible for planting and not all treatments result in successful revegetation, the cost of these treatments and their apparent long-term effectiveness suggests that this can be a highly cost-effective type of treatment. However it is rarely employed, probably because most landslides are believed to be completely untreatable, except with very large amounts of money.

We have learned several things from our revegetation efforts on many slide surfaces:

1. Inoculated nitrogen-fixing species such as alder (*Alnus* sp.), black locust (*Robinia pseudoacacia*), and sweet clover (*Melilotus sp.*) should be used because the soils on bare slide faces have not hosted plants before and are therefore very low in nitrogen. Survival rates were not related to nitrogen-fixing, but overall growth and vigor was. Non-nitrogen-fixing species that were planted have not thrived, while those that do fix nitrogen have grown much more quickly and are providing more stabilizing effect.

   Nitrogen-fixing species will tend to build up nutrient capital in the site, greatly hastening the development of topsoil, plant succession, and ecosystem recovery.

2. Fertilization alone sometimes produces adequate revegetation, with native or local species. In the humid North Coast, seeds of pioneer species are abundant and ubiquitous. If the surface is at least temporarily stable, seedlings will become established each

spring. However, unless there are sufficient nutrients, root growth is too slow to keep up with the summer drought period and seedlings dessicate and die. A single treatment of an N-P-K fertilizer has often proven adequate to achieve revegetation.

3. Cuttings, such as willow (*Salix*) and coyote brush (*Baccaris pilularis*) seem inexpensive, but often have a low survival rate. Unless labor is free, cuttings are not inexpensive when the overall success rate of plantings is considered. Our experience is that rooted stock is much more likely to survive and is worth the extra initial cost, if suitable species can be obtained.

4. Vegetation needs no maintenance and gets more effective with time. Deep-rooted woody species require several years to become well-established and effective. Managers must be willing to wait for several years to see distinct beneficial effects.

Conclusions

In some situations, inexpensive measures for the protection of landslide toes from erosive streamflow can be effective. Channel realignment with flow obstructions to maintain new configurations can be as effective as more costly solutions such as rip rap.

Revegetation of bare, eroding slide faces is a cost-effective treatment almost anywhere it is feasible, and should be more widely used.

Where revegetation is to be employed, nitrogen-fixing species should be included to accelerate soil building. Fertilization can be a useful treatment alone or in combination with introduced vegetation.

Landslides that degrade fish habitat and riparian resources can sometimes be stabilized with relatively inexpensive treatments. Land managers should be willing to consider low-cost treatments before concluding that landslides cannot be stabilized.

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SESSION E: COASTAL STREAMS-ECOLOGY AND RECOVERY

European settlement and occupation of California began on the coastal plains, and the earliest impacts of that invasion were concentrated in the riparian zones of the coastal streams. Subsequent urban and residential growth depended on the availability of increasingly far-flung sources of water. Many coastal streams were obliterated, undergrounded, or sucked dry. The balance between the capturing and stabilizing of sediment by vegetation, and the eroding power of freshets has been weighted in favor of erosion. Plant communities formerly well adapted to the hydrologic regime are no longer able to survive, introduced invaders are becoming established, and the animal communities are changing in response. The riparian systems of many coastal streams are unraveling.

This session observes the nature of those changes and considers what must be done to mend the balance and heal the streams.

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ALLUVIAL SCRUB VEGETATION IN COASTAL SOUTHERN CALIFORNIA[1]

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Abstract: Certain floodplain systems in southern California sustain a unique scrub vegetation rather than riparian woodlands due to a lack of perennial water. Alluvial scrub occurs on outwash fans and riverine deposits along the coastal side of major mountains of southern California. This vegetation type is adapted to severe floods and erosion, nutrient-poor substrates, and the presence of subsurface moisture. Ten major stands were sampled by line intercepts to determine their species composition, community structure, and successional status. Plant ecology and successional dynamics of these stands are compared. Loss of this unique floodplain vegetation type in the past, and current urban pressures from mining and flood control practices are discussed.

Scrub vegetation in California is extensive and diverse, occupying coastal and desert dunes, coastal valleys and foothills, interior mountains and desert flats. Holland (1986), in the State's Preliminary Descriptions of the Terrestrial Natural Communities of California, recognizes 73 different scrub types endemic to California. However, one scrub type not included in these descriptions is the unique and threatened vegetation called alluvial scrub. This vegetation is considered a unique habitat with a high priority for preservation by the California Natural Diversity Data Base (1987).

Alluvial scrub is an open vegetation adapted to the harsh conditions of the outwash environment. It grows on sandy, rocky alluvia deposited by streams that experience infrequent episodes of severe flooding. This vegetation dominates major outwash fans at the mouths of canyons along the coastal side of the San Gabriel, San Bernardino, and San Jacinto Mountains and lesser floodplain and riverine locations of southern California. Some alluvial scrub species occur also in sandy washes of coastal southern California apart from alluvial fans and large rivers.

Alluvial scrub is composed of an assortment of drought-deciduous subshrubs and large evergreen woody shrubs that are adapted to the porous, low fertility substrate as well as to survival of intense, periodic flooding and erosion. Step-like shrub covered terraces above the wash channels exhibit different phases of alluvial scrub vegetation. These phases are related to the amount of time that has elapsed since the most recent flood at each level. Three types of alluvial scrub have been recognized and are related to such factors as the scouring action of flood channels, distance from the flood channel, time since the last catastrophic flood, and substrate features such as texture and moisture content (Smith 1980). The three types can be referred to as: *pioneer* - vegetation is sparse and of low species diversity and stature, and is found within active stream channels or recently scoured streambeds; *intermediate* - vegetation is rather dense and is composed mainly of subshrubs; and *mature* - vegetation is composed of fully developed subshrubs and woody shrubs.

Mature alluvial scrub is distinguished by its vegetative composition, which contrasts in several respects with that of coastal sage scrub as described by Axelrod (1978), Cooper (1922), Epling and Lewis (1942), Kirkpatrick and Hutchinson (1977), Mooney (1988), Smith (1980), and Westman (1981a,b). Specifically, (1) alluvial scrub has more mesic species than most coastal sage scrub stands; (2) alluvial scrub consists of numerous evergreen shrubs, a diverse assemblage of subshrubs, and a springtime ground cover of annual wildflowers, whereas coastal sage scrub vegetation is composed primarily of drought-deciduous subshrubs with sparse, if any, annual wildflowers; (3) scalebroom *(Lepidospartum , quamatum),* a shrub with high fidelity to alluvial substrates, is found throughout alluvial scrub communities, but seldom in coastal sage scrub vegetation; (4) species commonly found in chaparral or desert plant assemblages, such as California redberry *(Rhamnus crocea),* lemonadeberry *(Rhus integrifolia),* sugarbush *(Rhus ovata),* mountain mahogany *(Cercocarpus betuloides),* holly-leaved cherry *(Prunus ilicifolia),* California juniper *(Juniperus californica),* and yucca *(Yucca whipplei)* are also common in the alluvial scrub community, but not in coastal sage scrub vegetation; and (5) small-statured riparian woodland species, such as California sycamore *(Platanus racemosa)* and mulefat *(Baccharis glutinosa)* are laced through alluvial scrub stands along major drainages, but are not present in stands of coastal sage scrub.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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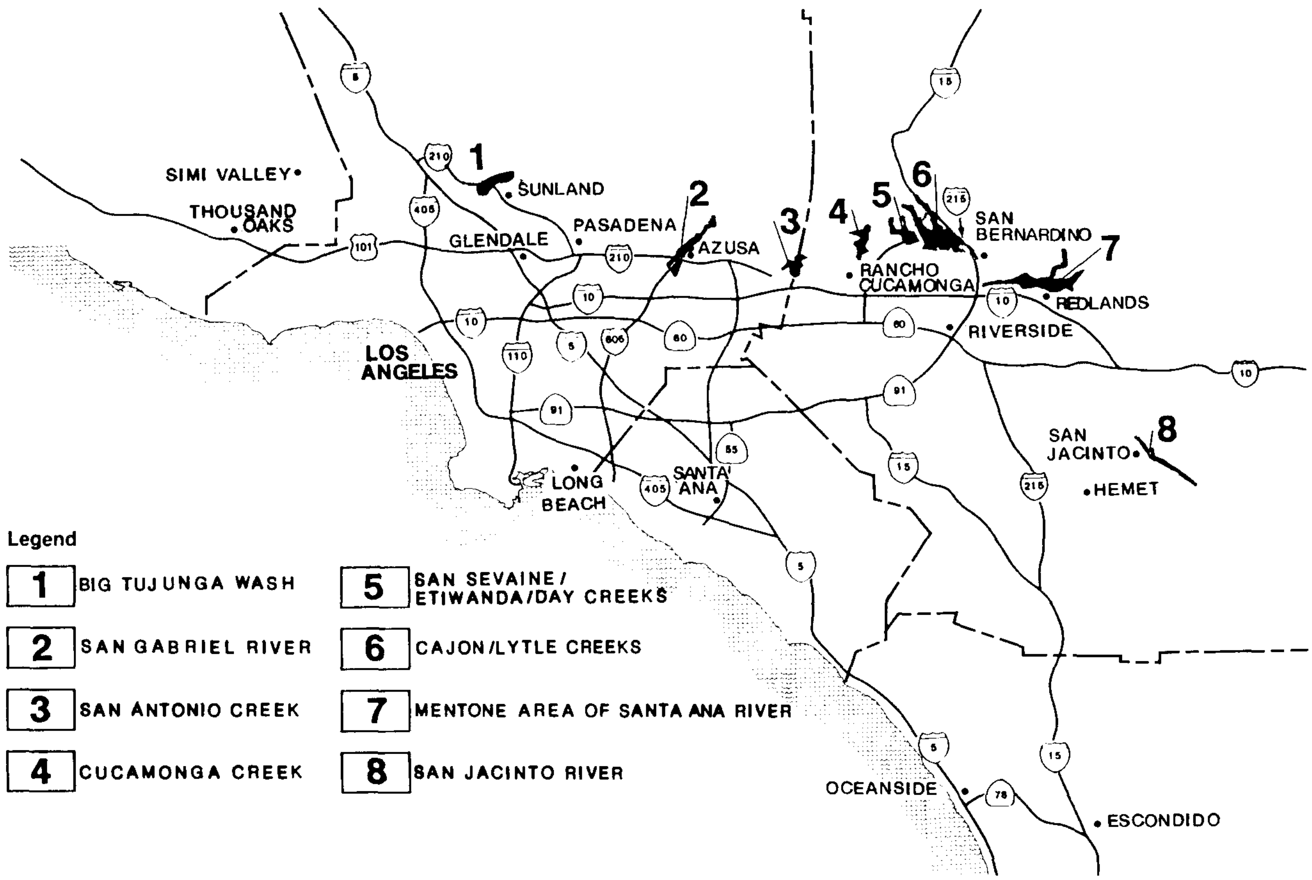

Figure 1– Distribution of major stands of alluvial scrub vegetation in southern California, U.S.A.

Methods

Ten stands of alluvial scrub vegetation were studied, comprising the largest, intact stands in southern California. These stands are associated with the Big Tujunga Wash and San Gabriel River (Los Angeles County); Cucamonga, Day, Etiwanda, San Sevaine, Lytle, and Cajon Creeks and the San Antonio and Santa Ana Rivers (San Bernardino County); and the San Jacinto River (Riverside County), (fig. 1).

Each stand was sampled by a series of 20 m line intercepts. Several "lines of march" along a compass line perpendicular to the associated stream channel were established within each of the alluvial scrub study sites, beginning at the edge of the stream channel in most cases and progressively moving up onto the higher stream terraces until reaching the site boundary. At 30 m intervals (50 m intervals in degraded alluvial scrub), a 20 m line intercept, perpendicular to the line of march, was established. The intercepts alternated at each interval from right to left of the line of march. Only subshrubs and evergreen woody shrubs were measured. Plants that were bisected by the intercept line (as projected vertically) were identified by species. Their intercept lengths (to the nearest 5 cm) were recorded, and the number of dead and live individuals of each species was counted along each 20 m intercept. Any intercept length not containing shrub cover was recorded as "bare ground." Intercept data were grouped by development stage of alluvial scrub vegetation (pioneer, intermediate, or mature) for each site. The values derived were used to describe and quantify the structural and successional composition and status of each alluvial scrub site.

Physical Setting

Soils

The floodplain soils upon which alluvial scrub occurs is of two types. Riverwash Association soils are found along the main river channels and consist of river-deposited sands, gravels, cobbles and stones. Inundation occurs each year and is accompanied by scouring, deposition, and removal depending upon the intensity and number of rainstorms each winter. All vegetation is scoured from the main channel during peak flow episodes.

Soboba Association soils are located along the terraced banks of the river and are formed of alluvium on the outwash of the rivers. Soboba soils have a cobbly, coarse loamy sand surface underlain by pale brown, single-grain, loosely stratified very gravelly and cobbly sand or loamy sand subsoils. These soils are excessively drained and exhibit very high permeability, very slow runoff, low water-holding capacity and low fertility.

Climate

The climate of the study area is Mediterranean, with an annual rainfall of approximately 460 mm, most of which falls during a few heavy winter storms. Once every 10 to 20 years, rainfall far exceeds the norm, resulting in catastrophic floods, such as 1938 and 1969. During such past floods, the rivers have carried debris eroded from upstream slopes and riverbeds, forming broad rocky alluvial outwash fans nearly 600 m thick. The river channels within the fans are subject to frequent scouring and flooding resulting in a barren state. The most significant recent floods in the study area occurred in 1938 and 1969. These and previous major floods produced floodplain terraces bordering the main channels and upon which the three recognizable phases of alluvial scrub vegetation have developed.

Site Conditions

The sample sites exhibit many similar conditions as well as a few distinctive features. Table 1 summarizes the various site conditions and features.

Results

A total of 237 plant species was encountered on the 10 study sites. To facilitate comparison of species composition between the sites, importance values were calculated for each species. Table 2 lists those species with importance values greater than 5.0 for each site.

Eriogonum fasciculatum was an important component of all 10 sites. *Lepidospartum squamatum* occurred on 9 of the 10 sites. *Salvia apiana* and *Lotus scoparius* were next in importance, occurring in 6 of the 10 sites. *Artemisia californica* occurred on 4 of the 10 sites. Longer-lived, woody species that characterized mature stands (see fig. 2) often had importance values less than 5.0 and are not shown in Table 2.

Most (6) of the sites were composed of all three successional stages, but a few sites had two or only one stage. Lytle Creek lacked mature alluvial scrub, whereas San Sevaine lacked intermediate scrub, and Etiwanda lacked both pioneer and mature stages. Presence and absence of developmental stages reflected various factors such as upstream damming or channelization, time since the last major flood, human disturbances, or soil moisture.

Table 1 - Summary of the Alluvial Scrub Sample Site Conditions and Features (material adapted from Michael Brandman Associates. 1988)

Site	Acreage	Location	Conditions and Features
San Jacinto	2,677	Upper San Jacinto River	Relatively undisturbed except for small sand and gravel operation, golf course downstream; limited water conservation dikes, diversion channels, and percolation basins.
Mentone	11,440	Upper Santa River	Variously disturbed by rock and sand quarries, aqueducts and railways; industrial, commercial, and residential developments; extensive flood control and water conservation facilities
Cajon/ Lytle Creeks (Combined)	17,347	Cajon and Lytle Creeks	Crossed by 2 railroad tracks, old Route 66, and (combined) Interstates 15 and 215. Residential and commercial developments along Route 66 and portions of Cajon and Cable Canyons. Quarrying operations in lower Lytle Creek
San Sevaine/ Etiwanda/Day Canyons	12,531	San Sevaine/ Day Canyon outwash	Large lateral flood control dikes, diversion canals, and percolation basin. Major electric transmission corridor and water treatment plant. New extensive residential developments south and west.
Cucamonga	3,091	Cucamonga Canyon outwash	Flood control structures and percolation basin; small rock quarry. Surrounded by residential developments.
San Antonio	2,318	San Antonio Canyon outwash	Streamflow controlled outwash by dam and large lateral dikes. Two highways cross the site. Quarry operation, small airport and commercial buildings present
San Gabriel	300	San Gabriel Canyon outwash	Streamflow controlled outwash by dams, major lateral dikes, drop structures, and percolation basins. Crossed by Route 66 and Interstate 210. Paved bikeway on east dike. Major quarrying operations. Dam, recreation area, and county natural area downstream.
Big Tujunga	1,587	Big Tujunga Canyon outwash	Natural braided floodplain flanked by hills. Bisected by Interstate 210. Dam, recreation area, and quarrying operation downstream.

Table 2 - Comparison of Species Composition of Ten Alluvial Scrub Stands Using Importance Values Greater Than 5.0*

		Importance Values by Development Stage		
Site	Dominant	Pioneer	Intermediate	Mature
San Jacinto	*Artemisia dracunculus*	7.74	16.77	4.13
	Baccharis glutinosa	16.10	0.82	
	Croton californica	7.13	8.02	
	Ericameria palmeri	4.96		4.25
	Eriodictyon crassifolium		1.75	11.61
	Eriogonum fasciculatum	10.59	31.54	41.17
	Lepidospartum squamatum	35.86	28.84	12.11
	Lycium andersonii	0.94	7.76	7.48
	Opuntia parryi		0.82	7.38
	Rhamnus crocea			9.51
	Salvia apiana		5.38	
Mentone	*Adenostoma fasciculatum*			28.96
	Baccharis glutinosa	8.24		
	Ericameria palmeri		19.50	3.91
	Eriodictyon trichocalyx		17.43	3.63
	Eriogonum fasciculatum	84.35	33.93	16.88
	Lepidospartum squamatum	7.40		
	Yucca whipplei		6.63	1.23
Cajon	*Eriodictyon trichocalyx*	18.20	18.79	12.00
	Eriogonum fasciculatum	51.18	18.87	8.76
	Lepidospartum squamatum		5.98	8.88
	Lotus scoparius	13.10	12.38	7.51
	Opuntia littoralis	4.34	4.69	7.84
	Salvia apiana		5.05	12.18
	Toxicodendron divers / ohm		3.95	8.42
	Yucca whipplei	4.30	12.46	16.74
Lytle Creek	*Artemisia dracunculus*	2.25	16.25	
	Eriodictyon trichocalyx		8.00	
	Eriogonum fasciculatum	63.20	30.98	
	Lepidospartum squamatum	30.19	5.43	
	Lotus scoparius	1.10	5.19	
	Opuntia littoralis	1.08	5.48	
	Opuntia parryi	1.08	7.88	
	Salvia apiana	1.08	6.10	
San Sevaine	*Adenostoma fasciculatum*			9.12
	Artemisia californica	6.28		17.04
	Cercocarpus betuloides	15.05		15.70
	Eriogonum fasciculatum	37.35		25.96
	Lepidospartum squamatum	15.04		7.32
	Lotus scoparius	10.64		1.38
	Salvia apiana	19.40		14.08
Etiwanda	*Croton californica*		7.54	
	Eriogonum fasciculatum		33.48	
	Lotus scoparius		9.06	
	Salvia apiana		43.70	
Cucamonga	*Adenostoma fasciculatum*			6.34
	Artemisia californica	22.69	12.30	23.70
	Eriodictyon trichocalyx		30.70	11.91
	Eriogonum fasciculatum	37.54	21.09	23.19
	Lepidospartum squamatum	30.46	16.65	11.73
	Lotus scoparius		7.47	1.88
	Rhamnus crocea			6.54
San Antonio	*Achillea millefolium*		9.50	8.13
	Artemisia californica		29.67	41.25
	Ericameria pinifolia		10.67	
	Eriogonum fasciculatum		10.09	14.51
	Lepidospartum squamatum		4.91	15.94
	Lotus scoparius		6.69	
	Malosma (=Rhus) laurina			8.13
	Salvia mellifera		12.99	2.22
San Gabriel	*Artemisia californica*		2.12	11.79
	Brickellia californica	8.10		
	Eriogonum fasciculatum		22.76	12.19
	Lepidospartum squamatum	31.43	22.53	13.02
	Opuntia littoralis		17.03	22.07
	Rhus integrifolia.			7.76
Big Tujunga	*Baccharis glutinosa*	29.29		
	Ericameria linearifolia		8.37	5.18
	Ericameria pinifolia	2.41	5.08	
	Eriogonum fasciculatum	33.56	36.39	33.37
	Lepidospartum squamatum	13.89	15.25	9.72
	Opuntia parryi		5.31	2.21
	Ribes aureum	1.36	1.35	5.97
	Salix sp.	4.53		9.85
	Yucca whipplei	3.35	10.48	12.71

*Standard importance values were utilized and divided by 3 to convert them to a base of 100 for convenience.

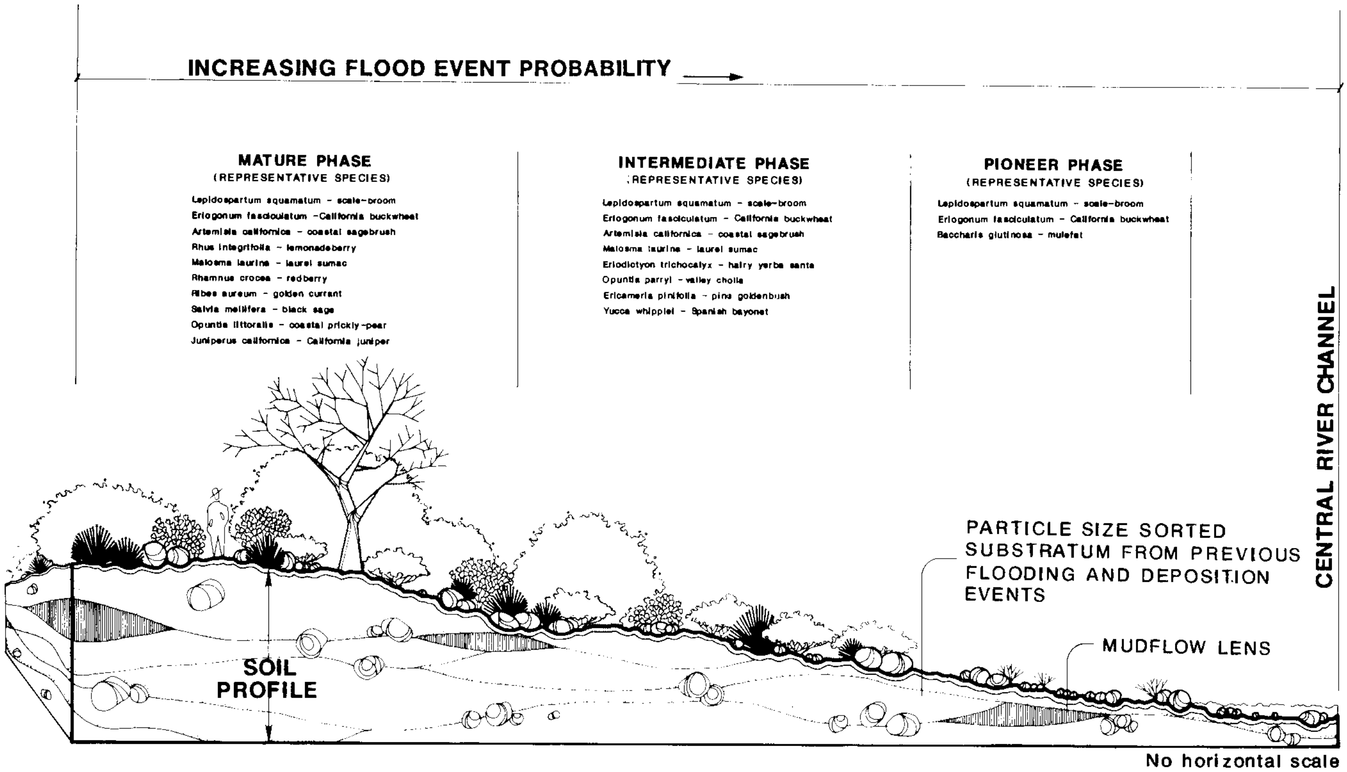

Figure 2– Profile diagram of alluvial scrub vegetation, showing representation of the three phases of development and their representative species.

In order to quantify compositional and structural features of the 3 phases of alluvial scrub at each sample site and to compare the 10 stands, various indices were used: native plant species diversity, percent dominance of the shrub component, and structural diversity of the shrub component (Table 3). These indices were standardized to values between 0.0 and 1.0 against an ideal condition in a manner similar to the Habitat Evaluation Procedure (HEP) developed by the U.S. Fish and Wildlife Service (USFWS 1980). The procedure for establishing and standardizing these indices are currently being documented in a manuscript in preparation by Friesen, Jones, and Keane, and are being referred to as a Habitat Quality Assessment (HQA).

San Jacinto, Cajon, and Big Tujunga sites exhibited the greatest species diversity of 8 sites. Etiwanda showed the smallest species diversity, having neither pioneer nor mature stages.

Cajon and Cucamonga sites had the highest shrub component of 8 sites with San Jacinto and Big Tujung a sites nearly as high. As with species diversity, the Etiwanda site showed the lowest shrub component.

The Cajon and San Gabriel sites exhibited the greatest structural diversity of 8 sites with Etiwanda showing the lowest structural diversity.

Current Status

The distinctive character of alluvial scrub vegetation as it relates to flood-deposited alluvia, makes it one of California's unique riparian systems (fig. 2). The intensity and magnitude of episodic floods creates recognizable vegetation phases that are related to both the age of the stand and to the site conditions of substrate and soil moisture. As a stand develops along a time gradient from pioneer to mature, there is a general trend in species composition replacement from short-lived subshrubs to long-lived woody shrubs. Severe flooding as well as fire and man-caused disturbances can eliminate existing stands of alluvial scrub, and thus initiate new pioneer stands. In contrast, a lack of sufficient soil moisture can prevent an intermediate stage stand from progressing to the mature stage. This condition is best illustrated in the Etiwanda stand. Such intermediate stands may be old in years, but not fully mature in species composition and stature.

Table 3 - Standardized Vegetation Parameters of Ten Alluvial Scrub Sites Based Upon Three Stages of Development

Site	Stage of Development	Species Diversity[1]	Shrub Dominance[2]	Structural Diversity[3]
San Jacinto	Pioneer	1.0	1.0	1.0
	Intermediate	0.8	0.8	0.2
	Mature	0.9	0.8	0.4
Mentone	Pioneer	0.2	1.0	0.0
	Intermediate	1.0	0.8	0.3
	Mature	1.0	0.5	1.0
Cajon	Pioneer	1.0	1.0	1.0
	Intermediate	0.9	1.0	0.8
	Mature	0.9	1.0	0.4
Lytle Creek	Pioneer	0.5	1.0	0.1
	Intermediate			
	Mature			
San Sevaine	Pioneer			
	Intermediate			
	Mature	0.9	1.0	0.4
Etiwanda	Pioneer	NP	NP	NP
	Intermediate			
	Mature			
Cucamonga	Pioneer	0.9	1.0	0.3
	Intermediate	0.7	1.0	0.2
	Mature	1.0	1.0	0.3
San Antonio	Pioneer	NP	NP	NP
	Intermediate	0.9	1.0	0.6
	Mature	0.8	0.6	0.3
San Gabriel	Pioneer	NP	NP	NP
	Intermediate	1.0	0.7	1.0
	Mature	1.0	0.8	1.0
Big Tujunga	Pioneer	1.0	1.0	0.4
	Intermediate	0.8	1.0	0.3
	Mature	1.0	0.7	0.2

[1] Species Diversity = $D = p_i \log_2 p_2$ where: p_i = decimal fraction of total individuals belonging to the ith species

[2] Shrub Dominance = $\frac{\text{total line intercepts of a shrub species}}{\text{total length of all intercepts per stage}} \times 100$

[3] Structural Diversity = ratio of shrubs (greater the 1.0 m tall) to subshrubs (less than 1.0 m tall)

* NP = not present

Alluvial scrub vegetation once was more widely distributed along the coastal washes and rivers emanating from the Transverse and Peninsular Ranges of southern California, where coalescing bajadas formed extensive, and in places nearly continuous, skirts along these ranges. Agricultural and urban developments in the past century have resulted in its elimination from most of its former range. As a consequence, alluvial scrub is isolated to stands along unaltered streams and outwashes on major alluvial fans. Industrial and residential developments and flood control projects continue to invade these remaining stands. A number of large projects, including a professional football stadium and an international-class golf course, are proposed for development within some of the premier examples of this vegetation.

Historically, rock and sand mining operations have quarried large pits within the floodplain alluvium upon which alluvial scrub vegetation depends. As these building materials become scarce in the southland, alluvial scrub resources become more threatened. Proposed flood control projects further threaten the integrity and long-term vitality of this unique floodplain scrub type.

Endangered Species

Two alluvial scrub species are listed as endangered by both the U. S. Fish and Wildlife Service and California Department of Fish and Game (State of California 1988): Santa Ana River woolly-star *(Eriastrum densi-*

folium ssp. sanctorum) is a much-branched subshrub now restricted to sandy soils on river floodplains or terraced alluvial deposits of the upper Santa Ana River drainage, San Bernardino County. These sites mostly are on privately owned and Bureau of Land Management lands. The Corps of Engineers currently is supporting research on the ecology of the woolly-star.

Slender-horned spineflower *(Centrostegia leptoceras)* is a delicate prostrate annual found on fine-textured, flood deposited river terraces and washes in Los Angeles, Riverside and San Bernardino counties. Extant populations are small and seriously threatened. Most occurrences are on private land and are unprotected.

Future Prospects

At present there is no program of conservation that will ensure the future existence of alluvial scrub vegetation. However, the designation of this vegetation by the California Natural Diversity Data Base (1987) as a unique habitat with a high priority for preservation is a worthy first step. Yet, this designation lacks legal power. The presence of the two rare and endangered plant species in some of the alluvial scrub stands brings both state and federal agencies into action in the protection and management of these alluvial scrub endemics. To a limited extent some alluvial scrub stands are the beneficiary of these agencies' actions.

Urban development pressures and flood control structures and practices increasingly will threaten alluvial scrub by direct removal or indirectly by altering the dynamics of its hydrology. Only through the acquisition and management of major stands of alluvial scrub can its future be secured.

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RECOVERY OF THE CHAPARRAL RIPARIAN ZONE AFTER WILDFIRE[1]

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Abstract: After the Wheeler Fire in southern California in July 1985, we monitored sediment deposition and vegetation recovery in a section of the severely burned chaparral riparian zone of the North Fork of Matilija Creek, near Ojai, California. Increased runoff was accompanied by low magnitude debris flows and fluvial transport of gravel, most of which was added to the channel and nearby hillslopes by post-fire dry ravel. The pre-burn riparian forest was dominated by white alder, California sycamore, and coast live oak. Regeneration of these species was entirely by resprouting, due to the absence of local viable seed sources. Recovery of the herb layer was affected strongly by the seeding of Italian ryegrass. Species richness of annuals decreased considerably in the second year, when perennials dominated the riparian zone.

The impact of fire on geomorphic processes is significant in the steep basins of southern California. The dominant sediment transport process on steep chaparral hillslopes is dry ravel or dry sliding of coarse colluvial soil fragments under the force of gravity. Fire increases the rate of dry ravel by removing stabilizing vegetation and litter (Krammes 1965). Rice (1982) reported 1.4 cubic meters per hectare per year of dry ravel in unburned chaparral in southern California, in contrast to 39 cubic meters per hectare for the 3 months following the 1959 Arroyo Seco Fire.

Chaparral wildfire can cause high temporary fluvial sediment yields (Scott and Williams 1978). Over 70 percent of the total long term sediment yield occurs in the first year following a fire (Rice 1974). Wells (1987) suggested that debris flows are an important form of sediment transport following fire in small steep watersheds. Keller and others (1988) suggested that large debris flows that affect higher order basins are related to long term instability, with fire and high intensity storms acting as potential trigger mechanisms.

Chaparral vegetation reduces flood potential by increasing evapotranspiration, interception, and infiltration (DeBano and others 1979). Vegetation removal by fire reduces evapotranspiration and infiltration. Also, the creation of a water-repellent (hydrophobic) layer in the soil during fire decreases infiltration (DeBano 1974). These post-fire conditions cause an increase in overland flow and streamflow (DeBano and others 1979).

The relatively open understory, mesic soil conditions and the high fuel moisture content of riparian vegetation usually restricts the spread of wildfire through the riparian zone. Flooding is probably a more important recurrent disturbance (Brothers 1985). The combination of intense wildfire and post-fire flooding and sedimentation represents an extreme disturbance of riparian vegetation, and we know of practically no information on the nature of recovery processes after such events.

The purpose of this project was to document changes in sediment storage and recovery of riparian vegetation in a chaparral basin after wildfire. A specific objective of the research was to evaluate the effects of wildfire on sediment routing and storage in the chaparral riparian system. Other objectives were to compare the role of seedling recruitment versus sprouting in regeneration of the tree layer, and to evaluate the significance of ryegrass seeding on recovery of the herb layer.

Study Site

We monitored post-fire events in a 270 meter study reach on a tributary to the North Fork of Matilija Creek, a tributary of the Ventura River (fig. 1). The drainage area of the basin is 2.14 square kilometers. Matilija Creek drains the tectonically active San Rafael Mountains, Ventura County, California. The geology of the area is characterized by a sequence of steeply south-dipping Eocene marine sandstones and shales. At least two distinct large debris flow deposits are recognized in the basin. Radiocarbon dating suggests that the oldest deposit (Q2) is 1045 ±95 BP, and the younger deposit (Q1), sampled in two locations, is approximately 385 ±85 BP or 295 ±35 BP (Florsheim 1988). Channel morphology in the study reach is characterized by step-pool sequences, a characteristic bedform in steep channels with coarse, heterogeneous bed material.

Detailed data on the pre-burn herbaceous flora in the area were unavailable, but standing trunks of trees that remained after the fire could be identified as a riparian forest of white alder (*Alnus rhombifolia* Nutt.), California sycamore (*Platanus racemosa* Nutt.), and coast live oak (*Quercus agrifolia Nee. var. agrifolia*). Shrubby species included willows (*Salix L.* spp.), hollyleaf cherry (*Prunus ilicifolia* (Nutt.) Walp.), laurel sumac (*Mal-*

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osma laurina Nutt. in T. & G.), poison oak (*Toxicodendron diversilobum* (T. & G.) Greene.), and Christmas berry (*Heteromeles arbutifolia* M. Roem.). All species nomenclature in this paper follows Munz (1974), and Abrams and Ferris (1960). A study of spatial distributions and regeneration of riparian tree species in three other canyons (Sisar Canyon, Horn Canyon, and W. Fork Santa Ana Creek) burned in the Wheeler Fire provided supporting data for the research at Matilija Creek (Parikh 1988, fig. 1).

Field Methods

In August 1985, we surveyed a longitudinal profile and 50 cross sections along the study reach (presumably the pre-fire condition), and constructed a contour map of the reach (fig. 2). The longitudinal profile and selected cross sections were resurveyed after the winter storms on January 30-31, 1986, and February 13-15, 1986. Dry ravel deposition was estimated by measuring the width, depth, and length of accumulations and then calculating the volume.

Rainfall data for storms that occurred during the winter following the Wheeler Fire were supplied by the Ventura County Department of Public Works. Flow discharge at the study site was estimated using the slope-area method for an ungaged channel (Dalyrymple and Benson 1967).

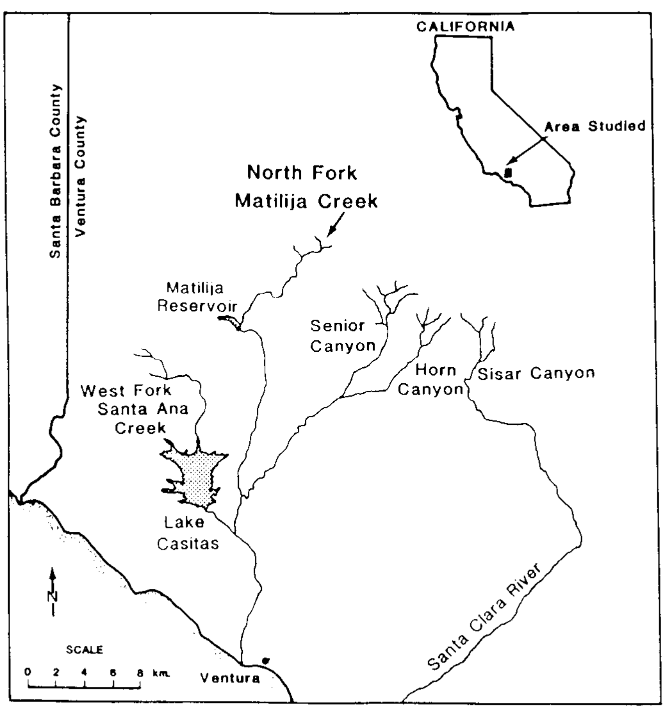

Figure 1– Locations of study sites.

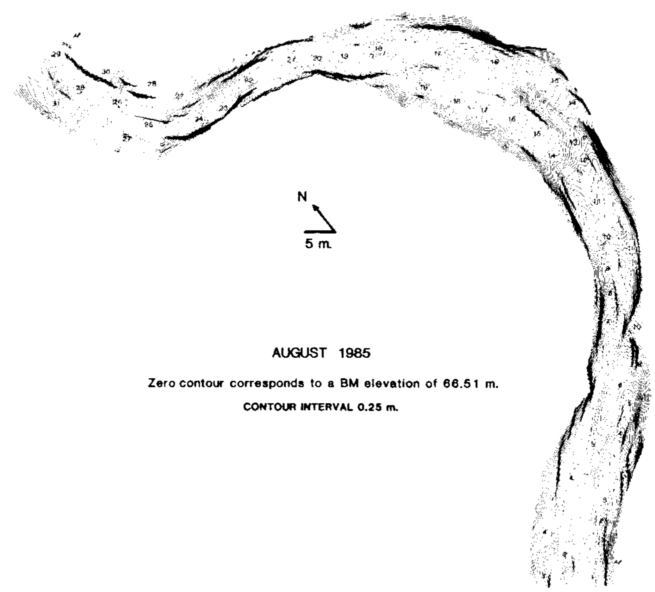

Figure 2– Contour map of the study reach.

The recovery of three riparian tree species and the herb layer in the study reach was documented at monthly intervals from September 1985 to May 1987. Three permanent plots of 250 square meters each were established in the upstream, middle, and downstream parts of the study reach. Sixty-three trees greater than 2.5 centimeters diameter at breast height (dbh) were tagged and mapped, including 23 alders, 19 sycamores, and 21 oaks. These trees were monitored to determine rates of re-sprouting, as well as the fate of dead standing timber in the riparian zone. Ten seed traps were located in each permanent plot to estimate monthly seedfall from alders and sycamores. Greenhouse germination tests for seed viability were also conducted on seeds collected at the site. Thirty plots of 1 square meter each were set up on different geomorphic locations to monitor the recovery of herbaceous species. The latter included Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot.), which was seeded in the area by the Forest Service, U.S. Department of Agriculture, for erosion control at an average density of 230 seeds per square meter.

Results

Effect of the Wheeler Fire on Hillslope Erosion

The Wheeler Fire burned 480 square kilometers in Los Padres National Forest, California in July 1985. Dry ravel was the dominant erosion process that occurred on burned slopes in the drainage basin following the fire. Slopes throughout the basin and in all lithologic units contributed dry ravel to the channel. Clasts averaged 4 millimeters in diameter. The volume of gravel which entered the channel in the study reach by the process of dry ravel was measured in August 1985 as 0.20 cubic meters per meter length of channel (it is assumed that this deposition post-dates the fire). The volume of dry ravel accumulation measured in a 176 meter reach in the burned headwaters of the North Fork of Matilija Creek near the study basin was 200 cubic meters per hectare (0.30 cubic meters per meter length of channel) for a 7 month period following the fire. Thus, we estimate the rate of dry ravel following the fire in the basin to be 29 cubic meters per hectare per month, much higher than the background rate suggested by Rice (1982).

Effect of the January 30-31 Storm

Two storms caused significant channel change the winter following the Wheeler Fire. The first storm, on January 30-31, 1986, resulted from 122 millimeters of precipitation (return period less than 2 years) and produced a flow of 2.1 cubic meters per second in the study reach. This was the first substantial flow following the Wheeler Fire, and the basin responded to this moderate sized event by contributing material from hillslopes and mobilizing sediment existing in the channel. The streamflow was clearly transport-limited and deposited fine-grained gravel-sized sediment, which filled pools and buried bedforms. Approximately 550 cubic meters of fine-grained gravel was deposited in the 270-meter study reach.

Based on a comparison of the volume of gravel-sized material deposited during the January storm (approximately 2 cubic meters per meter length of channel) to the volume of dry ravel existing in the channel following the fire but before the storm, only 10 percent of the gravel-sized material in the January fill was derived from gravel existing in the channel. The remainder was derived from fine material stored on hillslopes near the channel and contributed to the channel by rills and small surficial slope failures during the storm.

The pattern of sediment deposition during the January event was dependent on channel geometry. Sediment filled the channel both upstream and downstream of bedrock constrictions, completely burying the pre-storm bed morphology (fig. 3). Little aggradation occurred in the constrictions. The distribution of sediment deposits resulting from this low magnitude event is similar to that predicted using the HEC-2 step-backwater computation to model the distribution of unit stream power (Florsheim and Keller 1987). The model predicted that sediment should be deposited upstream of constrictions where backwater effects were present, and downstream of constrictions in channel expansions, leaving constrictions free of sediment.

Effect of the February 13-15 Storm

The second storm, resulting from 244 millimeters of precipitation (return period 2-4 years), occurred on February 13-15 and produced a flow discharge of 2.5 cubic meters per second, only slightly higher than the January 30-31 flow. This event scoured nearly all the gravel deposited by the late January event, suggesting that this flow was supply-limited. The February flow was capable of transporting the small gravel out of the system, and because slopes were depleted and little new sediment was added to the channel in the 2 weeks between the January and February storms, the later flow nearly eroded the channel to the level of its pre-January thalweg.

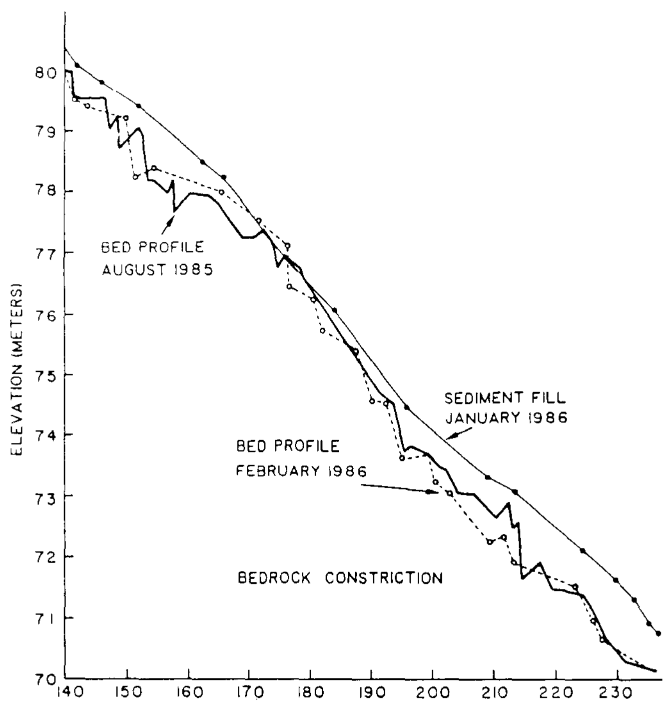

Figure 3— Longitudinal profile of lower portion of the study reach. Bed profile surveyed in August 1985; following the January 30-31, 1986 event; and following the February 13-15, 1986 event. Constriction extends from approximately 170-200 meters.

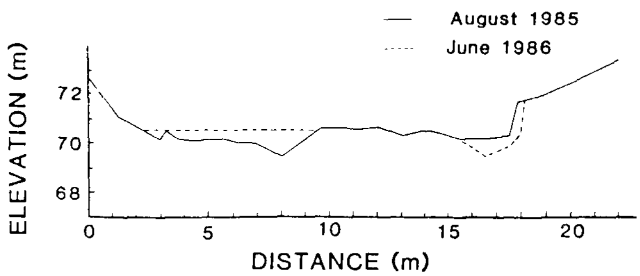

Figure 4– Cross section 6 surveyed in August 1985 and in June 1986 shows January fill in the left channel and scour resulting from the February storm in the right channel.

Pronounced changes in channel morphology occurred at the downstream end of the study reach during the February event. Sediment stored in the channel was eroded during the February flow and bank erosion occurred locally along vertical edges of the debris flow terrace. The channel widened 0.5 meters and deepened 0.7 meters at cross section 6 as a result of erosion during the February flow (fig. 4).

Importance of Fire on Long Term Sediment Storage and Yield

The impact of fire on long term sediment storage and yield can be estimated by comparing the volume of sediment deposited during sediment transport events such as the January 30-31 storm to deposits of large debris flows preserved in the channel. The volume of sediment deposited in debris flows Q1 and Q2 before subsequent incision is estimated as 32,800 cubic meters and 65,600 cubic meters, respectively. Thus, the total volume of sediment deposited in debris flows in the study basin in the past 1000 years is approximately 94,000 cubic meters. The average volume of sediment deposited during the January 30-31 storm was approximately 2 cubic meters per meter length of channel. Assuming that the upper 850 meters of the basin was too steep to allow for sediment deposition, and that sediment was transported to the lower part of the basin (1640 meters upstream of the mouth), the volume of sediment deposited in the first substantial post-fire storm was 3,280 cubic meters.

Assuming that the recurrence interval for fire in the Santa Barbara area is 30-65 years (Byrne 1979), and that a sediment transport event such as that on January 30-31 occurs following every fire, then 15-33 such events occur in 1000 years. Therefore, the volume of sediment contributed to the basin due to post-fire fluvial sediment transport is estimated as 49,200 to 108,200 cubic meters per 1000 years. This calculation suggests that fire may cause 30 to 50 percent of the total debris deposition over a 1000-year period. The remaining deposition is due to high magnitude debris flows related to factors such as basin stability and intensity of precipitation, with fire and earthquakes acting as potential trigger mechanisms. Small gravel deposited in the channel is stored for short periods of time, on the order of months or several years. However, large debris flows remain in the channel as terraces and lag deposits for hundreds to thousands of years.

Vegetation Recovery

Tree Overstory Layer

The riparian zone of North Fork Matilija Creek was dominated by a central corridor of white alders, with California sycamores and coast live oaks situated at higher elevations above the stream on upper terraces and hillslopes. These relationships were typical of the watersheds in the region (Parikh 1988). There was no apparent relationship between the spatial and size-class distributions of the three species. The range of occurrence of the three species above the channel is given in table 1.

Most tree trunks along the channel reach remained standing until the storm events in winter 1986, when large flows caused the erosion of mid-channel bars, and subsequent uprooting of many alders growing near the stream. In the first year after the fire, 8 of 23 alders fell, and 2 more were uprooted in the next 2 years (i.e., 44 percent of alders in the study reach, and 3.84 percent of the total basal area of alders on that plot). No sycamores fell during the first 2 years after the fire. During the second year, 6 of 19 oak trees fell following severe windstorms (i.e., 29 percent of oaks in the study reach, 11.04 percent of the total basal area of oaks on that plot). The combined effect of wind and rain during winter storms in the second year caused much breaking of dead tree trunks and branches, and the accumulation of debris in the wider parts of the channel.

Table 1 – Elevations of species in meters above the channel, North Fork Matilija Creek

Species	Range of Occurrence	Mean elevation	Standard deviation
White alder	0.05 to 1.32	0.51	0.33
California sycamore	0.41 to 4.76	2.84	1.11
Coast live oak	1.29 to 7.80	4.15	2.63

The regeneration of alders, sycamores, and oaks occurred exclusively by sprouting. Seedlings were not observed in the permanent plots, although they occurred in unburned areas immediately downstream of the study reach. Less than 1 percent of alder seeds collected from the burned areas were viable. Alder seedfall was consistently low (< 7 per square meter) during the study period. Burned sycamores released large numbers of seeds (up to 170 per square meter) immediately after the fire, but viability was low (< 5 percent). The maximum number of seeds fell about 6 months after the fire (late fall and early winter are the seasons of seed dissemination of both species).

Among the trees surveyed in May 1987, 7 percent of alders had sprouted, 83 percent of the sycamores, and 70 percent of the oaks. Surviving alders sprouted several months after the other species. At the study site and in sample transects located in three other burned canyons in the Ojai area (Parikh 1988, fig. 1), alders sprouted the least, and sycamores the most. Alder seedlings were more numerous than sycamore seedlings along the unburned channel in the second year. In the third year after the fire, some of these alder seedlings grew rapidly during the spring season, reaching heights of almost 2 meters; others were flooded out during preceding winter storms.

Stepwise logistic regression analysis (Ezcurra and Montana 1984) was used to test the rate of re-sprouting by each species as a function of canyon (N. Fork Matilija Creek, W. Fork Santa Ana Creek, Sisar and Horn Canyons), size-class (dbh), and height above the stream (Parikh 1988). The sprouting of alders was affected most by canyon location ($p < 0.0001$). The sprouting of sycamores was negatively and significantly related to height above the stream ($p < 0.005$) and secondarily to regional location ($p < 0.1$). The sprouting of oaks was positively and significantly related to size class ($p < 0.0001$). The differences between canyons in rate of resprouting by alders and sycamores is probably due to regional variation in fire intensity. Height above the stream is a factor operating at a smaller scale. More sycamores sprouted closer to the stream, probably due to fire being less intense in the mesic areas of the canyon, and more water being available for sprouting. The thick bark of larger oaks probably accounts for their higher survival rate (Plumb 1980).

Herb Layer

We began monitoring the herb layer in September 1985. Fifteen annuals occurred in the plots during the first year after the fire, the most frequent of which are listed in table 2. Some of these were fire-followers (e.g., *Eucrypta chrysanthemifolia*, see Keeley and others 1985). The second-year annual flora decreased in species richness, and annual species present in both years generally showed considerably reduced frequencies in the second year. Most annuals occurred patchily on higher geomorphic surfaces such as hillslopes and upper terraces (fig. 5). *Sanicula crassicaulis* and *Dichelostemma pulchella* also occurred on higher geomorphic areas in the first year after the fire.

Perennials such as *Toxicodendron diversilobum, Rubus ursinus,* and *Calystegia macrostegia* were common in the entire riparian zone, while others such as *Solanum douglasii, Artemisia douglasiana, Urtica holosericea* and *Mimulus cardinalis* were more frequent on lower and middle terraces (fig. 5). Several shrub species developed and persisted after the burn on various geomorphic surfaces, e.g., *Malosma laurina, Eriophyllum confertiflorum,* and *Prunus ilicifolia.* A number of species were flooded out in winter storms during the first year. Some species, viz *Artemisia douglasiana* and *Solanum douglasii,* did not recover fully from these storms until the second year.

The second-year perennial flora was somewhat different in species composition. Although *Toxicodendron diversilobum, Rubus ursinus, Urtica holosericea,* and *Solanum douglasii* persisted, species such as *Baccharis glutinosa, Heteromeles arbutifolia,* and *Eriogonum fasciculatum* ssp. *foliolosum*– normally components of undisturbed riparian, chaparral, and coastal sage scrub communities – also appeared. Woody perennials dominated the lower riparian zone in the second year, notably willows (*Salix* L. spp.).

Ryegrass that was seeded in the area in October 1985 germinated in December. Sedimentation events that followed the fire affected the spatial distribution of the species considerably – it grew most densely on lower hillslopes and on terraces where sediment accumulated due to dry ravel processes (fig. 6). Maximum density occurred soon after germination (January 1986) and declined thereafter due to thinning and, on lower terraces, due to mortality during flooding (fig. 6). The ryegrass attained an average frequency of 35 percent and average density of 91 plants per square meter (i.e., 39 percent recruitment from broadcasted seed) in the first year. Second year growth started in November 1986, and the species occurred at 50-100 percent frequency on all geomorphic surfaces.

At the end of the first year growth in spring 1986, the subplots were harvested, and dry biomass was measured for all herbaceous species on each subplot (fig. 7). Ryegrass dominated the plant communities at all locations, suggesting that native plants were reduced considerably by the growth of this species (Nadkarni and Odion 1986).

Table 2 — Frequent post-fire species observed (*) at North Fork Matilija Creek

Scientific Name	Common Name	Abbre-viation	Year 1	Year 2
Annuals and Biennials				
Allophyllum divaricatum (Nutt.) A. & V. Grant	Straggling gilia	Ad	*	*
Claytonia perfoliata Donn. var *perfoliata*	Miner's lettuce	Cp	*	*
Collinsia concolor Greene.	Southern chinese houses	Cc	*	*
Dichelostemma pulchella (Salisb.) Heller.	Wild hyacinth	Dp	*	*
Eucrypta chrysanthemifolia (Benth.) Greene var. *chrysanthemifolia*	Common Eucrypta	Ec	*	*
Callum aparine L.	Goose grass	Ga	*	*
Gnaphalium californicum DC.	Green everlasting	Gc		*
Lolium perenne L. ssp. *multiflorum* (Lam.) Husnot	Italian ryegrass	Lp	*	*
Phacelia cicutaria Greene var. *hispida* (Gray) J.T. Howell	Caterpillar phacelia	Pc	*	*
Phacelia viscida (Benth.) Ton.	Sticky phacelia	Pv	*	*
Pholistoma auritum (Lindl.) Lilja.	Common fiesta flower	Pa	*	*
Rafinesquia californica Nutt.	California chicory	Rc	*	*
Sanicula crassicaulis Poepp. ex DC.	Pacific sanicle	Sc	*	
Perennials				
Artemisia douglasiana Bess in Hook.	Douglas' mugwort	Ad	*	*
Baccharis glutinosa Pers.	Mule fat	Bg		*
Calystegia macrostegia (Greene) Brummitt ssp. *cyclostegia* (House) Brummitt	Coast morning-glory	Cm	*	*
Eriodictyon crassifolium Benth. var *denudatum* Abrams.	Thick leaved yerba santa	Ecd		*
Eriogonum fasciculatum Benth. ssp. *foliolosum* (Nutt.) Stokes	California buckwheat	Ef		
Eriophyllum confertiflorum DC. Gray var. *confertiflorum*	Golden yarrow	Ecc	*	*
Heteromeles arbutifolia M. Roem.	Christmas berry	Ha		*
Lotus scoparius (Nutt. in T. & G.) Ottley ssp. *scoparius*	California broom	Ls		*
Malosma laurina Nutt. in T. & G.	Laurel sumac	MI	*	
Mimulus cardinalis Dougl. ex Benth.	Scarlet monkey-flower	Mc	*	*
Mimulus longiflorus (Nutt.) Grant ssp. *longiflorus*	Salmon bush monkey-flower	Mc	*	*
Phacelia ramosissima Dougl. ex Lehm. var. *suffrutescens* Parry.	Branching phacelia	Pr		*
Prunus ilicifolia (Nutt.) Walp.	Holly-leaved cherry	Pi	*	*
Rubus ursinus C. & S.	California blackberry	Ru	*	*
Salvia mellifera Greene.	Black sage	Sm	*	*
Solanum douglasii Dunal in DC.	Douglas' nightshade	Sd	*	*
Toxicodendron diversilobum (T. & G.) Greene	Poison Oak	Td	*	*
Urtica holosericea Nutt.	Hoary nettle	Uh	*	*

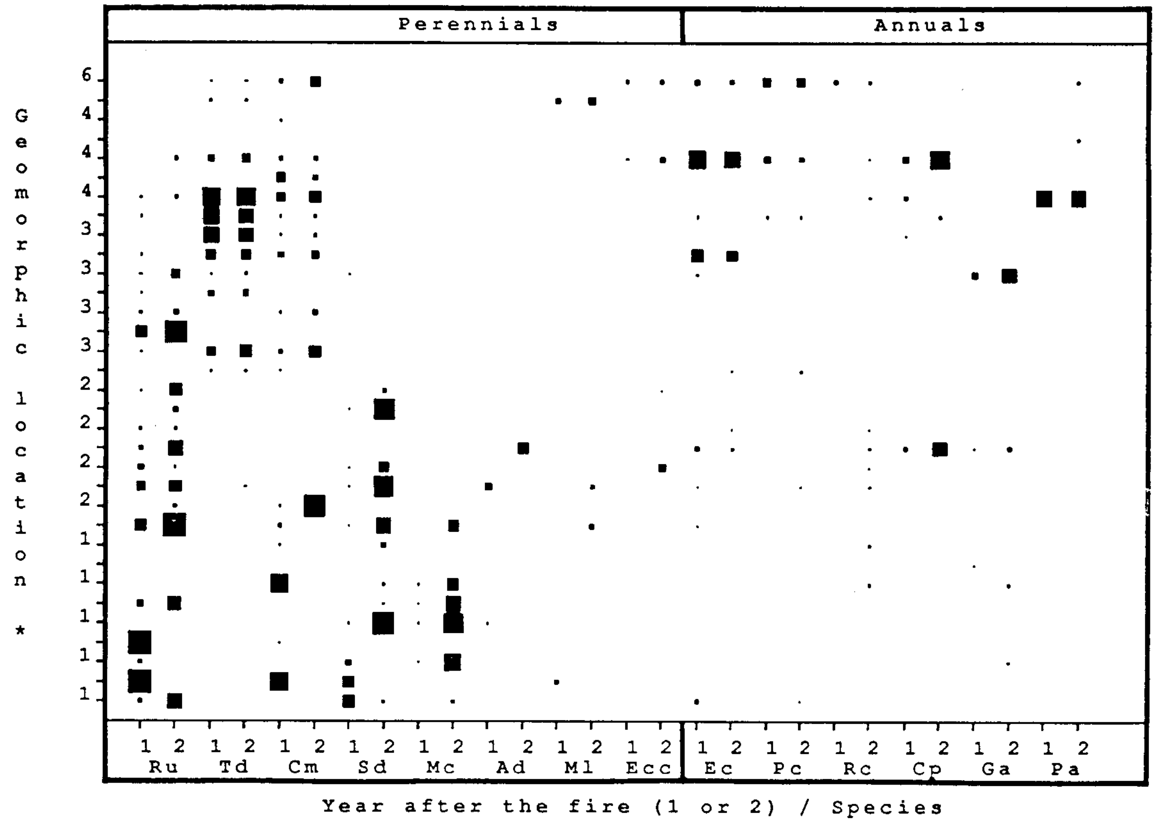

Figure 5– N. Fork Matilija Creek: post-fire development of species. Largest square represents maximum species frequency of 100 percent. 1,2,3 = lower, middle, upper terrace; 4,5,6 = lower, middle, upper hillslope. For abbreviations of species names, see table 2.

The study reach was monitored at quarterly intervals during the third year after the fire. A final survey of the site in spring 1988 (about 3 years after the burn) showed some changes in the flora. Most subplots were dominated by perennials such as *Rubus ursinus, Urtica holosericea, Baccharis glutinosa, Calystegia macrostegia, Mimulus cardinalis, Toxicodendron diversilobum,* and *Salix* spp. Shrubby chaparral species that persisted from the first 2 years included *Malosma laurina, Heteromeles arbutifolia, Prunus ilicifolia, Eriogonum fasciculatum, Eriophyllum confertiflorum,* and *Salvia mellifera.* Some new species were seen, for example, California lilac (*Ceanothus* L. sp.)

The most interesting feature of the third-year postfire flora was a return to the species composition of the first year on some subplots. Species included *Phacelia cicutaria, Eucrypta chrysanthemifolia, Pholistoma auritum, Allophyllum divaricatum,* and *Galium aparine.* Ryegrass was frequent on most subplots. New species observed in June 1988 downstream of the study site in an area burned in August 1987 included short-lobed phacelia (*Phacelia brachyloba*) (Benth.) Gray), western morning-glory (*Calystegia purpurata* (Greene) Brumitt.,) and iris-leaved rush (*Juncus xiphioides*) E. Mey.)

Discussion and Conclusions

Hydrologic processes in drainage basins in southern California are controlled by infrequent storms and episodic streamflow, and erosional processes are dominated by frequent dry season gravitational sliding of small gravel sized clasts (dry ravel) and infrequent large magnitude debris flows. Hillslope stability and fluvial processes in chaparral basins are influenced by periodic fire.

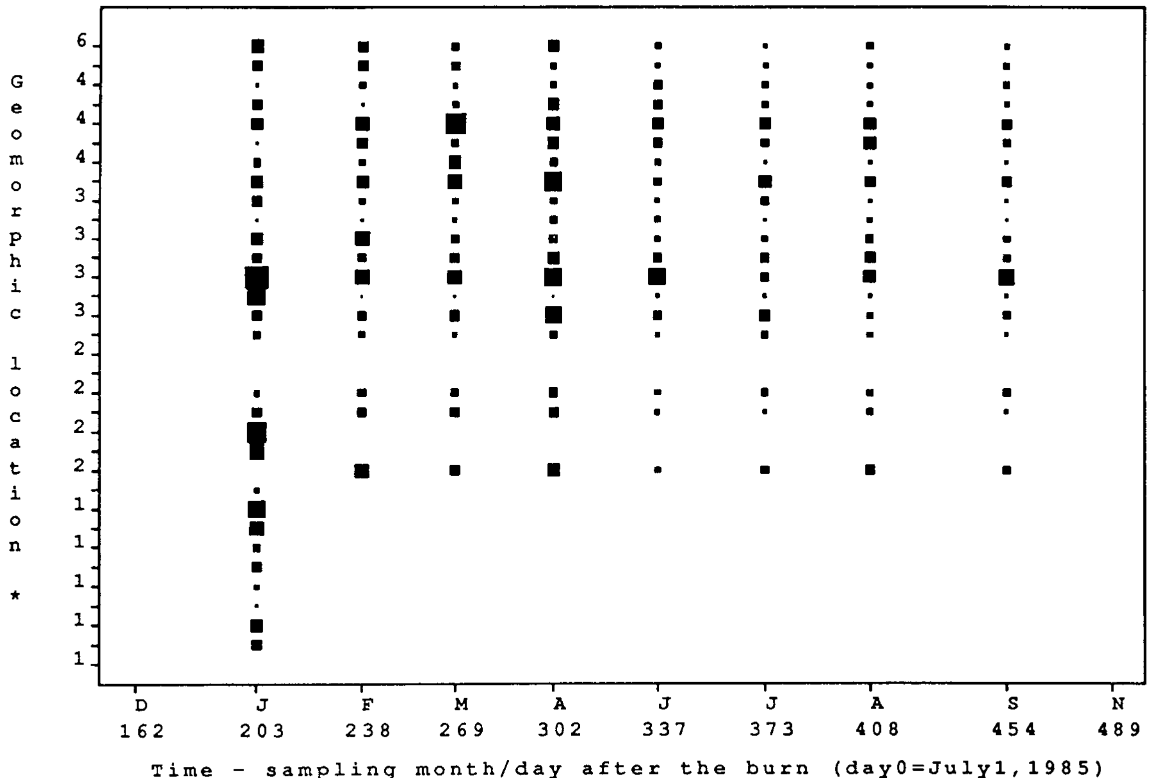

Figure 6– Matilija Creek: post-fire density of seeded ryegrass. Largest square scaled to represent maximum ryegrass density of 310 plants per square meter. 1,2,3 = lower, middle, upper terrace; 4,5,6 = lower, middle, upper hillslope.

Fire decreases basin stability; sediment deposition during the January 30-31, 1986, storm may be typical of the chaparral ecosystem following wildfire. Evaluation of debris flow deposits suggests that the recurrence interval of large debris flows in a particular basin is at least hundreds and perhaps thousands of years. By comparison, the recurrence interval of wildfire in the Santa Barbara area is 30-65 years (Bryne 1979). Thus fluvial transport of sediment derived from dry ravel and small landslides off hillslopes is much more common following a fire than is a large debris flow.

The recovery of vegetation following chaparral wildfire shows the combined disturbance effects of fire and flooding. Recovery processes in the herb layer are closely linked to geomorphic location in the riparian zone, and to the density of seeded ryegrass. Annuals become well-established on higher geomorphic locations less prone to flooding, but often in loose soil subject to dry ravel. Perennials, on the other hand, grow better on lower, more disturbed geomorphic locations near the stream. The overall species richness of annals decreased in the second year after the fire due to the predominance of ryegrass, although perennials took over the riparian zone to a large extent.

Sprouting is the dominant means of recovery of the tree species due to the lack of viable seeds following the fire. Certain species such as sycamore show rapid recovery, while others such as alder may be very slow to reestablish in the absence of a viable seed source. Full recovery of the alder canopy after unusually hot fires such as the Wheeler Fire may take many years or decades.

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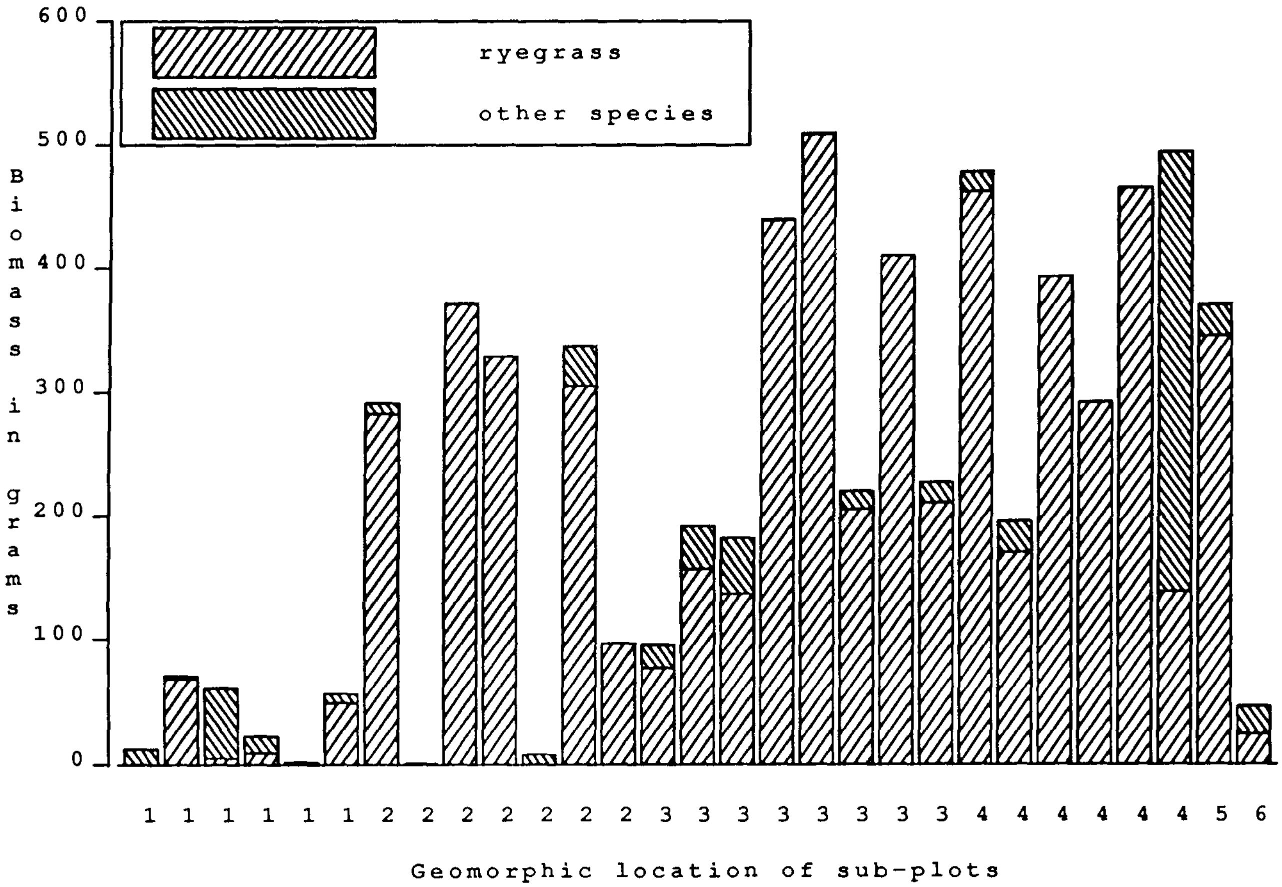

Figure 7– Matilija Creek: dry biomass of herbaceous species harvested June 2, 1986. 1, 2, 3 = lower, middle, upper terrace; 4, 5, 6 = lower, middle, upper hillslope.

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RIPARIAN RESTORATION AND WATERSHED MANAGEMENT: SOME EXAMPLES FROM THE CALIFORNIA COAST[1]

Laurel Marcus[2]

Abstract: Managing and restoring watersheds often involves re-creation of riparian habitats. The natural functions of riparian forest natural to slow flood water, stabilize stream banks and trap sediments can be used in restoring disturbed creek systems. The State Coastal Conservancy's wetland enhancement program is preserving wetlands on the California coast through repair and management of watersheds. Examples from rural and urban areas illustrate how riparian restoration can be integrated into watershed projects.

The coastal wetlands of California have dwindled in acreage to one-fourth of their former extent. While much of this loss has come from diking, filling, and dredging development, indirect filling from sedimentation is a major problem. With the passage of the California Coastal Act in 1976, the direct filling of wetlands became severely restricted. However, indirect filling is a largely unregulated and ubiquitous problem involving large land areas, many government jurisdictions and all sorts of land uses.

What does the sedimentation of coastal marshes have to do with riparian habitats? There is a very direct relationship. The California State Coastal Conservancy through its efforts to restore and preserve coastal wetlands has had to look upstream into watersheds and stream systems to find the sources of sediment and reduce erosion problems. The following two examples demonstrate how the preservation and restoration of riparian systems helps protect coastal marshes and estuaries.

Buena Vista Lagoon

The Problem

Buena Vista Lagoon lies in northern San Diego County. Its small 20 square mile watershed is linear in shape; the upper half lies in the city of Vista and the lower half, as well as the lagoon, lie in the cities of Oceanside and Carlsbad.

The lagoon originally was a tidal system which probably closed off from the tides during the summer months. The beach berm at the lagoon mouth, remained in its natural state allowing the lagoon to open and flush out sediment during winter floods. During the 1940's the basic hydrology of the lagoon changed – housing was developed on the beach berm, the lagoon mouth location was fixed and a weir was placed at the mouth. The weir created a freshwater lagoon and maintained a consistent water level in the lagoon for aesthetic reasons. Unfortunately these changes, combined with the construction of three road crossings in the lagoon, created a perfect settling basin for sediment.

Concurrent with these changes in the lagoon, the watershed was dramatically altered. The mainstem of Buena Vista Creek has perennial waterflow making an environment suited for dense riparian growth. The natural floodplain served to slow floodwaters and sieve out heavy sediments. The floodplain gradually builds up sediment protecting the lagoon from rapid filling. During the 1950's – 70's much of the Buena Vista Creek floodplain was developed with a primary focus on creek "improvements" – concrete channels to drain water as quickly as possible off the development site. These channels not only have no sediment retention qualities, they serve to greatly accelerate stormwater flow rates. In addition to altering the creek, development resulted in the paving of many square miles of the lagoon watershed. The overall effect of both changes was an enormous increase in the peak volume of stormwater and a loss of natural floodplain.

This dramatic transformation altered the hydrologic balance of the watershed. The increased volume of stormwater eroded a 20 foot gully in the channel toppling riparian trees and moving tons of sediment downstream. As the stream system attempts to regain a balance with this increased water volume, this gully will widen and deepen causing trees to be undercut and fall over. An arroyo will eventually form particularly if development progresses (Figure 1).

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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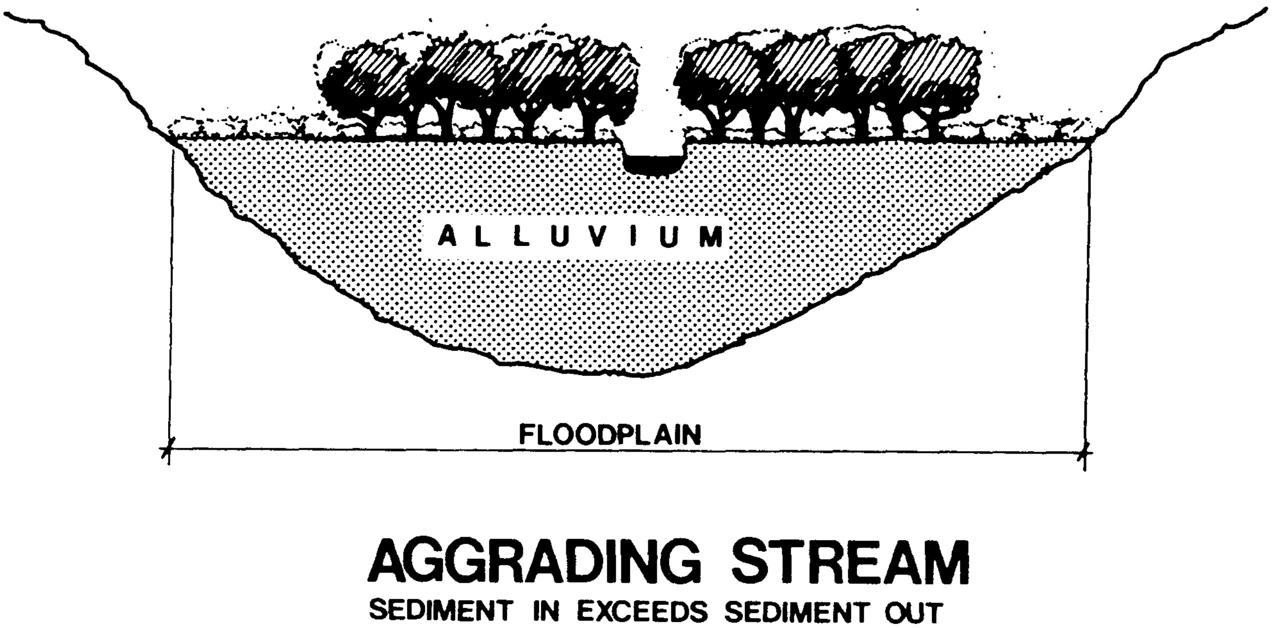

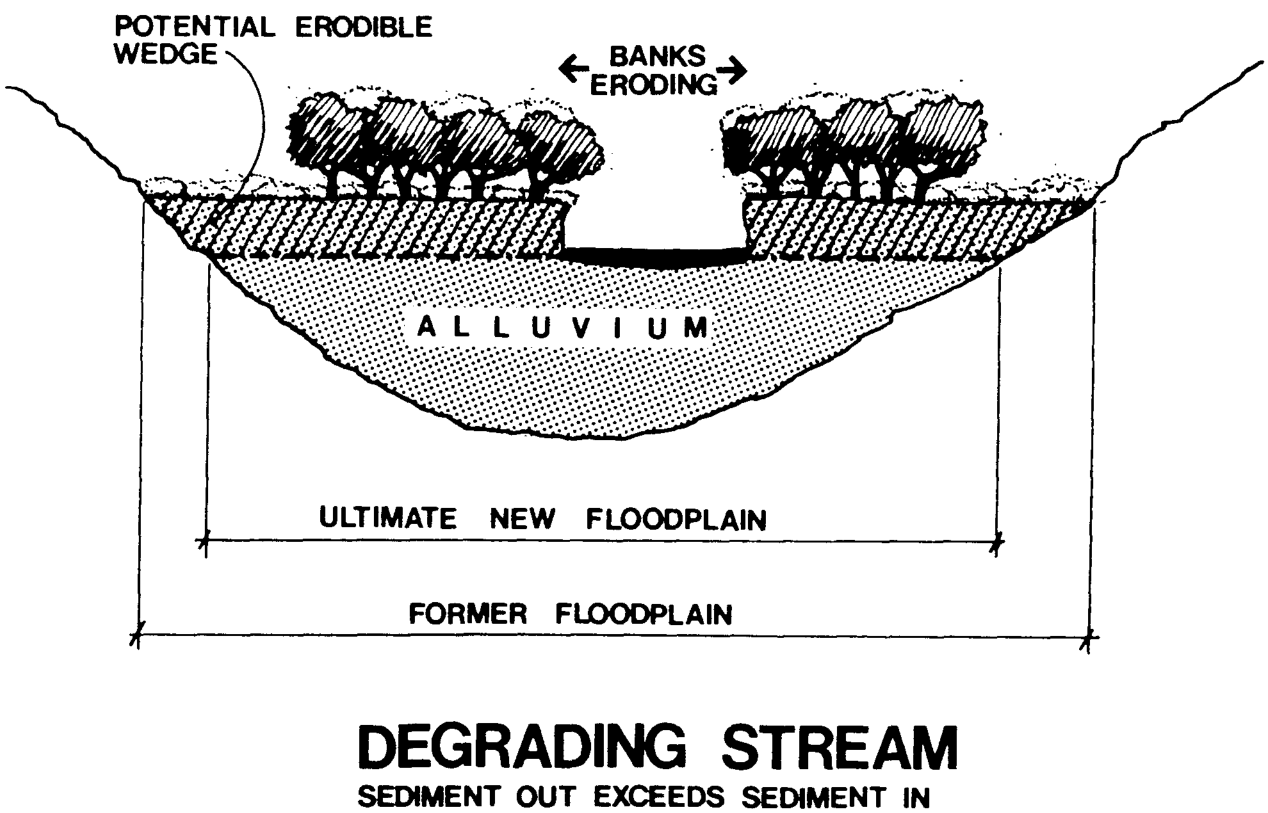

Figure 1- Arroyo Formation.

In 1978-79, a series of large storms filled the eastern basin of the lagoon with sediment and brought an outcry from local citizens. The California Department of Fish and Game which owns the lagoon spent over one million dollars to dredge out the muck; however, the lagoon still retains much of the sediment it received.

Sediment Control Plan

Sedimentation-periodically dredge it from the lagoon, or find and correct the source of the erosion. The Conservancy chose the second option and has thus become involved in riparian habitat restoration. The primary reason for this choice lies in a rule of sediment transport/the quantity of sediment transported in a creek is an exponential function of the quantity of stormwater flow. Consequently, the greatest control of sediment into Buena Vista Lagoon can be achieved by reducing peak flows of stormwater. This concept was the product of a comprehensive watershed plan prepared by Applegate and Associates that involved extensive computer modeling and evaluation of cost-effective control measures. The Conservancy plan recommends two primary measures to reduce the cause of sediment movement-urban stormwater flows: detention of stormwater, and creek-restoration.

Stormwater Detention

Our studies showed that increased urban peak storm flows had dug a 20 foot deep gully in Buena Vista Creek. This massive hole was a primary source of sediment to the lagoon. If no changes were made complete build-out of the watershed would cause further down-cutting and widening of this gully with loss of riparian habitat and rapid filling of the lagoon.

The plan recommends the construction of several large stormwater detention basins in the watershed. These basins consist of a small dam or a road crossing with a restricted outlet. The basin allows water to pond during storms and to be slowly released. The computer model showed installation of these basins alone would produce an estimated 20 percent reduction in sediment deposition in the lagoon.

Creek Restoration

The model for the plan predicts the most cost effective way to lower storm flows to restore those areas of remaining unimproved creek to function as a natural floodplain. The basic idea is to rebuild the creek to a fully vegetated channel with a series of drop structures which create small hydraulic drops and slow water flow. The natural function of the riparian forest in slowing water is used and the acreage of riparian habitat increased throughout the creek corridor. Because portions of the remaining creek channel cross developed areas, the channel dimensions must be reduced and the side slopes made relatively steep (2:1 and 3:1). The installation of the detention basins is an integral part of the creek restoration. The flood flows would be lowered enough by the basins to allow for a fully vegetated channel in a confined area (Figure 2). The width restriction requires use of dense plantings of tree species over the entire slope using an irrigation system. The engineering design also incorporates a high channel roughness coefficient so that the channel bottom may be planted and maintained with tree species. Channel maintenance will involve hand cutting of trees over a certain diameter; no dragline work in the channel is envisioned. While this maintenance scheme may seem excessive, it is the only way to have the channel continuously slow stormwater. Were half the channel to be drag-lined, the hydraulic characters would be changed and waterflow would accelerate, diminishing the channel's intended purpose. The model for the plan predicts that the combination of the detention basins and creek restoration could reduce sedimentation to the lagoon by 45 percent (Figure 3).

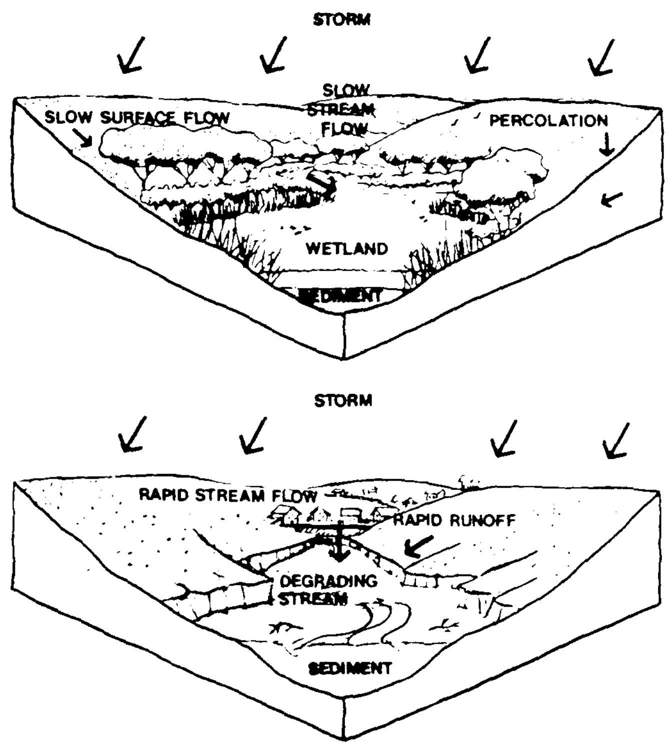

Figure 3— Comparison of a natural watershed where water flows and sediment are in balance and an urban area where impervious surfaces cause increases in water flow, upsetting the balance and resulting in sedimentation of the wetland and loss of riparian forest.

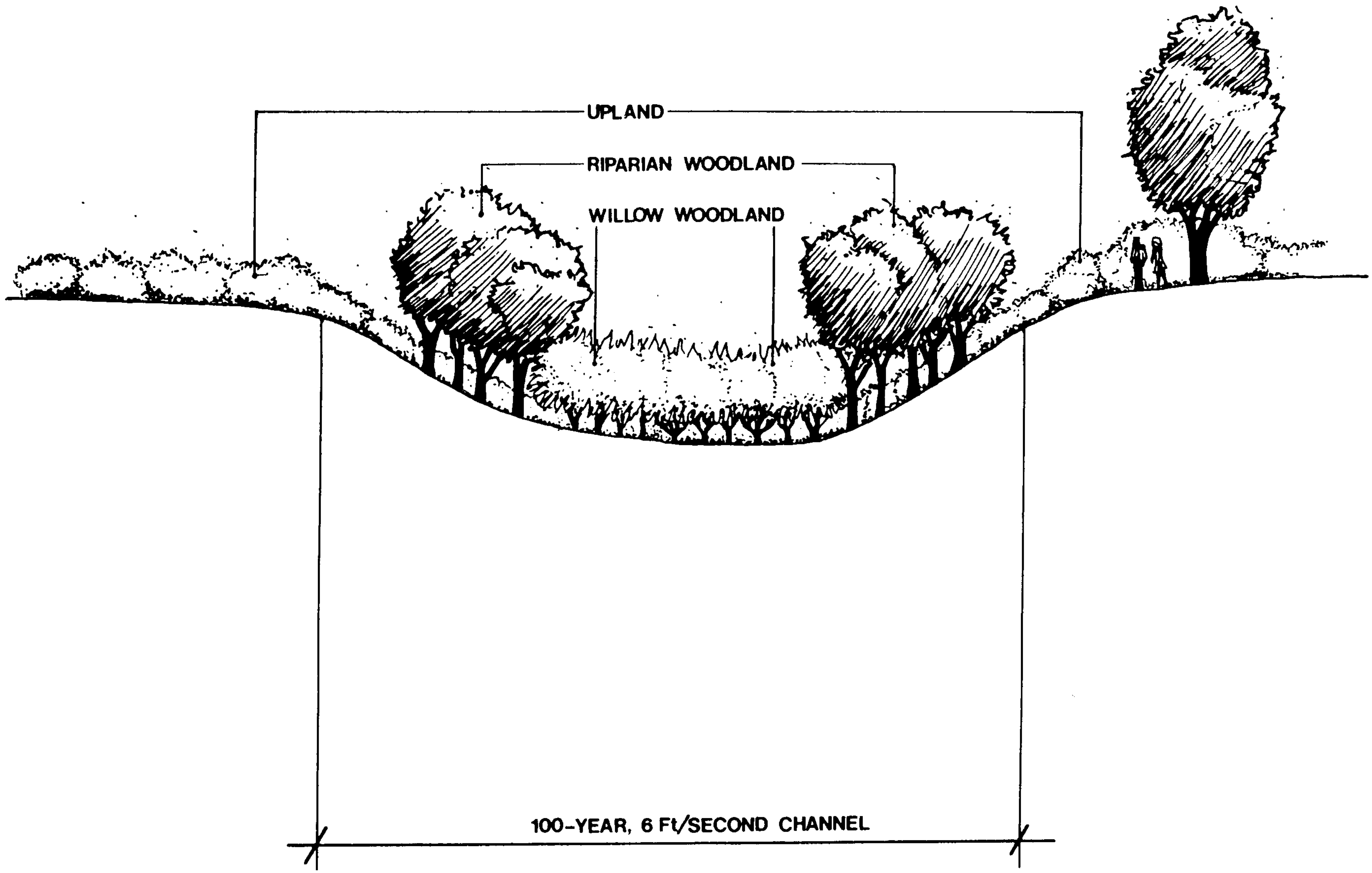

Figure 2— Cross Section of Proposed Enhanced Buena Vista Creek Channel

This channel design is revolutionary and downright frightening to many civil engineers used to the standard trapezoidal cement channel. The mathematical calculations inherent in this design are complex and use the current state of the art in hydraulic and hydrologic modelling. But this design will serve as a model for many of the surrounding communities whose waterways and wetlands suffer the same problem. In addition, the local government intends to re-develop its downtown facing onto this green corridor, an encouraging trend.

A final recommendation of the plan is to preserve a large riparian forest along the lower creek near the lagoon. Preserving natural floodplain even when it involves expensive acquisition is a more cost-effective sediment control measure than dredging and disposing of spoils from the lagoon.

The Conservancy is currently implementing the plan recommendations by having detailed creek designs prepared in conjunction with the city of Vista. Several of the detention basins have been built or are under construction. The local government has cooperated in using this vegetated channel design largely because of the permit requirements of the Army Corps of Engineers and streambed alteration agreement Terms of the California Department of Fish and Game requiring riparian mitigation.

The Conservancy intends to maintain highly accurate records for design, construction, and maintenance costs for this channel for comparison with standard hard lined channels. Through the implementation of this plan the life of Buena Vista Lagoon will be extended by at least a hundred years, and Buena Vista Creek will become a restored riparian habitat.

Tomales Bay

The Problem

Tomales Bay is one of the largest estuaries in California. Its 223 square-mile watershed is composed of agricultural land, dairies and cattle ranches. However, despite the differences in land use, the Tomales Bay watershed suffers from many of the same problems as that of Buena Vista Lagoon. The two primary tributaries, Lagunitas Creek and Walker Creek, have filled Tomales Bay with tons of sediment and the deltas of these creeks continue to grow at the rate of 35-50 feet per year (Figure 4). The source of this sediment can be traced to historic and present land uses.

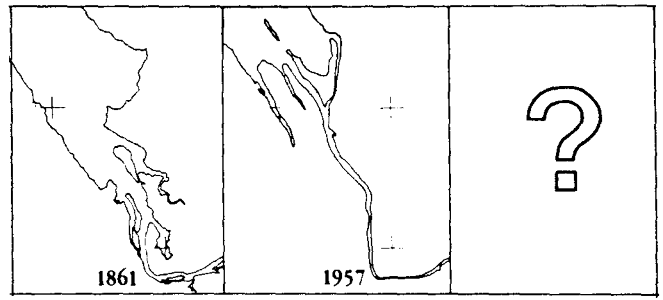

Figure 4– The Lagunitas Creek delta progressively stretches into Tomales Bay at the rate of 50 feet a year.

In the last 200 years, the Tomales Bay watershed has undergone a number of significant changes. When the first Europeans arrived, its watershed was largely native grassland with some tracts of redwood forest oak woodland and many streams lined with riparian forest. The thick rooted native perennial bunchgrasses stayed green year round and created a thick mulch over the soil. The Spanish first introduced cattle to Tomales Bay in the early 1800's. The American influx to California brought dairy farms, sheep grazing, and potato farms. By the turn of the century, intensive grazing had practically eliminated the native grasses. Introduced annual grasses from southern Europe, North Africa and Australia, were adapted to heavy grazing and replaced the native prairie.

The displacement of native perennial grasses has had a major effect on the hydrology of the watershed. The dense perennial grasses screened the soil from surface erosion and provided a dense fertile mulch which retained moisture. Annual grasses do not provide as much erosion protection; the mulch washes away and the soil layer becomes thinner and less productive. These changes result in greater surface runoff during storms, higher soil erosion rates, and less storage of water in the soil. Higher peak flood flows occur during winter storms eroding channels and under cutting riparian forest. Summer flows in creeks are lower reducing the ability of riparian species to survive and recolonize denuded areas. Through time, the form and structure of the streams feeding Tomales Bay has significantly altered.

Historic and continued activities that have contributed to the accelerated erosion of the watershed include:

- Livestock trampling of streambanks and grazing of riparian seedlings has denuded many streams and caused streambank erosion.

- Extensive logging began in the 1860's, which exposed the soil to direct erosion and thinning of the soil mantle, as well as initiated landslides on steep slopes. Such landslides can remain active for long periods and contribute very high volumes of sediment to stream courses.

- Extensive potato farming occurred in the Tomales area during the late 1800's. Tilling of the soil for crop cultivation caused a major increase in surface erosion.

- Poorly located roads often initiate landslides, improperly designed road culverts frequently cause the formation of gullies.

- Overgrazing loss of native grasses and compaction of soils increase the rate of water runoff resulting in increased peak storm flows. These increased flows have caused severe arroyo formation along Walker Creek with nearly complete loss of riparian habitat.

- Livestock trampling of streambanks and grazing of riparian seedlings has denuded many streams and caused streambank erosion.

If current sedimentation rates continue, the tidal volume of Tomales Bay would be reduced by 10 percent over the coming 50 years. This would be a significant amount in terms of the physical size of the bay.

Erosion Control Plan

The Conservancy, working in conjunction with the Marin County Resource Conservation District, a local agency which undertakes soil erosion control projects, completed erosion control plans for the two main tributaries to Tomales Bay. As with Buena Vista Lagoon, the expense of removing accumulated sediment from Tomales Bay, far exceeds the cost of controlling the sources of erosion. Consequently the Conservancy has focused on repairing the causes of erosion, a task which involves extensive riparian revegetation. These plans surveyed each subwatershed, mapping erosion problems and their prospective repairs. The Conservancy has granted over $1,200,000 dollars to implement these plans.

Lagunitas Creek, which drains the southern portion of the watershed carries large sediment loads. Its water shed includes some agricultural land, state park land and many rural residential developments. Sediment comes from inadequately drained roads, gullies, streambank failures and intensive uses such as horse corrals next to the creek.

Walker Creek, which drains the northern portion of the watershed, is almost entirely agricultural land. Erosion occurs in the channel itself; the creek is wide and braided with 15 foot vertical banks and limited riparian forest, despite year-round releases from an upstream reservoir. The Walker Creek watershed also shows highly compacted soils, numerous large gullies and roads with inadequate drainage.

Repair of many erosion sites has involved a great deal of riparian revegetation often combined with structural stabilization measures. In many instances water flows or erosion problems are too great to be stabilized with plantings alone; rock or other hard surface stabilization is required to accompany plantings.

Repair of large gullies, which can erode tons of sediment in a single storm is a major component of the plans for both creeks. Gully repairs typically consist of rock, concrete or redwood checkdams-small structures which produce a staircase of small hydraulic drops within the gully and significant slowing of water flows. Once the water is slowed and its erosive force lowered, each stair step fills in with sediment. Willow sprigs are planted along side walls and headcuts. Willow can grow in near vertical areas and is easy to establish. The gully is then fenced to exclude livestock so that riparian plants can get a firm hold. Often road repairs accompany gully repair as inadequate road drainage or poorly located or graded roads can cause gullies to form. Riparian vegetation alone can be used to stabilize smaller, less incised gullies.

Streambank stabilization and revegetation, is a major component of the program, on Walker Creek the it there it will be a three-step-process. Until the problem of increased peak stormflows is solved, riparian vegetation along the creek will continue to be undercut and wash away. The easiest way to slow channel downcutting may be the installation of large concrete checkdams (grade stabilization structures) which produce a hydraulic drop and slow water as do small checkdams. These checkdams will be located in the upper tributaries. Along the lower portions of the channel rock riprap bank stabilization combined with riparian plantings will be used. Simultaneously, range management plans for ranches in the watershed are being discussed with landowners. The purpose of these plans is to alter the concentration of livestock on already compacted soils through cross-fencing of pasture, development of additional water supplies, fertilization planting of native bunchgrasses and year-round rotation of livestock. If overall vegetative cover can be increased through these measures the stormwater percolation may increase and peak stormwater flows be reduced. Once the erosive problems along the creek are reduced, intensive planting and exclusionary fencing can begin. Establishment of a thick riparian forest will be aided by the year-round flow of water and should greatly help to stabilize steep banks and reduce sediment deposition in Tomales Bay.

Since the completion of the Lagunitas Creek restoration project in 1986 our monitoring has compared the many different types of repair measures installed. Many of the most successful repairs combine some structural control measure (small checkdam rock riprap) and planting. Deep incised gullies are now forests of willows and Tomales Bay receives less sediment. The repairs on Walker Creek are in their third year and are expected to take another three to four years to complete.

Conclusions

The State Coastal Conservancy through our mandate to preserve and enhance coastal wetlands in California has become involved in extensive restoration projects in coastal watersheds. Our studies and experience have found that repairing the sources of erosion is a more cost effective strategy than attempting to dredge sediment from the estuary or wetland. The repairs cited in the two examples involve stabilizing the stream system using riparian forest and limited structural control measures. Watershed management and use of the natural function of riparian forest to slow water and trap sediment is a new strategy in preserving coastal wetlands. As the Conservancy continues to implement these types of projects this strategy will benefit both the riparian and coastal wetland resources.

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RESTORING AND MAINTAINING RIPARIAN HABITAT ON PRIVATE PASTURELAND[1]

Nancy Reichard[2]

Abstract: Protecting riparian habitat from livestock grazing on private land is a complex task that requires paying attention to sociological and economic as well as physical and biological factors. Six livestock exclusion fencing projects on private property in northwestern California are described. The importance of long term maintenance and the need for landowner incentives are discussed. Significant gains may be made via a statewide, coordinated effort to encourage the protection of riparian habitat on private property.

A muddy stream devoid of riparian vegetation and trampled by livestock is a raw wound, in the eyes of those knowledgeable of stream and stream-side ecosystems. The wound can be healed if fences are constructed to exclude livestock from the riparian corridor. The cessation of grazing allows existing or new vegetation to grow. Although there may be several physical and social challenges to creating a fenced riparian corridor on private property (Reichard 1984), once these are overcome, the benefits may be observable within months, due to the resilient nature of some riparian plant species.

The Natural Resources Services division of Redwood Community Action Agency (RCAA) constructed six livestock exclusion fencing projects on private property between 1982-1986. The long term success of these projects depends almost entirely conmaintaining an intact fence — simple inconcept but complex in practice.

This paper summarizes RCAA projects and recommends measures for improving riparian habitat protection.

The North Coast Setting

Because of topography and land use patterns, streams which flow through pastures in Humboldt and Del Norte Counties are almost entirely coastal. In this paper, "pasture" refers to a fenced plot of relatively level land used for grazing livestock, usually relatively intensive due to the limited size of the plot. Most pastureland in this region is used by dairy and beef cattle operations. Residential area streams may be impacted by numerous small pastures used for the "family" horses or cows.

Several dozen coastal streams in Humboldt and Del Norte Counties have reaches that lack riparian vegetation, due at least in part to livestock impact (Streamfellow and Reichard 1983). Many other stream reaches are bordered only by a residual canopy of vegetation. We have observed, as has Shanfield (1984) and others, that riparian stands to which livestock have free access usually lack understory vegetation.

Little work has been done to describe the ecology of North Coast riparian systems. In his thesis work on habitat relationships among riparian forest birds in the Eel River Delta, Kelly (1987) provides one of the only detailed analyses. Undisturbed, mature, North Coast riparian vegetation typically is comprised of a dense, diverse understory of herbaceous and woody plants. A canopy of deciduous and/or coniferous trees may include Sitka spruce *(Picea sitchensis),* redwood *(Sequoia sempervirens),* black cottonwood *(Populus trichocarpa),* red alder *(Alnus rubra),* bigleaf maple *(Ater macrophyllum),* and willows (*Salix* spp.) Younger stands have less species diversity. Willows are typical pioneers in disturbed areas. (Kelly 1987, Ray and others 1984, Roberts 1984).

Projects Implemented by RCAA

The livestock exclusion fencing projects undertaken by RCAA have enclosed a total of approximately 37 hectares of habitat, along six different streams (fig. 1). Approximately 10 hectares are riparian and 5 are instream. The projects were funded by either the State Coastal Conservancy (SCC) or the Department of Fish and Game (DFG). Landowners and the California Conservation Corps (CCC) provided substantial in-kind contributions to several of the projects. At all of the project sites, most of the original riparian vegetation had been cleared at least a generation before the present landowners took charge. Some project characteristics are presented in table 1. Figures 2-5 depict typical pre- and post- project conditions and will be referred to later.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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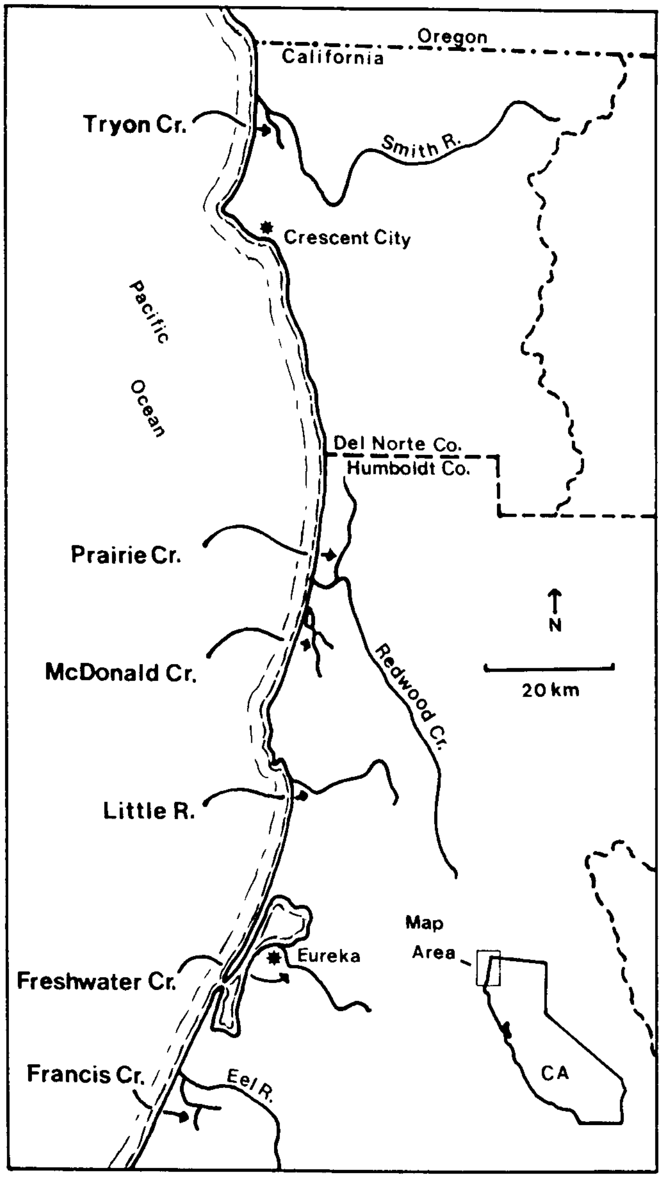

Figure 1– Location of RCAA livestock exclusion fencing projects.

All fences were constructed with split redwood posts and five strands of barbed wire. Vegetation was planted at all sites. Willow cuttings from on-site, red alder, and sitka spruce were planted predominantly, along with big leaf maple and redwood. The tree seedlings were obtained from commercial nurseries in northern California and southern Oregon.

Project sites are monitored informally by RCAA staff, except at McDonald Creek, where a monitoring project is under way as a part of the SCC contract. Observations at McDonald Creek are being made annually for a 5-year period, including stream channel cross sections, vegetation transects, and photographic documentation. Baseline data collected at project sites included stream reach maps of McDonald and Freshwater Creeks, and a year-long avian census on Tryon Creek.

Five of the projects have to date resulted in the exclusion of livestock from the fenced riparian corridor, and in the subsequent establishment and growth of significant numbers of native woody plants. Livestock have not yet been completely excluded from the Little River site.

Maintaining these projects is addressed in agreements that RCAA has executed with each of the landowners. Both SCC and DFG require that a license agreement between the landowner and the contractor (RCAA) be recorded on the landowner's property deed. In the agreement, fencing and planted vegetation are defined as "improvements." The landowner agrees to maintain the improvements and not to allow their alteration, for a period of 20 years for an SCC-funded project and 10 years for a DFG project. The agreements are recorded so that they will be effective even if the property changes ownership.

In practice, maintaining most of RCAA's projects has been a collaborative effort. The CCC has provided invaluable assistance with maintenance and improvements at the Tryon, Prairie, and McDonald Creek sites. A commercial fishing group has helped to maintain the Little River project. The landowners have played a minor to major role in project maintenance. Their attention to maintenance is proportional to their level of vested interest in the project, and can also vary, dependent on whether or not the landowner lives on the property, leases it, or has a caretaker.

Of all of RCAA's projects, Tryon Creek has the most supportive landowner. As a fish and wildlife enthusiast and a third-generation cattle rancher, the landowner had for several years wanted to reestablish vegetation along the stream. Financial support from the SCC made the project possible. Substantial instream habitat improvements were also made as a part of this project.

The Prairie Creek landowner was primarily interested in a project because he was losing pasture to streambank erosion. If he had been able to finance bank stabilization on his own, he probably would have used traditional, non-vegetative measures. He had, in fact, started to install some car bodies along the bank several years ago, but was halted by DFG.

He was willing to convert several acres of pasture into a protected riparian corridor in return for our publicly-funded services used to apply various bio-technical stabilization measures to his banks (figs. 2 & 3). Unlike many landowners RCAA has talked with, he recognized the role that vegetation can play in maintaining streambank stability. As a secondary benefit, he knew that streamside fencing would trap flood-borne woody debris, which he previously had to clear from his pastures after each flood.

Table 1— RCAA livestock exclusion fencing projects.

Stream name	Tryon	Prairie	McDonald	Little R.	Freshwater	Francis
Date completed	1986	1985	1983	1984	1986	1983
Funding source	SCC	SCC	SCC	SCC	DFG	SCC
Management[1].	Resident	Resident	Mgr.	Non Res	Mang'r	Resident
Fence length (m)[2]	4,100	2,650	2,440	79	610	335
Set-back(m)[3]	12	3	11	1	8	12
Hectares enclosed:[4]						
Riparian	4.8	0.8	2.8	0.	0.4	0.4
Active channel	1.2	2.4	0.8	[5]n/a	0.4	0.2
Total	6.0	3.2	3.6	0.	0.8	0.6
Water accesses[6]	1	2	3		1	1
Bank stabilization[7]	no	yes	yes	no	yes	no

[1] Property managed by, in order: resident landowner, res. manager, non res. landowner.
[2]Includes fence on both sides of stream, where applicable.
[3]Average, from edge of active channel.
[4]All acreages are approximations.
[5]Only one side of the channel was fenced. Stock have access to the stream from the other
[6]Barriers that allow access to or across the stream but not into the fenced corridor.
[7]Streambank stabilization measures applied as part of project.

Figure 2— Bank stabilization along Prairie Creek. Willow logs and hog wire were staked to what was a bare, eroding streambank. January 1984.

Both of these projects allowed the landowners and public-interest groups to work together to solve resource management problems and to learn from each other. Symbolic of these opportunities is the day at the Prairie Creek dairy ranch that a CCC crew of primarily urban kids from southern California, RCAA staff and the landowner planted several thousand trees, saw steelhead spawning, and watched a calf being born in the barn.

The McDonald Creek property was being managed for both agricultural and recreational uses. Establishing trees along the stream and improving fish habitat makes the area more attractive to visitors, which was an acceptable trade for the loss of pasture (figs. 4 & 5).

The initial project that RCAA implemented included fencing and planting only. Subsequently, we determined that streambank erosion was going to take out some of the fencing and vegetation before natural healing processes could take place within the corridor. Additional SCC funds and CCC labor enabled us to apply rock riprap and additional vegetation, which has effectively controlled most of the erosion.

Figure 3— Same site as in figure 2, June 1984. Note livestock exclusion fencing installed along top of streambank. As of 1988, willows and alders at this site were six to eight feet tall.

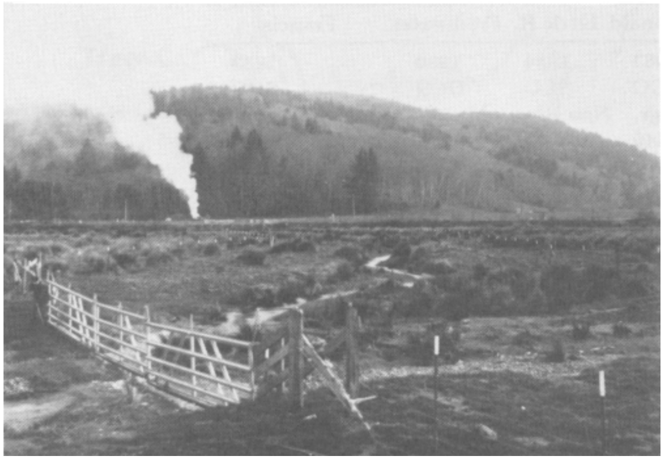

Figure 4— McDonald Creek, December 1982, just after fencing installed. View is looking up the perennial north fork, mainstem entering from right. Metal gates in the foreground are suspended from a cable, allowing water and flood-borne debris to pass under them, while preventing livestock from entering the protected corridor.

Figure 5— McDonald Creek, same site as in figure 4, September, 1987. Planted and volunteer red alder is the predominant vegetation.

The barbed wire fence constructed along the right bank of Little River does not prevent livestock from crossing the channel from another landowner's property on the left side during low water. Fortunately, because livestock are not always present on the left side and due to steep banks and pools in some areas, stock have not had a complete or continuous impact on the vegetation within the fenced corridor. Some of the planted red alders and Sitka spruce are thriving. The project was acceptable to the landowner primarily because the exclosed area is not high-quality pasture.

A proposal to fence the left bank, although acceptable to the (different) landowner, was met with resistance from the pasture lessee. A barbed wire fence was not acceptable because of the potential for injury to a spirited horse. A pump was not acceptable as an alternative source of drinking water for livestock because it would not be as reliable a water source as the river.

An electric fence powered by a solar charger was installed, but did not stand up to woody debris carried into it by streamflow, and dropped on top of it by beavers and overhanging trees. Several shorts were caused by growing vegetation which came into contact with the fence wires. The fence was removed when it became clear that with a sympathetic but absentee landowner, an unsympathetic lessee, and a need for frequent maintenance, it was not going to be effective.

As a partial substitute, we designed five "willow pods" — oval exclosures averaging 3 meters wide by 12 meters long. The exclosure fence was made with smooth wire and with live willow branches for fence posts. Willow cuttings were planted within the pods. After two years of growth, substantial die-off occurred, possibly due to an inadequate freshwater table and/or to contact with saline water (the site is along the upper part of the Little River estuary.) Cows were able to reach through the smooth wires to browse about two feet within the pods. This reduced the area of effectively protected vegetation noticeably in these relatively small nexclosures. Two pods are still functioning and growing.

A commercial fishing organization which operates salmon rearing and habitat restoration projects in the upper watershed planted big leaf maples along the right bank and is planning to construct a strong fence along the left bank in 1988. It is also maintaining contact with the landowner, to encourage the ultimate dedication or sale of the property for conservation purposes, so that livestock exclusion in this challenging location may ultimately be unnecessary (Farro 1988).

The Freshwater Creek landowner was willing to "contribute" pasture for the sake of aiding fisheries restoration. It was probably significant that the property was not a primary source of his income. The Francis Creek landowner agreed to a fencing project as part of a package that included streambank stabilization at an adjacent site.

The Challenges

The physical and biological challenges to restore riparian habitat on private pastureland are minor compared to a broader socioeconomic challenge: securing the stewardship of natural resources on private property when there is no legal or other institutional mechanism for restoring and protecting these resources. In California, the impact of livestock to riparian habitat on private land is virtually unregulated (Sommarstrom 1983). Unless that situation changes, protecting the habitat cannot occur without the voluntary cooperation of the landowners.

The total area of privately owned riparian habitat that is impacted by livestock may not be very large; however, along a given stream the damage may be significant. The great number of people involved is both a problem and an opportunity. Landowners with impacted streams can be directly responsible for restoring and protecting the natural resources on their land. Better strategies for encouraging that responsibility need to be developed.

Like other resource conservation measures on private land, there has to be incentive and means to implement, and the means and the will to maintain the improvements. Landowners may or may not perceive benefits to be obtained from an exclusionary fencing project. Besides those previously mentioned, benefits of cross-fencing and reduced livestock drowning hazard may be provided.

Livestock exclusion fencing will always cost the landowner, in reduced pasture acreage. A subsequent cost will be the maintenance of the fence. RCAA has negotiated for fencing projects with at least 12 landowners, all of whom sooner or later decided that the costs outweighed the benefits. In a few instances, persistence has paid off, particularly as landowners become more interested in playing a positive role in the salmon and steelhead trout restoration "movement."

Constructing a fence is only the first phase of protecting the streamside corridor. A fence must be inspected regularly and repaired promptly when damaged. Damage from hungry cows in the corridor for just one day can be substantial. (Cross-fencing within the corridor can limit such damage to the segment with the hole in the fence.) Platts (1984a) presents average costs of $60-$200 per mile per year for fence maintenance.

Using alternative grazing systems to provide riparian habitat protection in lieu of fencing (Platts 1984b) may have applications in some pastureland situations. Implementing and maintaining an alternative system on private property may be at least as challenging as a fencing project.

Recommendations

Protecting riparian habitat on private pastureland presents unique opportunities and challenges. A statewide, coordinated effort to identify and promote means to restore and maintain this habitat could be very effective, especially if it included landowner representatives.

Inventorying pastureland riparian habitat, identifying the potential for restoration, and assessing the costs and benefits of doing so, would help determine just how aggressively this component of riparian habitat restoration should be pursued and what the priorities should be.

Because of the nature of the problem, negative incentives — i.e. regulations — may not be very effective or manageable. As Sommarstrom (1984) put it, mandating fencing might be like trying to legislate morality. On the other hand, there is room for progress in developing and using positive incentives, ranging from education to tax benefits.

A compendium of information regarding conservation easements and tax considerations related to livestock exclusion would be useful for both landowners and promoters. Educational campaigns through agricultural, equestrian, and other organizations could make "riparian habitat" a household concept among riparian landowners.

Conclusions

Management of riparian habitat on private pastureland is a broadly interdisciplinary topic. Its complexity is both a blessing and a curse — solutions to the problems of protection are not simple, but they hold the promise of improved public/private cooperation. This area of riparian habitat management warrants special and focused consideration by those interested in seeing that the habitat is restored and protected.

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RECOVERY OF RIPARIAN VEGETATION ON AN INTERMITTENT STREAM FOLLOWING REMOVAL OF CATTLE[1]

Jerry J. Smith[2]

Abstract: In 1984 – 1987 the recovery of riparian willows (Salix spp.) *and sycamores* (Platanus racemosa) *was studied on two short, intermittent stream sections in a newly acquired portion of Henry W. Coe State Park in central California. Prior to removal of cattle in 1983, the plots contained mature sycamores, one young sycamore, and five willows. By 1985 over 320 willows, 16 sycamores and 1 cottonwood* (Populus fremontii) *had appeared, and basal sprouts had developed on the mature sycamores. Young willows and sycamores grew slowly, and establishment and growth generally ceased as surface flows disappeared. Because of slow growth at the sites, a significant willow corridor is probably only possible in the absence of cattle browsing.*

Grazing has been found to have severe effects upon riparian habitats (Meehan and Platts 1978). Altered species composition and vegetation density, along with streambank erosion and channel widening, have stimulated research on fencing (Platts and Wagstaff 1984) and seasonal regulation of grazing (Bryant 1985; Siekert and others 1985) as ways to reduce impacts. However, most studies of grazing impacts and treatment strategies have been conducted on public lands outside of California. A century or more of intensive private ranching has probably substantially changed parts of the California landscape, but left us with few undisturbed areas with which to judge the impacts of cattle.

In 1982 the California Department of Parks and Recreation acquired two former ranches as additions to Henry W. Coe State Park. Cattle grazing was halted in 1983, but a heated public debate over the general plan for the park included consideration of the desirability of renewed grazing. The absence of documented evidence for grazing damage in central California was used by some as proof that no damage occurs. The removal of cattle in 1983, however, provided an opportunity to assess the effects of longterm cattle grazing.

Study Area

North Fork Pacheco Creek is a fourth order stream in the eastern portion of Henry W. Coe State Park in the Mt. Hamilton Range of central California. Although a tributary to the coastal Pajaro River, the stream is east of and in the rain shadow of both the coast range and the highest ridges of the inner coast range. Vegetation within the 200 to 800 m high watershed is primarily: chaparral, dominated by chamise (*Adenosloma fasciculatum*); oak woodland, dominated by blue oak (*Quercus Douglasii*), buckeye (*Aesculus californica*), California bay (*Umbellaria californica*), and digger pine (*Pinus sabiniana*); and grassland, dominated by introduced annual grasses (*Avena spp. and Bromus spp*). The stream is intermittent and generally dries to a few isolated pools by early to mid summer. During the study surface flow ceased by late June of 1984, May of 1985, late May of 1986, and March of 1987. At the start of the study, woody riparian vegetation consisted almost exclusively of mule fat (*Baccharis viminea*) and mature sycamores (greater than 25 cm in diameter).

Methods

In March 1984 all young willows greater than 5 cm tall in a 35 m section of North Fork Pacheco Creek (study area A) were tagged with numbered Floy tags, and heights of longest stem recorded. The plot was resurveyed again in July and October 1984, May and October 1985, and October 1987, and heights of tagged and untagged willows recorded. New willows taller than 30 cm and a portion of shorter willows were tagged during resurveys, and evidence of browsing and general plant health (dead branches, desiccated leaves, etc.) were recorded during each survey. In May 1985 study area B, a 300 m long stream section 0.1 km upstream of study area A, was established, and all willows, cottonwoods, and young sycamores were tagged with numbered Floy tags, and heights and health recorded. Study area B was resurveyed in October of 1985 and 1987.

Five willows and one young sycamore were present in the streambed between the two study areas prior to removal of cattle in 1983. These 6 young trees plus 20 associated mature sycamores were cored with an increment borer to determine approximate ages of the trees. Ages determined from cores were considered approximate for the young trees, as subsequent studies suggested that several years of suppressed growth, with possibly no growth rings, could have occurred during early years due to cattle browsing. Ages of mature

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sycamores were approximated by extrapolating growth rates found in the outer portion of the core to the rotted interior found in all trees. Cores were coated with phloroglucinol to improve their readability.

Numbers of basal sprouts on mature sycamores were counted on 50 trees in October 1984 and October 1985 for comparison with 1983, when sprouts were absent. Sprouts were not counted in October 1987, but general observations were made on condition of sprouts within the two study areas.

Results

Photographs of study area A taken in April 1983 showed no plants larger than 30 cm, other than mulefat and mature sycamores, but by March 1984, 70 willows to 130 cm high were found (table 1). By July of 1984, 271 willows were present, with 3 exceeding 150 cm tall. No new willows appeared by October and two tagged willows had died. In 1985, no new willows appeared and 26 died. By October 1985, nine willows exceeded 150 cm in height and the tallest was 265 cm high. By October 1987, only 86 willows remained, with most small willows apparently buried or washed away by an intense February 1986 flood. Fifteen willows died in 1987 due to desiccation.

Photographs of study area B in April 1983, showed no plants larger than 30 to 50 cm tall. By May 1985, 45 willows, with two-thirds taller than 1 m, were present (table 2). Fifteen young sycamores and one cottonwood were also present. By October of 1985, seven additional willows and one additional sycamore were present. Two new sycamores appeared in 1987, but Seven willows and two sycamores were apparently lost to 1986 flooding. Study area B had a lower density of young trees than study area A, but the trees grew faster. By October 1987, the majority of willows and all but 1 sycamore exceeded 1 m in height, and 12 trees exceeded 3 m in height (table 2).

Table 1 – Heights (cm) and numbers of willows in study area A on North Fork Pacheco Creek.

	Date					
	1984			1985		1987
Height	Mar	Jul	Oct	May	Oct	Oct
5 - 9	7	73	65	45	10	7
10 - 19	35	63	67	53	38	8
20 - 29	6	40	43	37	51	5
30 - 49	13	46	45	67	74	23
50 - 99	8	36	36	38	49	23
100-149	1	10	10	11	12	13
150-199		2	2	3	5	4
200-299		1	1	1	4	2
300-399						1
Totals:	70	271	269	255	243	86

Table 2 – Heights (cm) and numbers of willows and young sycamores in study area B on North Fork Pacheco Creek.

	Willows			Sycamores		
	1985		1987	1985		1987
Height	May	Oct	Oct	May	Oct	Oct
5 - 49	3	10	5	1	2	
50 - 99	12	12	13	2	2	1
100-149	5	3	6	2	2	2
150-199	8	11	4	4	4	2
200-299	13	9	8	5	3	8
300-399	4	6	8	1	2	1
400-499					1	2
500-599		1	1			
Totals:	45	52	45	15	16	16

Most willows tagged in March of 1984 showed substantial growth by July, despite limited browsing by rabbits and deer (fig. 1). Surface flow in study area A was gone by late June of 1984, and few willows showed growth between July and October (fig. 2). All willows showed some browsing by October, and some larger willows suffered limited damage from sparring male deer. In 1985 surface flow ceased by May in both study areas, and only larger willows and sycamores showed May to October growth (fig. 3).

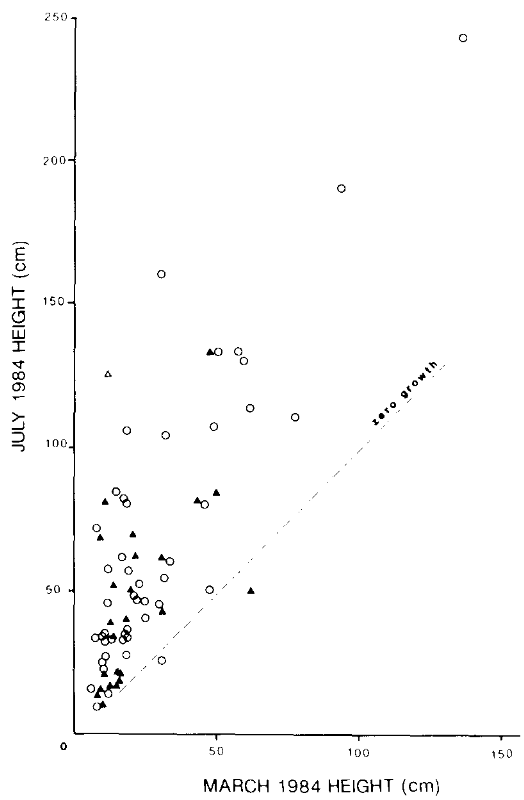

Figure 1- Growth of browsed (triangles) and unbrowsed (circles) willows from March to July 1984 in study area A.

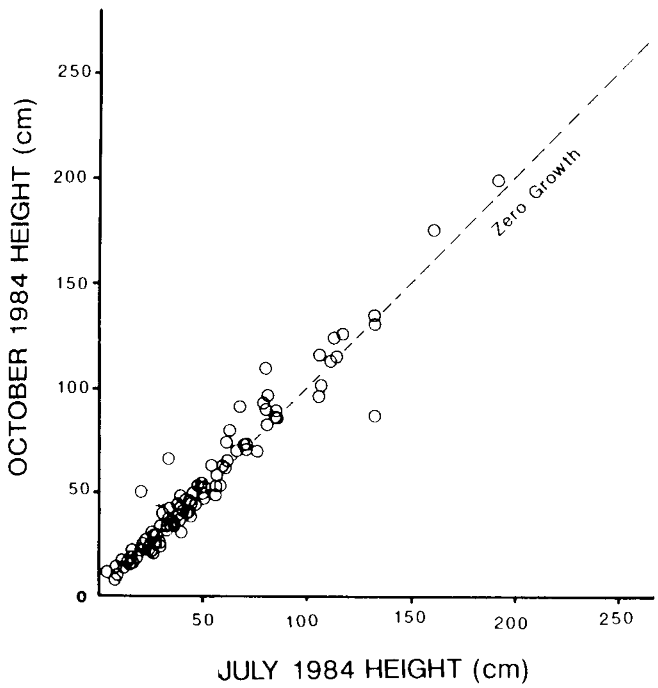

Figure 2– Growth of willows from July to October 1984 in study area A.

From October 1985 to October 1987 willow recovery was hindered by browsing by trespass cattle. Although few cattle were present, they spent much of their time along the stream. The problem was especially pronounced in 1987, when nine cattle were present on and near the study areas. Although 1986 was a relatively wet year, growth of willows from 1985 to 1987 was generally poor, especially on study area B, where the cattle spent more of their time (fig. 4). In study area B, only half (21 of 42) of tagged willows showed any growth from October 1985 to October 1987, while nine willows were reduced 20 to 70 percent in height by severe cattle browsing. Willows 1 to 2 m high in 1985 suffered most, with 8 of 12 being reduced in height and 4 being reduced more than 40 percent. In study area A, heavy 1985 – 1987 tag loss limited height comparisons, but all 4 willows which were 1 m to 2 m high in October 1985 and retained tags were reduced in height by October 1987 (5 to 45 percent). Although all willows taller than 3 m showed some growth from 1985 to 1987, most, including the five large willows present prior to cattle removal, showed pronounced browse lines in 1987.

On the 50 sycamores examined for basal sprouts only a total of 46 sprouts were found in October 1984, but by October 1985 the total had reached 197. Sprouts were present on all but 2 trees by 1985. Although trespass cattle heavily browsed willows, there was no evidence that they browsed sycamore basal sprouts or young sycamores in 1987. All but one young sycamore showed growth from October 1985 to October 1987, with 5 of 14 showing height gains of 50 percent or more (fig. 4). The sycamore showing no height gain was broken off near the base, apparently during the February 1986 flood.

Three of the five willows present before cattle removal were dated by cores to 1977. The other two were dated to 1978. The single young sycamore present prior to cattle removal was dated to 1977. Estimated ages of mature sycamores ranged from 79 to 135 years.

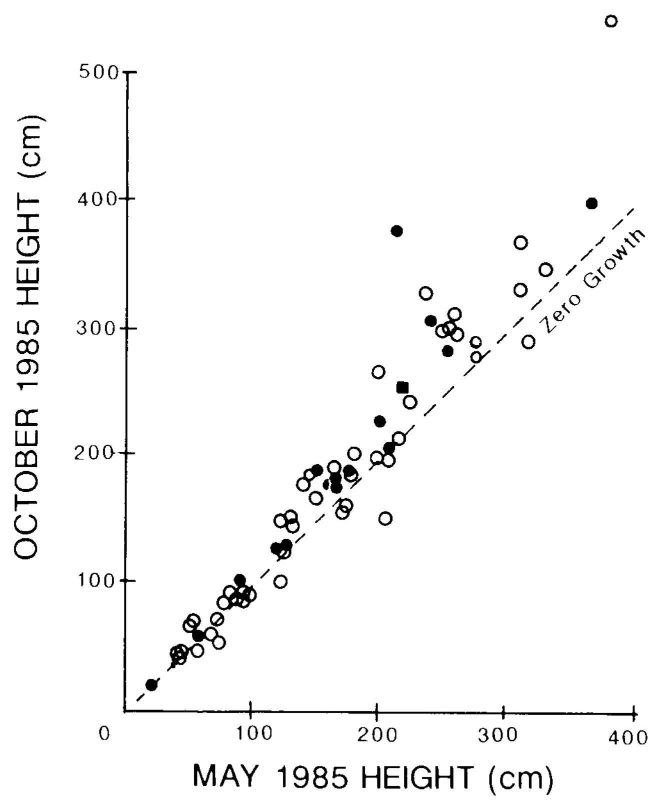

Figure 3– Growth of willows (open circles), sycamores (closed circles), and cottonwoods (square) from May to October 1985 in study area B.

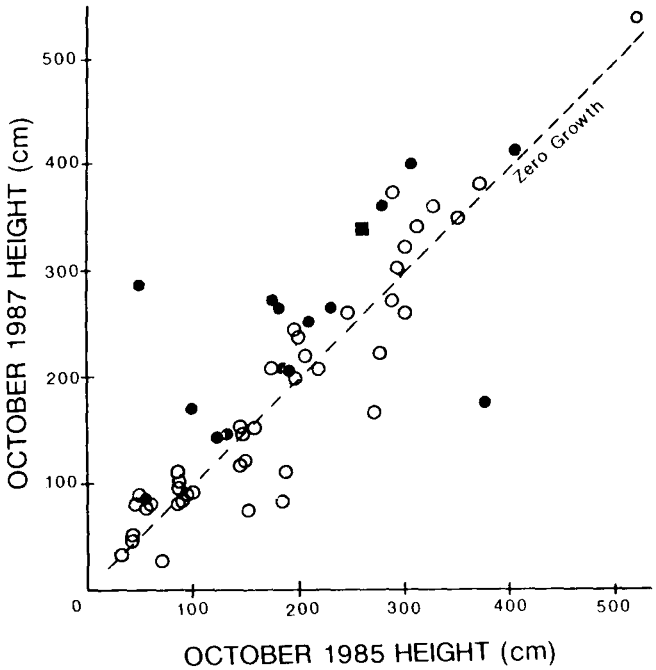

Figure 4— Growth of willows (open circles), sycamores (closed circles), and cottonwoods (square) from October 1985 to October 1987.

Discussion

Prior to removal of cattle, the study sections on North Fork Pacheco Creek contained primarily sycamores germinated prior to 1910 and unpalatable mule fat. The single young sycamore present and three of the five willows date to approximately 1977, and the other two willows date to 1978. It appears that successful survival of young willows and sycamores on this intermittent stream has been limited to a single period within the last 70 or more years of intensive cattle use. The isolated survival of a sycamore and possibly three or more willows in 1977, the second year of a severe drought, is a surprising pattern for riparian species. However, poor forage conditions and surface water availability during the drought resulted in removal of cattle from ranches in the area in 1977 (Peter Andresen, pers. comm.), and 1978 was a wet year, apparently allowing successful establishment.

Most of the new willows and sycamores appeared in 1984, and total numbers actually declined from 1984 to 1987 (table 1). The loss of established plants was due to the 1986 flood and to desiccation. The lack of significant recruitment in 1985 and 1987 was apparently the result of wide year to year variation in water availability. Successful willow and sycamore germination sites were mostly at the tails of pools and along riffles, sites where seeds are likely to lodge, and where subsurface water remains as flows decline. In 1984 surface flows lasted into late June. In 1985 — 1987 surface flows ceased by May, providing less time for successful seedling establishment. Desiccation losses of established willows in study area A were also much greater in 1985 (26 deaths) and 1987 (15 deaths) than in 1984 (2 deaths).

The presence of 131 willows, 16 young sycamores, and 1 cottonwood three years after the removal of cattle indicates that, despite the intermittent character of the stream, portions of North Fork Pacheco Creek have the potential to develop significant riparian vegetation in the absence of cattle. Growth rates, however, were low, and germination and growth of small trees was generally limited to the relatively brief period of surface flow. Because of slow growth and infrequent germination success, willows were unable to establish or survive previous intensive cattle browsing. Even light or seasonal cattle presence might be sufficient to prevent establishment of a significant willow population; in 1985 — 1987 many established willows suffered severe hedging by only a limited number of trespass cattle.

Young sycamores and basal sprouts on mature sycamores are apparently not preferred food and were not browsed by the few trespass cattle present in 1985 — 1987. However, young sycamores were absent and basal sprouts very rare or absent during the period of intensive grazing prior to 1984. The sycamore population might be able to maintain itself under a regime of light cattle stocking or in a wetter area, where young sycamores grow faster. However, previous persistant heavy browsing by cattle apparently eliminated recruitment on this intermittent stream. Although sycamores are presently the "typical" riparian tree of many intermittent streams in central California, widespread and intensive cattle grazing may be jeopardizing recruitment. Longevity of sycamores has not yet been studied, but all 20 of the 79 to 135 year old sycamores cored on North Fork Pacheco Creek had partially rotted trunks. For many grazed intermittent streams in California, lack of recruitment and loss of older sycamores makes barren streamsides a real possibility in the future.

Acknowledgements

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GIANT REED (*ARUNDO DONAX*): A CLIMAX COMMUNITY OF THE RIPARIAN ZONE[1]

John P. Rieger and D. Ann Kreager[2]

*Abstract: Active management of coastal streams is needed to ensure the continued existence of significant riparian systems in Southern California. The concept of a dynamic self-replacing plant community is no longer a truism there. In the past decades one exotic species in particular, the Giant Reed (*Arundo donax *L.) has had an ever-increasing negative role in the succession of riparian systems. The aggressiveness of this exotic has enabled it to invade disturbed areas along many water-courses of Southern California. Giant Reed is also capable of invading mature woodlands, interrupting the cycle of regeneration normally experienced in river systems. Giant Reed stands can become climax communities, replacing natural riparian habitats. Without active management of the vegetation, the survival of many riparian residents, including some endangered species, may be at risk. Mitigation by replacement of lost habitat must be combined with proper management of the areas surrounding those sites lest Giant Reed communities claim much new acreage.*

The floristic structure and composition of riparian forests can provide examples of developmental patterns and successional stages within a biotic community that may be indicative of the system's future. Because vegetation dynamics of a riparian system remain in a state of perpetual succession in part due to the reshaping of the riverbed by storm events and less frequent high flood events, it may follow that plant succession is defined by the presence or absence of individual species.

Disruption of vegetational succession by social, commercial, and agricultural development can alter the physical and biotic composition of a riparian system to the extent that natural regeneration often cannot occur, thus encouraging the proliferation of exotic species. *Arundo donax,* or Giant Reed, was introduced to the California landscape in the 1800's. Due to the prolific nature of this grass, presence of this species within a riparian community is becoming increasingly common.

Examination of the properties of this invasive plant suggests that proper management of a riparian system which contains Arundo will involve active participation of control and eradication to maintain a heterogeneous plant community.

Methods

Three locations on the San Luis Rey River and the San Diego River in San Diego County were studied. Sites within these locations were chosen for sampling purposes to include riparian vegetation of different known ages and habitat quality.

Frequency and percent cover of Arundo were determined on a stretch of river immediately east of the State Route 76 bridge crossing on the San Luis Rey River. A 610-meter transect was established parallel to the river's edge. Some 40 7.6-meter diameter quadrats were located at random distances away from the river off this transect at 15.2-meter intervals. Measurements were made within the quadrats to estimate frequency, percent cover, and average maximum height of Arundo.

Colony distribution was determined using an aerial photograph (1:600 scale) covering an area approximately 6.1 hectares on the San Luis Rey River. A belt transect 365.9 meters by 15.2 meters (0.56 hectares) was randomly located in each of four equal cells oriented parallel to the river's edge. A digital planimeter calculated the area comprised of Arundo.

Plant maximum heights were measured at several sites on both rivers using a telescoping metric measure rod. Individual stands of Giant Reed were randomly selected and the maximum heights of each stand recorded and averaged. Maximum average heights were not obtained in riparian habitat where A. donax colonies were established 4 years or less. Average growth rates were determined by measuring plant heights at various intervals after existing Arundo stands were cut back to soil level. Ages of Arundo stands were determined from aerial photograph series and personal knowledge of the authors.

More detailed vegetation data were collected on the San Diego River east of Mast Street Bridge adjacent to Mission Trails Regional Park in Santee. Measurements of randomly located circular quadrats and line intercept analysis were used to estimate density, dominance, frequency, and cover values for all species encountered.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] District Biologist, California Department of Transportation, San Diego, Calif.; Ecological Consultant, California Department of Transportation, San Diego, Calif.

Results

A. donax growth appears quite rapid at the onset of colony establishment, especially if growth occurs from previously established rhizomes. The average maximum stem height of observed *A. donax* stands of various ages expressed in mean height and standard deviation were as follows:

	Mean[3]	SD
40 days[1]	2.5	0.28
150 days[1]	4.0	0.74
4 years[2]	3.8	1.12
35 years[2]	5.9	1.27

[1] Duration of growth since cutting of established
[2] Original stand.
[3] Height in meters.

A maximum average height of approximately 6 meters was reached in the mature riparian zone which corresponds to maximum heights reported by the University of California Agricultural Extension Service (Fischer 1983).

Growth rates of *A. donax* from established rhizomes averaged 6.25 cm/day (S.D ± 0.7) for 40 days' growth. And 150 days of growth averaged 2.67 cm/day (S.D. 0.49).

The area occupied by *Arundo donax* and its pattern of distribution along a section of the San Luis Rey River is presented in table 1.

Although the area occupied by Giant Reed throughout this stretch of established riparian habitat is relatively small, a dense distribution occurs in the belt transect closest to the riverbank. The belt transect closest to the river incorporated 97.1 percent of the Arundo encountered. Giant Reed occupied 6.0 percent of all transects studied. Quadrats sampled further from the river show a dramatic decrease in presence of Arundo.

Table 1 Distribution and Area of A. donax in transects parallel to San Luis Rey River.

Transect	1	2	3	4
Distance from river (meters)	7.3	39.1	80.3	114.5
Area comprised of Arundo (sq. meters)	1365.6	33.5	0	7.3

Table 2 - Circular quadrat vegetation analysis on the San Diego River.

	Dom.	Rel. Dom. (%)	Freq.	Rel. Freq. (%)	% Cover
Vegetation Group					
Native Trees	0.3	20.0	0.01	1.3	57.0
Native Shrubs and Herbs	0.02	1.4	---	---	11.9
Arundo donax	0.1	6.8	0.9	92.3	26.0
Exotic Shrubs and Herbs	1.5	2.8	0.1	6.4	6.4

If dominance is defined as occupation of the largest basal area per area sampled it is evident that *A. donax* within this riparian zone is dominant only in the vicinity adjacent to the riverbank. On the San Diego River, native flora was dominant and provided the greatest amount of cover of the 4 vegetation groups used to classify the riparian community. However *A. donax* was encountered far more frequently than any other vegetative group. Relative frequency of Giant Reed on the San Luis Rey was approximately 30 percent less than its relative frequency on the San Diego River and provided 10 percent less cover (table 2).

Arundo donax comprises a significant proportion of the riparian habitat on the San Luis Rey and San Diego rivers of San Diego County. Regardless of quadrat distribution, more than half of the quadrats sampled along both drainages contained Arundo. Both areas sampled were within established riparian zones however the amount of disturbance and degradation varied between drainages.

Discussion

A. donax does not invest large amounts of energy in the development of an extensive woody root or branch system which may account for its rapid rate of growth. Growth rates of 1.02 to 1.52 cm/day were recorded for *Salix goodingii* and *Salix laevigata* on the Kern and Lower Colorado River in California (B. Anderson, telephone communication). Recorded growth rates for *A. donax* are 2.1 to 4.9 times faster.

The physical presence of Arundo can inhibit to some degree the establishment or growth rate of native and exotic species often resulting in pure stands of Giant Reed. This situation can be observed readily along all the major river drainages in San Diego county. The fast growth rate and ability to attain heights of between 2.5 and 4.0 meters in less than a complete growing season assures a competitive advantage over slower growing native species. By comparison, willow trees on the Sweetwater River in San Diego county were reported to have grown 1.5 to 1.8 meters in one growing season (Rieger 1988).

Flowering in Giant Reed occurs after intervals of several years, thus propagation is primarily vegetative. Open colonies or groves are established as shoot-producing rhizomes are spread extensively underground (Bailey 1976). New growth can also be established by simple division of the colony; as older stems fall to the earth or are torn from the ground, stem segments can reestablish themselves, producing a new colony.

Within a river system the distribution of establishment does not appear to be random (table 1). The highest concentration of colonies occur closest to the river. Frequency and magnitude of the river flow is most likely the major contributing factor influencing this pattern of distribution. Strahan (1983) found that distribution and development of riparian vegetation is regulated by erosion, deposition, and lateral channel migration. River currents create a constant process of erosion with deposition of eroded material occurring further downstream. Flooding, scouring and debris sedimentation serve to promote expansion of *A. donax* colonies along this zone of frequent inundation.

Disruption of a stream system by natural events (flooding) is not the only avenue available to Giant Reed for its establishment into a system. Disturbance from earth-moving activity can encourage the spread of *A. donax* (fig. 1) even in areas far removed from the water table. Where earth-moving equipment is used the colony can actually spread at a much faster rate than by rhizome growth alone. Evidence can be found in newly graded restoration projects or other construction sites (Rieger 1988). For years Camp Pendleton had a program of clearing the riparian habitat as part of a water conservation program. Giant Reed present within the community was distributed throughout the area which had been denuded. Expansion of the existent population occurred when this practice had been eliminated thus increasing the area previously occupied by the species (Rieger, pers. obs.).

Arundo donax occupies a substantial portion of the riparian system. It far exceeds all other exotic species on the San Diego River and it occurs with a very high frequency on both drainages studied. This high frequency indicates a greater presence within the vegetation community than cover alone would imply. This suggests that the invasive ability of Giant Reed is high regardless of the nature of the existing habitat, though establishment of *A. donax* is probably limited in more dense and mature riparian stands (fig. 2).

Although a few bird species have been observed utilizing the plant for nesting. purposes (Kreager, pers. obs.), the presence of Giant Reed essentially creates a zone devoid of wildlife. The dry climate of San Diego precludes extensive decomposition of its vegetation, therefore even dead, arundo remains and continues to preclude encroachment by plant species with wildlife values.

Figure 1 – In a newly graded site along the First San Diego River Improvement Project *Arundo donax* has become established before native species. Another exotic, the Castor-bean *(ricinus communis)* can be seen in the foreground.

Figure 2– Arundo colonies at the edges of riparian habitats on the San Diego River.

Several significant differences between *A. donax* and other perennial exotics exist. Very few form expanding contiguous colonies or attain large heights as do several native species. The dependence of Arundo upon flooding and vegetative propagules has acted as a limiting factor for its invasion into a habitat. The low rainfall and infrequent flooding in Southern California has kept arundo dispersal rates down, however the slowness of dispersal compared to other exotic species is compensated by its permanence following colonization.

Conclusions

Arundo donax is an extremely fast growing perennial plant reaching mature heights within the first growing season. Dispersal is primarily by vegetative means of stem and rhizome fragments. Flooding is considered the primary natural mechanism of dispersal. Grading and other construction activity can greatly increase the area occupied by Arundo colonies. Restoration sites are easily and quickly invaded especially if the plant was present on site prior to preparation. Arundo is found throughout the river drainages studied. This distribution is viewed as being potentially disastrous for the overall habitat quality of the riparian system.

Recommendations

Loss of riparian habitats has prompted increased interest in them. The presence of Arundo and its ability to compete successfully in riparian systems indicate a future decline in the habitat quality of riparian systems. The end result may be riparian habitat comprised of large percentages of *A. donax* with greatly reduced habitat quality. Several California endangered bird species are dependent upon riparian habitat, therefore it is extremely important that active Giant Reed management be implemented.

Successful techniques have been developed for eradication of Saltcedar (*Tamarix spp.*)(Kerpez and Smith, 1987) from significant areas in the desert. Eradication principles must be applied for the management and control of *A. donax* as well if the many endangered and other sensitive species dependent upon riparian communities are to proliferate.

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TECHNIQUES FOR MINIMIZING AND MONITORING THE IMPACT OF PIPELINE CONSTRUCTION ON COASTAL STREAMS[1]

Thomas W. Mulroy, John R. Storrer, Vincent J. Semonsen, and Michael L. Dungan[2]

Abstract: This paper describes specific measures recently employed for protection of riparian resources during construction of an oil and gas pipeline that crossed coastal reaches of 23 perennial and intermittent streams between Point Conception and Gaviota in Santa Barbara County, California. Flumes were constructed to maintain stream flow; anchored straw bales and silt fences were used to filter sediment in the streams; water bars, incorporated straw mulch, anchored jute fabric, and trench plugs were installed to minimize soil loss on slopes; jute and synthetic fabrics were used to stabilize stream banks; construction-related removal of vegetation was minimized through site-specific project modifications agreed to prior to construction; and impacts on sensitive plant species were reduced by transplanting or by salvaging and replanting after construction. Construction at stream crossings was limited by permit to the summer period of normally low streamflows and was required to avoid the breeding season of sensitive riparian-dependent bird species. Restoration of native woody vegetation was encouraged through a number of approaches emphasizing use of material native to the individual watersheds. Many of the more successful approaches employed in this project resulted from refinements to original plans made in the field by representatives of the applicant, construction contractors, consultants to the applicant, environmental monitors, and representatives of Santa Barbara County.

The Point Arguello pipeline was recently constructed by Chevron U.S.A. Inc. to convey outer-continental-shelf (OCS) oil and gas from offshore platforms near Point Conception to a processing facility at Gaviota in Santa Barbara County, California. Construction of the onshore portion of the pipeline, which parallels the coastline, involved crossing 23 perennial and intermittent streams along its 16-mile onshore alignment (Figure 1). Distance from the ocean along the alignment ranges from about 1 mile on the west to a few hundred feet at Canada Agua Caliente and Canada de Alegria. The project involved burial of a 24-inch diameter oil pipeline and a 20-inch gas pipeline within a single trench. Burial depth was a minimum of 36 inches to top of pipe, with greater depths required at certain stream crossings in order to protect the pipes from scour during floods. Construction activities were confined to a 100-foot maximum right-of-way (ROW). The construction corridor was narrowed to less than 100 feet (from 20 to 80 feet) at stream crossings where feasible.

From a landfall about 1.5 miles north of Point Conception, the pipeline crosses coastal terraces and low hills vegetated primarily by annual grassland dominated by a variety of introduced grasses. Coastal sage scrub, dominated by coastal sagebrush (*Artemisia californica*) or purple sage (*Salvia leucophylla*), occurs locally, especially on hillsides leading into drainages. The drainages are typically well-incised into the terraces, with the streambeds generally lying 40 feet or more below the terrace elevation. The stream corridors typically are vegetated by riparian forests or woodlands. These are dominated exclusively by arroyo willow (*Salix lasiolepis*) along the drier watercourses. In addition to arroyo willow, larger streams may support occasional red willow (*Salix laevigata*), black cottonwood *(Populus trichocarpa*), western sycamore (*Platanus racemosa*), and box elder (*Ater negundo* subsp. *californicum*). White alder (*Alnus rhombifolia*) occurs in the vicinity of the ROW and is confined to areas of perennial flow. Coast live oak (*Quercus agrifolia*), toyon (*Heteromeles arbutifolia*) and elderberry (*Sambucus mexicana*) commonly occur in and adjacent to the riparian zone, but are not exclusively riparian species in this region. Steep hillsides, leading into the streambeds, are occasionally dominated by nearly pure stands of holly-leaf cherry (*Prunus ilicifolia*), that may be relicts of an earlier occurrence of chaparral.

From west to east, the pipeline corridor crosses the Bixby Ranch, the Hollister Ranch, Gaviota State Park and smaller private landholdings near its eastern terminus. Livestock grazing is the predominant land use along the pipeline ROW, except in Gaviota State Park. The Hollister Ranch is subdivided into 100-acre parcels, most of which contain residences.

The entire pipeline alignment lies in the Coastal Zone and most of the riparian habitats it crosses are designated environmentally sensitive habitat areas (ESHA) in the Santa Barbara County local coastal plan (LCP) (Santa Barbara County 1982). Among other things, the ESHA designation recognizes the importance of these

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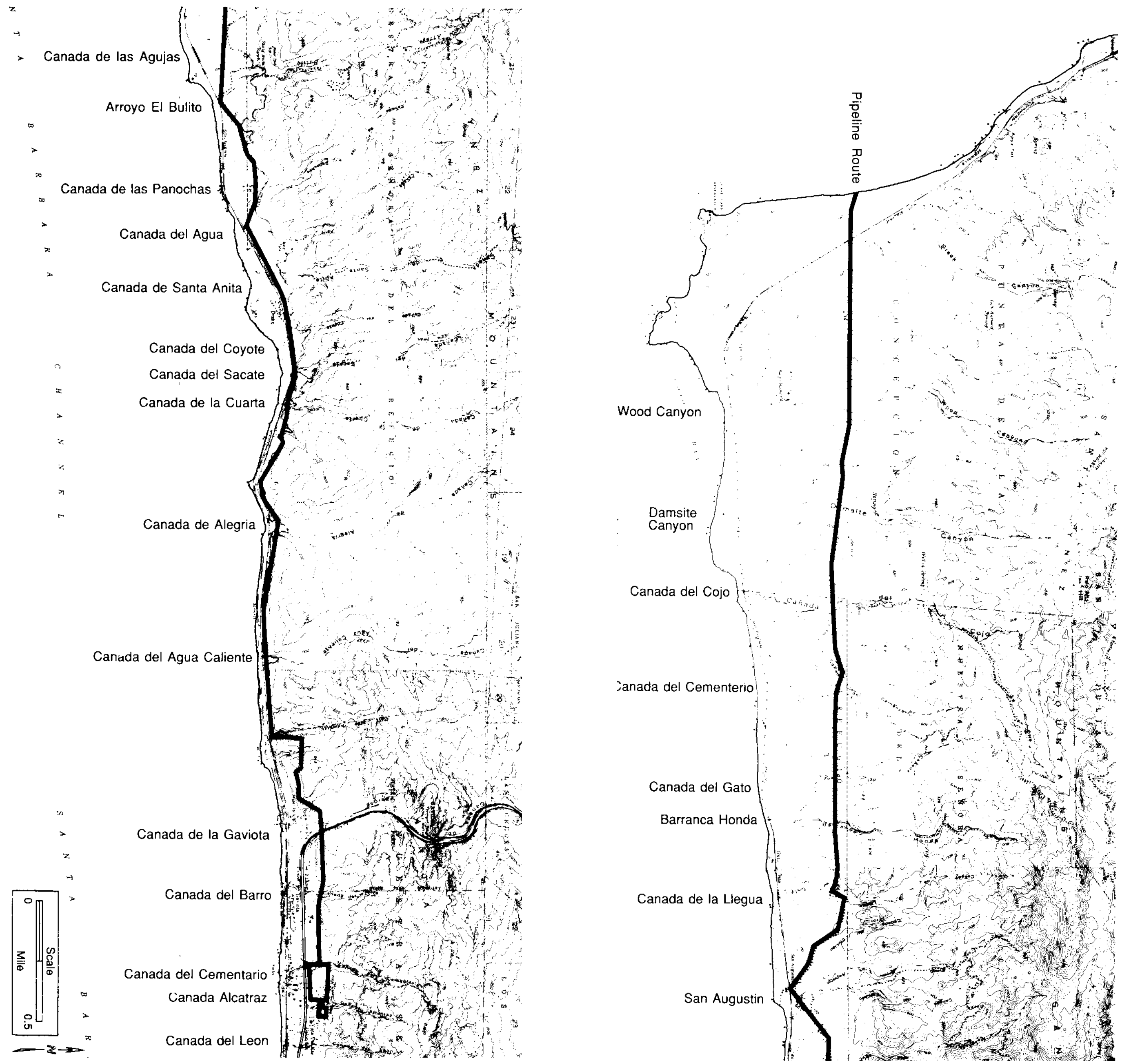

Figure 1 — Project location near Point Conception

corridors to the overall landscape. They provide food, escape cover, water sources, and movement corridors for a variety of wildlife that use the surrounding upland habitats.

A number of sensitive aquatic and avian species were located in these habitats, especially in the larger, less disturbed streams. Sensitive aquatic species occurring in streams crossed by the pipeline alignment included tidewater goby (*Eucyclogobius newberryi*), California red-legged frog (*Rana aurora draytonii),* and southwestern pond turtle (*Clemmys marmoraia pallida*), and reported runs of steelhead trout *(Salmo gairdneri).* The tidewater goby, red-legged frog and southwestern pond turtle are category 2 candidates for federal listing as threatened or endangered. (A category 2 candidate species is one that U. S. Fish and Wildlife Service [USFWS] believes may be appropriate for listing but for which additional information is required.) Preservation, maintenance and improvement of steelhead trout habitat is of high management interest to both California Department of Fish and Game (CDFG) and USFWS. Site-specific information on the stream crossings as well as additional general information on the project region is provided in Mulroy and others (1984).

Environmental Protection Measures

Specific environmental protection measures were developed through the environmental review process and incorporated into the project. These include measures to maintain stream flow, to control sediment, to stabilize stream banks, to minimize construction-related removal of vegetation, to preserve rare plants, to protect sensitive wildlife and aquatic species, and to restore the native vegetation. Some of these measures were originally developed by the applicant and outlined in the original project description; others were recommended by the EIS/EIR preparers. The EIS/EIR review was directed by a joint review panel of permitting agencies, led by the U.S. Minerals Management Service and the County of Santa Barbara. Many of the mitigation measures were originally described in a restoration, erosion control, and revegetation plan for the onshore work area (Chevron 1986) prepared by Chevron after the EIS/EIR as part of their final development plan (FDP) as required by Santa Barbara County permit conditions. This plan was developed in consultation with Santa Barbara County and refinements were made in response to comments from the Santa Barbara County Resource Management Department, Energy Division.

Further developments and refinements of the approved plans were made in the field during their implementation. This was generally done with the input of engineers, environmental staff, and consultants employed by Chevron, and input from environmental staff, monitors, and consultants representing Santa Barbara County. Environmental monitoring to ensure compliance with permit conditions was done according to a detailed environmental quality assurance program (EQAP) employing an onsite environmental coordinator (OEC), general environmental monitors, and resource specialists such as biologists.

Maintenance of Stream Flow

Permit conditions (Santa Barbara County 1984) required that construction activity be confined to low-flow periods, basically the summer and early fall months, and that the existing flow be maintained across the construction area at all times. Construction during the low- flow period helps minimize impacts on water quality; maintenance of low flows was judged essential to maintain downstream populations of aquatic biota, including several sensitive vertebrate species.

Prior to construction at a given stream crossing, sediment traps were installed as described in the next section, and vegetation was removed from the construction right-of-way (ROW). The initial work involved crews using chain saws, who were able to minimize disturbance to vegetation outside the ROW (e.g., by directional felling of trees). The ROW was generally perpendicular to the stream course and a flume was installed to convey water across the ROW. The flume consisted of a large pipe along the bottom of the streambed extending from a short distance upstream of the ROW to a short distance downstream from the ROW. Project specifications called for construction of a temporary dam, consisting of straw bales and plastic, at the upstream end of the ROW to direct water into the pipe. Generally, it was necessary to have the pipe flush with the stream bottom and to have the opening surrounded by sandbags to minimize leakage. At the downstream end, simple energy dissipation structures were installed to prevent erosion caused by the concentrated flow exiting the pipe.

Following sediment trap installation, vegetation removal, and flume installation, pipeline trenching was conducted with backhoes under the flume, which stayed in place for the duration of construction activities at a given stream crossing.

Sediment Control

Conveying the stream water across the construction area in a flume minimized the construction-related sediment that could have fallen into the water. At the downstream side of the ROW, silt traps were installed prior to construction. These traps typically consisted of a combination of two staggered rows of straw bales anchored with rebar and a curtain of commercial silt fence fabric keyed into the stream bottom at the downstream side of the straw bales. These sediment traps served as the primary means of sediment control after the trench had been backfilled and the flume removed. Accumulated sediment was removed from the upstream side of the traps by hand and disposed of away from the creek. It was found that the silt fence fabric by itself was ineffective. The fabric rapidly became clogged with sediment, causing stream flow to back up until the water began to flow around, over, or under the fence. The silt fences required regular monitoring and maintenance. The staggered straw bales were relatively effective and simple to maintain, provided that the flow was not too great.

At higher flows, the sediment traps acted like a dam, retarding the flow until the water backed up and cut around the sides of the bales, eroding the banks. Sediment would drop out of the water behind the dam. Eventually this problem was solved by installing one or more L-shaped overflow pipes that would take the cleaner surface water from behind the dam and convey it under the hay bales and silt fence.

The sediment traps were left in place until after the first rainstorms following construction. Prior to their removal, the accumulated sediment was removed and disposed of away from the creek bed.

Accumulation of water in the trench created a problem at several crossings. When pumped from the trench, the discharged water tended to be sediment-laden, and the concentrated pump discharge caused local scouring of the streambed. In cases of very low discharge rates, the sediment was controlled by silt traps such as those described above. At certain streams, groundwater accumulation necessitated pump discharge rates that exceeded the capacity of the sediment control system. In these cases, one or two swimming-pool-sized "baker" tanks were used to receive discharge and to act as sediment traps by allowing sediment to settle out of the relatively calm water. Sediment-free water was then siphoned from the top of these tanks and returned to the stream bed. An alternative way of handling the higher rates of accumulated groundwater was to discharge it through sprinklers to upland habitats draining into the creek.

At one crossing, buried marsh sediments yielding abundant groundwater were encountered during trenching. This water was laden with hydrogen sulfide and fine sediment. Observation at other stream crossings indicated that the material was toxic to invertebrates. To maintain workable conditions in the trench, several shallow dewatering wells were installed and cased with perforated PVC plastic drain pipes. The discharge from these wells was too copious for the above-described systems to handle. The short distance of stream between the construction site and the shore was considered extremely sensitive to impact because it contained three aquatic species that are candidates for federal listing (tidewater goby, red-legged frog, and southwestern pond turtle) and had very little flow at the time of construction. To protect the stream and its biota, the water was piped to the nearby beach and discharged onto the sand, where filtering by the sand and dilution in the ocean water would minimize adverse ecological effects.

Stream-Bank Stabilization

After completion of welding and testing, the trench was backfilled, and the crossing was recontoured to its approximate preconstruction configuration. Original specifications called for armoring stream banks below the normal high water level with a three dimensional nylon "geotextile fabric." This armoring was intended to protect the banks and cause sediment to accumulate in the mesh, where it would ultimately be stabilized by vegetation.

In practice, the fabric proved to be relatively difficult to install, especially where it had to be keyed in to the stream bottom. There were concerns about its longevity, the aesthetic impact of exposed portions of the mesh, and the possibility of its being washed out by floodwater and causing downstream problems (e.g., clogging culverts). There was also a concern that the mesh would cause girdling of roots of willows and other woody plants expected to colonize the banks. As a result, this material was removed from several drainages. Where it was left in place, the material functioned adequately in low-flow situations where the drainage was broad with little gradient. However, these situations are the least prone to erosion. Elsewhere, it was heavily damaged by seasonal runoff or by livestock. Based upon this experience, we would not recommend the use of this material in a similar environment, especially in areas frequented by cattle.

Water bars (earthen berms graded across the ROW at a slight angle to the topographic contour) were installed at intervals along the steeper slopes to divert runoff from the ROW into adjacent vegetated areas. The spacing between water bars depended upon the steepness of the slope. On the steepest slopes, they were installed at 25-foot intervals. These bars effectively prevented the concentration of runoff and consequent erosion along the ROW but did require periodic repairs after winter storms. Damage caused by livestock also required repair. Gullying occurred at the edge of the ROW if the berms were not continued a slight distance beyond the ROW into the adjacent vegetation.

Jute netting was installed on steep slopes above the high water mark. This fabric was intended to retard washing of the exposed soil and backfill from the ROW into the creek. It was also expected to facilitate the establishment of vegetation by trapping and holding seeds in place, as well as by holding the soil. Proper installation requires that the fabric be placed in intimate contact with the soil surface, otherwise it can be undermined by runoff and become ineffective. Damage caused by cattle was extensive. Where properly installed and undamaged by cattle, the jute appeared to be an effective erosion-control measure. Postconstruction revegetation on the jute-netted slopes has been relatively slow, however, leading to speculation that some property of the jute might have been inhibitory to seed germination or establishment. We believe that this could as easily have been a function of the poor soils and steep slopes where the jute was used. We would recommend establishment of appropriate control areas in subsequent applications to resolve this issue and to better evaluate the effectiveness of the material.

Minimize Vegetation Removal

Santa Barbara County permit conditions required construction activities to be confined to a 100-foot wide ROW. Narrowing the ROW in sensitive habitats and avoiding sensitive resources such as trees wherever feasible was also required. Preconstruction walk-throughs were conducted by Chevron's consultant biologists and a Chevron inspector familiar with pipeline construction methods. Trees and large shrubs that would unavoidably be removed by construction were enumerated by species for the purpose of developing site-specific replanting specifications. In the process, possibilities for minimizing impacts were discussed, and sensitive vegetation was identified, prioritized, and flagged for avoidance. Later, trees were protected by surrounding them with heavy lath and wire snow fencing. Because we attempted to err on the side of saving trees, we identified and flagged the maximum number of plants that could possibly be avoided by construction, using optimistic assumptions.

It was later determined that removal of some marked trees was unavoidable, and these were unfenced after notification of the on-site environmental coordinator.

The snow fence proved to be very effective both in designating trees or resources to be avoided and in preventing the plants from being buried by spoil or damaged by heavy equipment operating in their vicinities.

Preserve Rare Plants

During preproject walk-throughs, seven local populations of Hoffmann's nightshade (*Solanum xanli* var. *Hoffmannii*), a California Native Plant Society List 4 species endemic to coastal Santa Barbara County, were located. Hoffmann's nightshade is a sprawling subshrub that clambers through other plants and roots at the nodes. Its characteristics led us to believe that it could be successfully transplanted (Mulroy and others 1984), and transplanting was incorporated into a permit condition by Santa Barbara County. The local populations were therefore flagged in the field for later salvage.

In early summer 1986, prior to construction, Hoffmann's nightshade plants were cut back, dug up, and potted using native soil. The plants tended to fragment into rooted divisions during the excavation and were thus placed three divisions to a pot into 15-gallon plastic pots, each of which was color-coded according to source locality. Initially, the plants were maintained in the field near the ROW where they were protected by hog wire and shade cloth. Subsequently, they were moved to a local nursery where they were maintained outdoors. Normally a summer-dormant, drought-deciduous species, the plants had been nearly dormant when salvaged. However, many plants became active again and flowered in response to periodic watering during the summer months. There was a relatively high but unquantified survival of salvaged plants in the nursery. Replanting was accomplished during spring 1987 at their original localities in chicken-wire exclosures. Thirty-eight percent of the outplanted plants, including several plants from each local population, were surviving when last monitored (July 1988). These appear to be fully established.

Also undertaken were transplants of giant stream orchids (*Epipaclis gigantea*) and scarlet monkey flower (*Mimulus cardinalis*). Both of these plants are widespread species but were singled out for this treatment because of their uncommonness in the project area. Both species occurred under the riparian canopy in relatively moist sandy soil adjacent to the bed of Canada del Cojo, one of the larger streams crossed by the ROW. The plants were dug up and immediately replanted in one of two preselected open sites outside of the ROW, one upstream and one downstream. Finding sites with the proper attributes that were not completely covered with vegetation was perhaps the most difficult aspect of this task. Excavating the root system of the monkeyflower proved to be impractical and the effort was abandoned after only a few were transplanted. To my knowledge, none of these survived. About a dozen of the stream orchid were moved, and some of these were surviving as of spring 1988.

Protect Sensitive Wildlife and Aquatic Species

The efforts to maintain stream flow and to protect instream water quality, described above, were directed at preserving local populations of the above-listed sensitive aquatic species. A permit requirement that construction be restricted to the low-flow season was directed at making these protection measures feasible. A related condition was placed on the project to delay construction until after the breeding period of a number of regionally rare and declining songbird species known or expected to breed in some of the habitats. The net effect of these two conditions was to leave a very narrow "window" for construction at stream crossings. Chevron approached this constraint by prioritizing stream crossing construction, having special crews work on the stream crossings.

These crossings were later tied in as the main construction spread traveled from west to east.

Survival of the tidewater goby populations was of special concern since, during most of the year, the fish are located in tiny lagoons near the stream mouths, where they would be vulnerable to local extirpation. Recolonization could only occur from other populations via the ocean and there had been no documented evidence that this could occur. For these reasons, sampling to monitor potentially affected goby populations was conducted before, during, and after construction as part of the Environmental Quality Assurance Program (EQAP). This sampling is described in a poster session at these meetings authored by Thompson, Dunlap, and Dungan.

Restore Native Vegetation

A detailed description of measures to revegetate the stream sides and adjacent slopes is beyond the scope of this paper. However, I would like to briefly mention a few things germane to the restoration of streambeds and riparian zones in particular. First, willow cuttings taken from trees immediately adjacent to the ROW were a rapid and inexpensive means of hastening the restoration of a tree cover over the stream. Generally, the use of dormant wood is preferred; however, cuttings taken in late spring survived. There was a high rate of survival of cuttings where soil moisture was adequate (i.e., near the streambed) even though they were not taken and planted until late spring.

Second, to hasten the stabilization of the streambed and recovery of marsh plants such as cattails in severely disturbed portions of the ROW, a simple method for salvage and replanting was developed for this project. This method involved digging individual clumps of cattails by hand out of the ROW prior to clearing, and storing them in plastic wading pools for later replanting. The wading pools can be located in shaded parts of the streambed adjacent to the ROW and watered periodically by construction monitors or inspectors. The ultimate success of this method remains untested because an errant bulldozer destroyed the plants and tub. Reestablishment of cattails from seed and rhizomes in the salvaged topsoil was rapid, however.

An example of a creative approach to seed collection was taken by one of the authors after a seed-collection contractor missed the brief period of seed availability of holly-leaf cherry or islay (*Prunus ilicifolia*), a large shrub or small tree forming coppices on steep slopes leading into several streams. A considerable amount of locally-collected seed was required for this species, which was one of the most important large shrubs along the ROW. One of the authors was able to collect nearly the entire required amount from the scats of coyotes which had fed upon the cherry fruits extensively. The work of pack rats or wood rats (*Neotoma*) in collecting both scats and seed was taken advantage of in respect to this seed-collection attempt.

For most of its length, the ROW passed through active cattle ranches. Protection from grazing livestock was an important factor in the design of the revegetation program and was important in determining the success of the tree and shrub plantings. Box fencing was most effective in excluding cattle from the ROW at stream crossings, but they prevent up and downstream movement of cattle in the streambed, and for this reason landowners strenuously objected to their installation at most locations. Where properly installed, wing fences (fences constructed across the ROW and angling downslope for varying distances off the ROW) inhibited cattle from using the ROW for access to stream crossings and, in such areas, tree and shrub plantings fared substantially better than in areas in which fencing was absent or ineffective. In the latter cases, cattle tended to congregate in the ROW at the stream crossings and restoration plantings, and erosion control measures were heavily affected, requiring considerable maintenance and repair.

In upland habitats outside of the wing-fenced areas, a two-tiered exclusion system designed by one of the authors was used to exclude cattle, deer, and small mammals from shrub and Hoffman's nightshade plantings. The plantings were clustered within an area enclosed with standard three-strand barbed-wire fencing designed to exclude cattle. The individual plantings were protected from deer and small mammals by individual cages fabricated from chicken wire. These cages were about 30 inches in diameter and about 54 inches from top to bottom. The bottom 12 to 15 inches of the cage was buried below ground to provide protection from pocket gophers (*Thomomys bottae*).

The timing of revegetation activities is critical. Plans had been to complete pipeline construction and restoration activities prior to the onset of the November-to-April rainy season, in order to give the plantings and reseeded areas the maximum amount of time to become established before the summer drought. The project, unfortunately, fell behind schedule, and revegetation activities were not initiated until January 1987. Tree and shrub plantings were not accomplished until later that spring, when runoff had diminished to low levels and soils in the riparian areas away from the immediate channel had dried out. As a result, establishment of riparian trees and shrubs from cuttings and transplants was poor, except in areas within a few feet of the existing channel. Considerable reseeding of adjacent shrub-dominated upland habitats was required as well, necessitating additional custom collections of native seed from the immediate vicinity of the ROW.

Conclusions and Recommendations

The maintenance of stream flow during periods of low flow proved easier than did the removal and redistribution of groundwater which accumulated in the pipeline trench. A trial-and-error approach was used to determine the best method for each drainage where this problem arose. For similar projects involving excavation through riparian zones, we would recommend that an estimation of groundwater quantity and quality and tactics for dealing with this excess water be determined prior to construction. As was the case with the Point Arguello pipeline project, appropriate site-specific solutions will have to be developed for this problem. In streams larger than those encountered in this project, reinjection of the groundwater may be feasible.

Use of geotextile fabric for stream bank stabilization did not appear appropriate and was discontinued. We believe that the revegetation of stream banks provides a superior degree of bank stabilization, without the potential drawbacks of the synthetic material.

Erosion was noted where water bars led into steep and poorly vegetated areas at the edge of the ROW. Otherwise, water bars were effective but required periodic repair of damage caused by storms or livestock.

Investigations of the effects of jute netting on plant growth are recommended. However, our experience suggests a possible inhibitory effect on revegetation.

Snow fencing was highly successful in protecting trees from burial and incidental damage by equipment operators.

A number of suggestions are made above for enhancing the reestablishment of riparian vegetation. An important step in much of the West is to restrict the access of livestock to recovering stream corridors. These areas are most vulnerable to damage from livestock during summer, when the animals tend to congregate in riparian areas and may do irreparable damage to young plants.

Finally, it is important that techniques to protect riparian zones from construction impacts be scrutinized and refined. Every attempt should be made to distinguish causal relationships from coincidences when the success or failure of mitigations is assessed. Ideally, this will involve rigorous experimental comparisons between treated areas and control areas.

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To make a list will ensure that some are left out, nevertheless the authors would like to acknowledge the efforts of the following: We thank Roz Muller, John Tiffany, Dennis Kennedy, Ted Potter, George Boscoe, Peter Catton, and Anthony Demes of Chevron U.S.A. Inc. or Chevron Pipe Line Company; George Welsh, of Ecology and Environment, Inc., and several persons from Santa Barbara County Resource Management Department, Energy Division, including Peter Cantle, Mary Ann Scott, and Tom Lagerquist for their creativity, patience, willingness to listen, cooperation, and hard work.

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SESSION F: WILDLIFE I-MANAGING FOR SELECTED SPECIES

One of the more obvious signs that riparian habitat has all but disappeared in California is the number of endangered species whose existence depends on it. Because of the legal protection accorded to endangered species, they have become a major reason that riparian habitat is being protected and restored. Riparian habitats that harbor endangered or threatened species or even "species of special concern," suddenly become impediments to development of marinas, rip-rapping projects, and rows of streamside condominiums. Then finding out as much as possible about the requirements of these species becomes imperative, so that the minimum amount of habitat can be set aside for their protection. Under these conditions, money usually becomes available for the study of some of the more obscure but fascinating species that inhabit riparian areas.

The twelve papers presented here deal with seven discrete animal groups–stoneflies, a beetle, salmonid fishes and four species of riparian birds. The beetle and all of the birds are considered to be at some level scale of concern over possible extinction. Protecting such fascinating species is reason enough to save riparian habitats.

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STONEFLY (*PLECOPTERA*) FEEDING MODES: VARIATION ALONG A CALIFORNIA RIVER CONTINUUM[1]

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Abstract: The distribution of Plecoptera along a California river was used to test several predictions of the River Continuum Concept about how functional feeding groups should change along a stream's length. Stoneflies were collected from stream orders 1-6 (123 km) of the Cosumnes River continuum in the central Sierra Nevada. The 69 stonefly species collected were separated into three functional feeding groups – 26 shredders (detritivores), 39 predators (engulfers), and 4 scrapers. Stonefly shredders and predators reached maximum species richness at middle stream orders (3-5). The relative abundance of shredders was highest in the headwaters, then declined with increasing stream order. Predator relative abundance exhibited an inverse trend to shredders. Few scrapers were present, but these were most abundant at middle stream orders; they were almost entirely absent from the headwaters. These trends in diversity and relative abundance of functional feeding groups agree with predictions of the River Continuum Concept and emphasize the importance of riparian vegetation in the structure and function of Sierra Nevada streams. The type of terrestrial plant community through which the stream was flowing did not appear to affect the diversity or relative abundance of shredders.

The River Continuum Concept (RCC) was proposed to explain the structural and functional changes which occur in stream communities, especially to streams flowing naturally through undisturbed forested watersheds (Vannote and others 1980). Inputs of organic detritus to the stream and detrital processing by functional feeding groups (FFG's) of aquatic invertebrates are central themes of this concept. The RCC predicts that shredder organisms, which consume large particles of organic detritus (>1 mm) that has accumulated on the stream substrate, should be relatively abundant near the headwaters of a stream, then decrease downstream as the stream widens and the relative importance of coarse detrital inputs from terrestrial vegetation and upstream habitats decline. The rationale is that the smaller streams in the upper reaches of a river continuum (stream orders 1-3) are greatly influenced by riparian vegetation, the overhanging plant canopy supplying large amounts of organic detritus, but shading and limiting instream primary producers. As the stream widens downstream and detrital inputs from streamside plants become less important, more sunlight can reach the substrate and enhance instream primary production. Scraper organisms, which graze algae and fine particles from the substrate, are predicted to be relatively abundant in the middle reaches of streams (orders 4-6) (Vannote and others 1980). Maximum biotic diversity is predicted to occur in middle stream orders where environmental variation is greatest.

The RCC has been an important catalyst for recent stream research throughout the world (Minshall and others 1985, Statzner and Higler 1985), and the validity of its tenets and predictions are currently being tested. However, the predictions of the RCC and the importance of riparian vegetation to the macroinvertebrate community have not been studied in Sierra Nevada streams, despite the potential value for watershed and forestry management practices.

Stoneflies are ideal organisms for testing some of the RCC predictions about how FFG's change along a river continuum. First, stoneflies are common components of the aquatic benthos of most streams worldwide, often with many species and individuals present at any particular location. Since they extend in distribution from headwaters to far downstream, long distance changes in faunal composition, FFG's, and diversity can be studied. By concentrating on a single aquatic insect order, a relatively complete taxonomic list can be obtained at the species level, eliminating the uncertainties of incomplete identifications. In keeping with the idealized, undisturbed stream of the RCC, stonefly nymphs are almost exclusively restricted to unpolluted running waters. In contrast with some aquatic insect groups, stonefly nymphs belong predominantly to only two of the six main FFG's (Merritt and Cummins 1984) – shredders (detritivores) and predators (engulfers). This basic feeding dichotomy is reflected in the morphological differences of their mouthparts, and also in the two taxonomic groups of the suborder Arctoperlaria (Zwick 1973), the Euholognatha (mainly shredders) and the Systellognatha (mainly predators). A few stoneflies are classed as scrapers (the Brachypteriginae), but very few are classed as collectors (Merritt and Cummins 1984). Stoneflies are also good study organisms because most of the food resources needed during their life cycle are obtained as nymphs in the stream habitat, many adults being short-lived and not feeding (the Systellognatha).

Because of the advantages of stoneflies, we used

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them to test several predictions of the RCC in an undisturbed California stream. The main objectives of the study reported here were to determine (1) if the relative abundance of stonefly shredders declines with increasing stream order (1-6), (2) if the relative abundance of stonefly scrapers increases with stream order to a maximum in middle stream orders (4-6), and (3) if the maximum diversity of FFG's occurs in the middle reaches. The RCC predicts little change in predator relative abundance along the continuum; however, because stoneflies are largely either shredders or predators, these two FFG's will demonstrate inverse trends. A final objective of the study was to observe if the diversity and relative abundance of the stonefly FFG's were influenced by the type of terrestrial plant community being traversed by the stream.

Study Stream

Plecoptera feeding modes were studied along one river continuum, the Cosumnes River and its North Fork, located in the central Sierra Nevada east of the city of Sacramento, California. The study stream flows westward 163 km from its headwater springs at 2249 m elevation to nearly sea level in the plains-like Central Valley, where it joins the Mokelumne River and enters the Sacramento-San Joaquin Delta estuary. Large physical gradients exist between the headwaters and lower reaches of the Cosumnes River, especially in mean discharge (0.007 - 13.8 m^3/sec), channel slope (12.9 - 0.06 percent), substrate (-8 to +3 phi scale), summer water temperature (4 - 28°C), and stream order (1-6). It is an unpolluted softwater stream (specific conductivity = 20-115 Mmho/cm), with dissolved inorganic solids increasing only slightly between the headwaters and lower reaches.

The Cosumnes River drains a largely undisturbed, forested watershed and traverses four major terrestrial plant communities as it descends the large elevation gradient of the Sierra Nevada (Griffin and Critchfield 1976) – red fir forest (> 2000 m elevation), mixed conifer forest (730-2000 m elevation), foothill woodland and chaparral (40-730 m elevation), and valley grassland (< 40 m elevation). Forests above 730 m elevation are primarily coniferous (*Abies, Libocedrus, Pinus,* and *Pseudotsuga*); forests below 730 m elevation are primarily broad leaf forms (*Aesculus, Arctostaphylos, Ceanothus,* and *Quercus*). In addition to these four terrestrial plant zones, the stream is bordered along its entire length by a narrow band of true riparian plants (*Alnus* 2 species, *Populus* 2 species, *Salix* many species, and other trees, shrubs, and herbs). The entire Cosumnes River drainage basin lies below tree line.

In contrast to most large rivers on the western slope of the Sierra Nevada, the Cosumnes River has no mainstream reservoirs; therefore, water temperature and discharge change naturally with the seasons. Because of the largely undisturbed watershed and lack of mainstream reservoirs, the Cosumnes River possesses the pristine conditions that formerly existed in many of the larger streams of the western Sierra Nevada and should be close to the typical stream defined in the RCC.

Methods

The distribution of stoneflies was determined for a 123 km reach of the Cosumnes River, extending from the headwaters (2249 m elevation) to the lower reaches (27 m elevation). Stonefly nymphs and adults were collected from nine sites in this study segment, which included stream orders 1-6 and four main terrestrial plant communities. Stoneflies were abundant at all nine sites of this study, including sites near sea level, but they were absent from the extreme lower reaches of the continuum (> 123 km, stream orders 7) in the Sacramento-San Joaquin Delta (California Department of Water Resources 1981).

Plecoptera nymphs were collected monthly (1980-1982) from both riffles and pools at each of the nine sites using a kick screen (0.9 mm mesh size). Most identifications were made to genus or species level; a few nymphs could be identified only to family level (some Capniidae, Leuctridae, and Chloroperlidae). The inability to identify all nymphs to species was not thought to greatly affect this study because identification to genus or family was often sufficient to determine the proper FFG. During this study, a total of 26,000 Plecoptera nymphs were collected and identified from the nine sites. Stoneflies were placed into FFG's based primarily on Merritt and Cummins (1984), plus the examination of gut contents for some stonefly nymphs when their feeding status was uncertain.

Plecoptera adults were collected in all seasons (1980-1986) using three methods: general search, timed sweep-net, and slit traps. General search along the streamside included examination of those substrates likely to contain adults, but difficult to adequately sample with a sweep net. In winter at high elevations, stoneflies were hand collected from snowbanks along the stream. Stream segments buried under snow were dug open, then adults collected as they emerged. Timed sweep-net collections (10 - 120 min) were made at all sites (biweekly 1981-1983, irregularly thereafter) to collect adults on streamside vegetation. Adults were also collected in slit traps (1981-1982) designed primarily to capture newly emerged Plecoptera (Kuusela and Pulkkinen 1978). These traps were placed on the stream bank just above water level immediately adjacent to the stream and operated continuously, day and night. Using these three methods, a total of 12,000 adults were collected from the nine sites, identified to species, and separated into their FFG's. In addition, stonefly exuviae were collected from rocks and vegetation along the stream banks and were identified to species for three families (Perlidae, Perlodidae, and Pteronarcyidae).

Since any collection of adult stoneflies along a river continuum represents a mixture of species derived directly from the river, plus those dispersing in from nearby smaller tributaries, an effort was made in this study to distinguish between these two faunas. To separate these two faunas, we (1) collected both nymphs and adults along the continuum, (2) associated many nymphs with adults, and (3) collected less intensively the nymphs and adults from side tributaries. The separation of adventitious species from the true river continuum fauna was important because our study was limited to FFG changes along a single continuum.

Stream order was used to define the position along the continuum. Stream order locates a stream segment within the drainage network (Strahler 1957) and is determined by the number and size of upstream tributaries. Headwater streams lacking inflowing tributaries are first order; higher order streams result from the confluence of two lower order streams (second order from the confluence of two first order streams; third order from the confluence of two second order streams, etc.) In this study of the Cosumnes River continuum, stream order was determined using U. S. Geological Survey topographic maps (1:24,000 scale), and all intermittent streams were included within the drainage network.

Results

A diverse stonefly fauna occurred in the Cosumnes River continuum. After excluding adventitious species, a total of 69 species, 36 genera, and all 9 North American families of stoneflies were collected in this study. Of these 69 species, 26 were shredders, 39 were predators, and 4 were scrapers (Brachypterinae: *Taenionema*). Four Chloroperlidae genera (*Alloperla, Bisancora, Kathroperla,* and *Paraperla*) may fit at least partially into the collector FFG; however, because few species were involved and little was known of their feeding mechanisms, the collector FFG was not considered further in this study.

The proportions of stonefly shredders, predators, and scrapers collected from the Cosumnes River continuum (fig. 1) were generally similar to the stonefly faunas of North America and California (Stark and others 1986), although the Cosumnes River fauna had slightly fewer shredders and slightly more predators than the other two areas. These slight differences were sampling artifacts caused by comparing the stonefly faunas of two large areas with a linear sample of one river continuum. Because we restricted our study to a single river continuum, stoneflies occurring in low order, low elevation streams in the Cosumnes River basin were excluded from the study, and these low order streams should contain higher proportions of shredders.

Species richness of stonefly shredders and predators was highest in middle stream orders (3-5) of the Cosumnes River continuum, with shredders reaching a maximum of 20 species at stream order 3 and predators reaching a maximum of 23 species at stream order 4 (fig. 2A). Near the headwaters and in the lower reaches of the stream, fewer species of both FFG's were present. At stream order 7, species richness was zero. These diversity trends in shredders and predators agree with the RCC prediction of maximum biotic diversity at middle stream orders. Stonefly scrapers were much less abundant than shredders and predators, but increased from none to three species along the continuum.

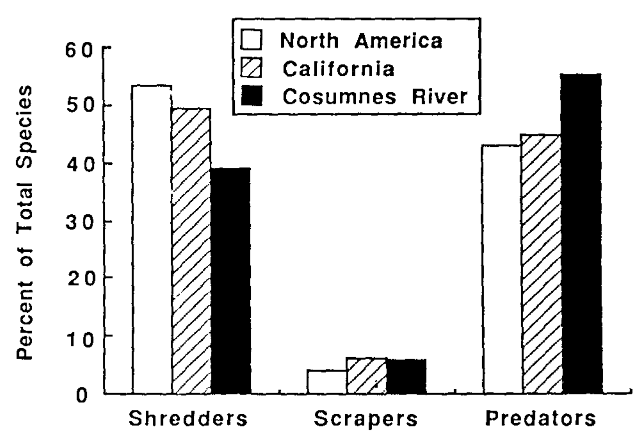

Figure 1 — Proportion (percent) of three functional feeding groups composing the stonefly faunas of North America, California, and the Cosumnes River continuum.

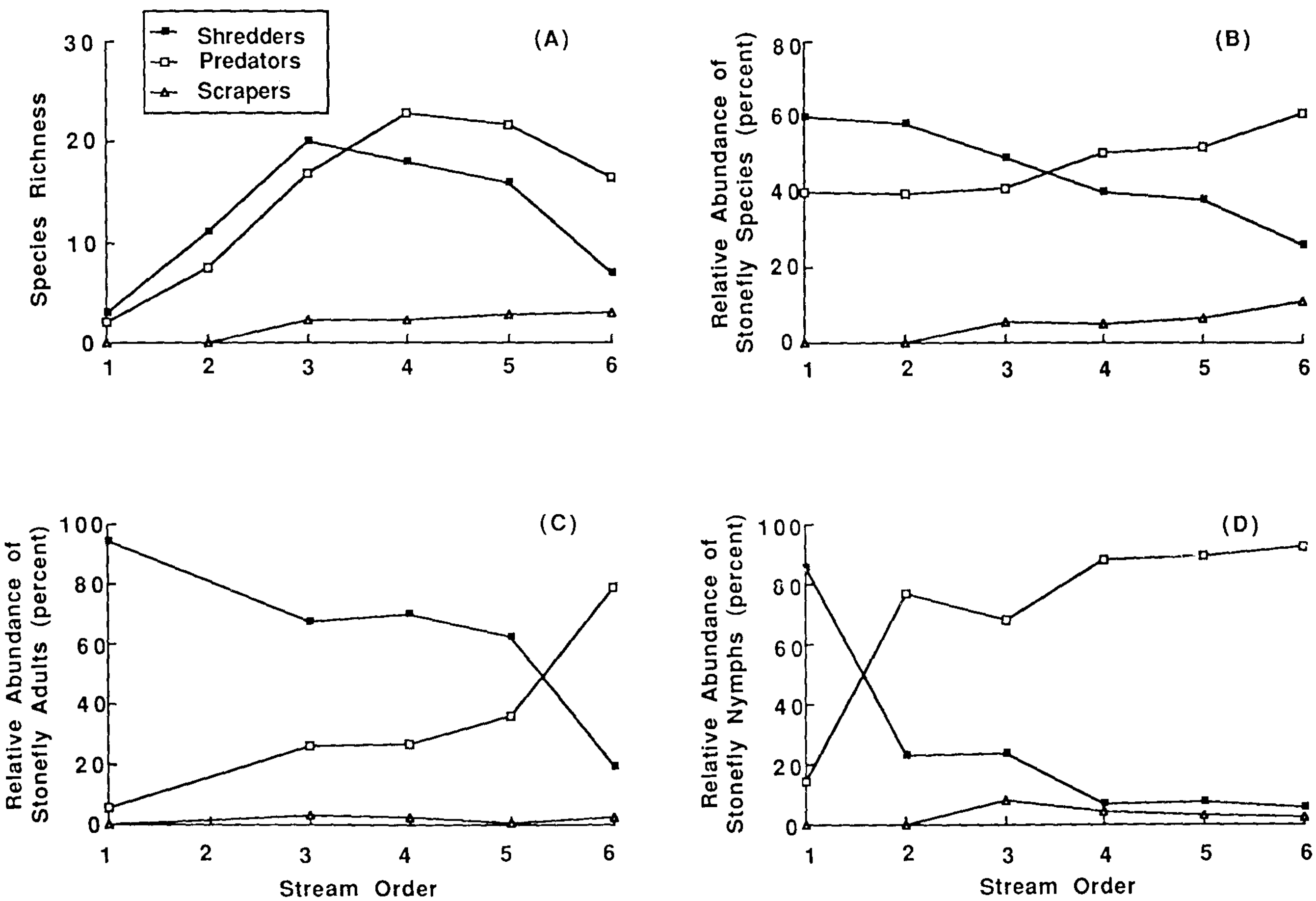

Figure 2 – Variation in species richness and relative abundance of stonefly functional feeding groups (FFG's) in stream orders 1-6 of the Cosumnes River continuum, California: (A) species richness of FFG's, (B) relative abundance (percent) of FFG's determined from the total stonefly species collected (adult + nymph data), (C) relative abundance (percent) of FFG's determined from the total number of stonefly adults collected, (D) relative abundance (percent) of FFG's determined from the total number of stonefly nymphs collected.

The relative abundance of stonefly FFG's along the Cosumnes River continuum was examined in three ways: (1) using the number of stonefly species collected (fig. 2B), (2) using the number of adult specimens collected (fig. 2C), and (3) using the number of nymph specimens collected (fig. 2D). All three data sets gave similar results (fig. 2B- D); shredder relative abundance decreased as stream order increased from 1 to 6, while predator and scraper relative abundance increased. Although the decrease in shredder relative abundance with increasing stream order occurred at slightly different rates in each data set, shredders were always most abundant (> 60 percent) near the headwaters and much less abundant in the lower reaches. Because of the basic FFG dichotomy in stoneflies, predator relative abundance exhibited an inverse trend to that of shredders. Scraper relative abundance was low (< 15 percent) at all stream orders and in all data sets, but did increase slightly in middle orders (3-6). Scrapers were especially sparse or absent from the Cosumnes River headwater region (orders 1-2).

The species richness and relative abundance of stonefly FFG's did not appear to be greatly affected by the type of terrestrial plant community through which the stream flowed (fig. 3A-B). Changes in species richness and relative abundance occurred gradually between sites, rather than exhibiting discontinuities at vegetation zone boundaries. The maximum number of shredder and predator species occurred within the mixed conifer forest zone (fig. 3A).

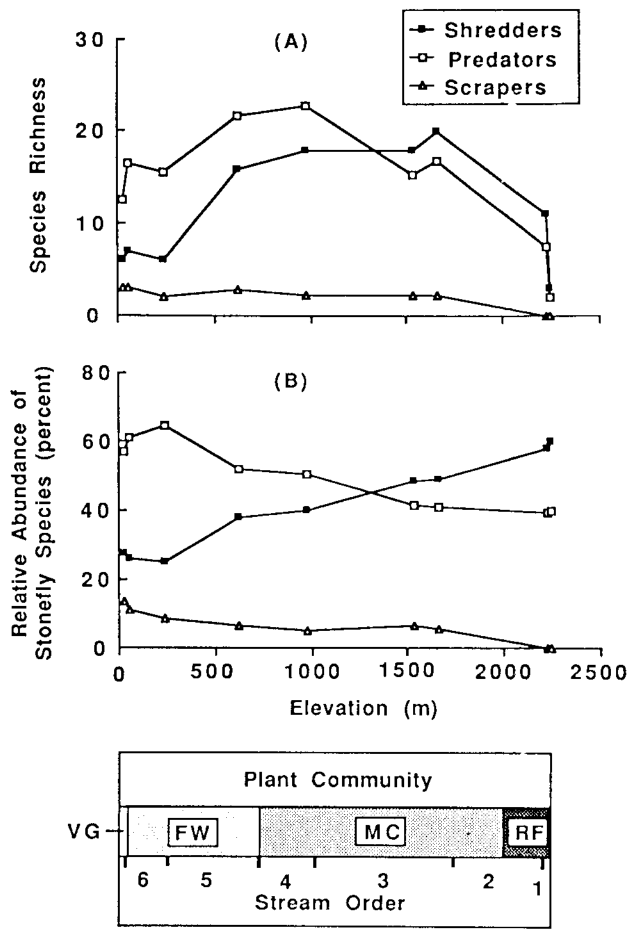

Figure 3 – Variation in species richness and relative abundance of stonefly functional feeding groups (FFG's) by elevation and terrestrial plant community along the Cosumnes River continuum, California: (A) species richness of FFG's, (B) relative abundance (percent) of FFG's determined from the total stonefly species collected (adult + nymph data). Plant community names: VG = valley grassland; FW = foothill woodland and chaparral; MC = mixed conifer forest; and RF = red fir forest. Stream orders are given to show their relation to elevation and the terrestrial plant communities.

Discussion

Since the RCC was first proposed (Vannote and others 1980), its worldwide applicability to all streams has been debated (Winterbourn and others 1981; Barmuta and Lake 1982; Minshall and others 1983, 1985; Statzner and Higler 1985), and certain modifications and exceptions have been noted, especially for streams in deserts and at high elevations where riparian vegetation is sparse (Busch and Fisher 1981). The concept was originally formulated for, and appears most applicable to, streams flowing through undisturbed, forested watersheds. Since the Cosumnes River has an undisturbed, forested watershed, the predictions of the RCC would be expected to apply. The results of this study agree with the RCC predictions that (1) shredders should be most abundant near the headwaters and decrease in relative abundance downstream, and (2) scrapers should be most abundant at middle stream orders. These changes in stonefly FFG's along the Cosumnes River continuum, plus observations of the watershed and stream canopy vegetation, strongly suggest that streamside vegetation (main terrestrial plant communities + true riparian plants) had an important organizing role on the stream biota, both as a source of organic detritus and as a controller of sunlight entry into the stream. It is likely that other streams traversing the heavily forested watersheds on the western slope of the Sierra Nevada are similarly influenced by riparian vegetation and demonstrate similar FFG changes with the Cosumnes River. Possible exceptions are those Sierra Nevada rivers extending above tree line where inputs of organic detritus may be sparse. Additional tests of the other RCC predictions should be made on Sierra Nevada streams using the entire macroinvertebrate community or various subsets.

Few other studies have examined stonefly feeding groups along a stream continuum. In contrast to our results, Knight and Gaufin (1966) found the proportion of predatory stonefly species increased with elevation in a Colorado drainage, while the proportion of vegetarian stonefly species decreased. These trends may be caused if the high elevation (> 10,000 feet) Colorado stream was above tree line and lacked sufficient inputs of organic detritus from riparian vegetation. Brink (1949) also found carnivorous stoneflies reached high dominance values on a mountain ridge in northern Sweden; however, these waters contained few plants and had little organic detritus. He found that phytophagous stonefly species were dominant in springs, trickles, and small eutrophic forest streams, all of which contained large amounts of organic detritus. These studies suggest that stonefly feeding modes vary directly with the food resources available in the stream habitat.

Stonefly scrapers were especially sparse or absent from the headwaters of the Cosumnes River continuum. We believe this is caused by the combination of heavy shading by riparian vegetation and by deep snow accumulations which bury the stream for many months in winter- spring. However, this possibility should be tested with other aquatic insect groups which naturally include more species of scrapers.

Although the RCC predicts maximum biotic diversity at middle stream orders, it was somewhat surprising to find this was also true for the different stonefly FFG's in the Cosumnes River continuum (fig. 2A). Originally, we expected shredder diversity to be highest near the headwaters where their food source of coarse organic detritus should have been most abundant. However, shredder diversity was maximum at stream order 3 and remained high at stream orders 4-5, suggesting that some factor other than detrital quantity controls diversity. Possibly, a favorable diversity of substrate or detritus promotes shredder diversity in middle stream orders. Maximum shredder diversity did occur slightly closer to the headwaters (order 3) than did maximum predator diversity (order 4-5).

Many studies have shown the importance of streamside vegetation to stream ecosystems, and it is well known that the type of terrestrial vegetation greatly affects the amount and timing of detrital input to streams, the decay rate of organic detritus, and the food preferences of shredders (see references in Hynes 1975, Minshall and others 1985). Some research suggests that the type of terrestrial vegetation through which the stream flows influences the composition of the benthic stream community (Ross 1963, Donald and Anderson 1977, Wiggins and Mackay 1978, Culp and Davies 1982, Molles 1982). Although the Cosumnes River continuum passed though four main terrestrial plant communities, no major discontinuities in species richness or relative abundance of stonefly shredders or predators were evident near vegetation zone boundaries. Species richness was maximum within the mixed conifer forest zone for both FFG's, but the gradual change in diversity across zone boundaries suggests vegetation type had little influence. Also, the decrease in shredder relative abundance with increasing stream order occurred uniformly across vegetation boundaries, suggesting that shredders were responding to the decreasing quantity of coarse organic detritus, rather than to the type of terrestrial vegetation.

The lack of FFG discontinuities at terrestrial vegetation zone boundaries may be explained by (1) the relative contribution of organic detritus coming from the main terrestrial plant communities versus that from the narrow border of true riparian vegetation, and/or (2) the downstream transport and mixing of organic detritus by the stream. Sierra Nevada streams are typically bordered by a few true riparian plant species which are adapted to the moist soil conditions near the stream. These riparian species often parallel the stream over much of its length, and extend their distribution through several terrestrial plant zones. Leaves shed from these true riparian species are known to quickly become preferred food items for shredders (Hynes 1975). If a major portion of the organic detritus originates from the true riparian species, then discontinuities in shredder relative abundance and diversity would not be expected to occur at the main terrestrial vegetation boundaries. The relative importance of the main terrestrial plant communities and the true riparian vegetation as detrital sources should be investigated further in Sierra Nevada streams.

Although stoneflies fit into two main feeding groups, shredders and predators (Merritt and Cummins 1984), much more research on food habits is needed for many genera and species. To accurately place a stonefly within one or more FFG's, it is not sufficient to just examine gut contents; in addition, observations of mouthpart morphology and feeding behavior are needed. Determination of FFG is complicated by food habit variations with stonefly age, size, and environment (Hynes 1976). Despite these uncertainties, few stoneflies seem to have evolved scraper and collector feeding modes, possibly as Wiggins and Mackay (1978) have speculated, because other aquatic insect orders (Ephemeroptera, Trichoptera, and Diptera) have completely exploited these feeding methods. Filter feeding is noticeably absent in Plecoptera nymphs, but is common in these other aquatic insect orders.

An interesting outcome of this study was that data from a small subset of the entire stream macroinvertebrate community could be used to test and support several predictions of the RCC, which was proposed to explain longitudinal changes in stream ecosystems and the entire macroinvertebrate community. Wiggins and Mackay (1978) used Trichoptera to test RCC predictions of FFG's and to compare differences between streams in eastern and western North America. The use of other taxonomic subsets to test the RCC could offer additional important insights into stream processes.

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HABITAT AND POPULATIONS OF THE VALLEY ELDERBERRY LONGHORN BEETLE ALONG THE SACRAMENTO RIVER[1]

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Abstract: Prior to 1985, the valley elderberry longhorn beetle, a threatened species protected under the federal Endangered Species Act, was known only from northern California riparian areas along the American River and Putah Creek in the Sacramento Valley, and along several rivers in the northern San Joaquin Valley. During 1985-1987, our study extended the known range of the beetle northward along the Sacramento River to Red Bluff by searching riparian areas for elderberry shrubs, the required habitat for beetle larvae; by searching shrubs for beetle emergence holes; and by searching for adult beetles during their brief spring emergence period. The survey results showed that the beetle is distributed widely along the river but is rare.

The valley elderberry longhorn beetle (*Democerus californicus dimorphus* Fisher [Coleoptera: Cerambycidae]), herein abbreviated VELB, is federally designated as a threatened species under the Endangered Species Act. VELB is endemic to riparian areas in the Sacramento and San Joaquin Valleys of California, where its larvae inhabit elderberry (*Sambucus* sp.) shrubs. Because of the severe reduction in the Central Valley's natural riparian vegetation over the last 150 years, the beetle's habitat has become scarce and discontinuous.

This paper describes a study to determine (a) locations of active colonies of the VELB along the Sacramento River from the City of Sacramento upstream to Red Bluff, and (b) the distribution of potential and actual VELB habitat within the same reach. Potential VELB habitat was defined by the presence of elderberry shrubs within areas of riparian vegetation. Actual VELB habitat was defined by the presence of VELB emergence holes in elderberry shrubs. Active colonies were defined by detection of adult VELB during their spring emergence period in April and May.

The Valley Elderberry Longhorn Beetle

Two subspecies of elderberry longhorn beetles, (*D. c. dimorphus* and *D. c. californicus*), occur in California. The California elderberry longhorn beetle (*D. c. californicus*) occupies valleys of the coastal ranges of California , from Los Angeles northward to Mendocino County. The two subspecies occupy distinct geographic ranges (Linsley and Chemsak 1972).

VELB (i.e., *D. c. dimorphus*) are moderate-sized, brightly colored, sexually dimorphic beetles with female body lengths of 18-25 mm and male body lengths of 13-21 mm (Linsley and Chemsak 1972). Their antennae are long, extending more than half their body lengths. Males exhibit one of two different color patterns. In some, the elytra (i.e., the first pair of hardened wings that protect the flight wings) resemble those of the coastal subspecies (*D. c. californicus*), whose elytra are dark metallic green with bright reddish orange borders (U.S. Fish and Wildlife Service 1984). In other VELB males, the solid green pattern is reduced to four oblong spots on the elytra. Intergrades between the two divergent color patterns also exist. In general, both male and female VELB are smaller than *D. c. californicus.*

Little is known about the life history of VELB; it is assumed, however, to follow a sequence of events similar to that of several related species of *Desmocerus* beetles (U.S. Fish and Wildlife Service 1984). Females may lay as many as 200 eggs during their short life span. Eggs are laid on foliage or leaf petioles at the outer tips of branches of living elderberry plants and in bark crevices of larger stems and trunks. Presumably, the eggs hatch 2-3 days after they are laid. Larvae bore through the pith of stems and possibly through the roots of elderberry shrubs. When larvae are ready to pupate, they work their way through the pith, open an emergence hole through the bark, and then return to the pith for pupation. Adults exit through the emergence holes, approximately 0.5 cm in diameter, and then can be found on elderberry foliage, flowers, or stems, or on associated plants (U.S. Fish and Wildlife Service 1984).

VELB was first described by Fisher in 1921 from specimens collected in Sacramento (U.S. Fish and Wildlife Service 1984). By 1984, VELB was known from only three Central Valley drainages: Merced River, Putah Creek, and the American River. Since designation of the VELB as threatened in 1980, a number of field surveys (in addition to those reported here) have produced new records of VELB through observations of adult beetles or their emergence holes. These new locations include many sites on the American River floodplain; the

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Cosumnes River floodplain; sites along several creeks near Roseville, California, west of Folsom Lake; and sites along the Mokelumne, Calaveras, San Joaquin, Middle, Tuolumne, and Merced Rivers in the San Joaquin Valley (Jones & Stokes Associates, Inc. 1987).

Study Area

The study area encompassed the floodplain of the Sacramento River, from its confluence with the American River at River Mile (RM) 60 in the City of Sacramento to Red Bluff Diversion Dam at RM 243. Within this 183-mile-long reach, the study focused on areas occupied by native riparian vegetation, which comprises a mosaic of riparian scrub on levees and other regularly disturbed areas, young-growth cotton wood-willow forest on lower terraces, and mature mixed-riparian forest on higher terraces. Many intervening sites have been cleared for agriculture or installation of levee protection. Other papers presented in these proceedings, such as by McCarten (1988), describe riparian vegetation along the Sacramento River in greater detail.

Methods

Riparian vegetation within the study area was delineated on aerial photographic map plates in the Sacramento River Aerial Atlas of the U.S. Army Corps of Engineers (U.S. Army Corps of Engineers 1984). At least 30 percent of the riparian vegetation area was selected randomly and visited during the winter surveys. Individual survey polygons were selected so that the probability of selection was proportional to the size of the polygon of delineated riparian vegetation (Husch and others 1972). Polygons of riparian vegetation varied widely in size from less than 1 hectare to more than 50 hectares. Use of the proportional probability selection procedure ensured that large-area polygons would not be underrepresented in the survey.

Each selected riparian polygon was searched thoroughly on the ground to determine the presence or absence of elderberry shrubs. If present, elderberry shrubs were in turn thoroughly searched for VELB emergence holes by inspecting the shrub stems carefully. Holes were presumed to have been produced by VELB emergence if they were of the appropriate shape and size (i.e., about 0.6 cm diameter and uniformly cylindrical). No other Cerambycid borers are known to occupy elderberry shrubs in Central Valley riparian areas. Stem searches were often quite difficult because of dense understories of poison-oak and blackberries. Any elderberries found to have VELB emergence holes were characterized on field data sheets.

Spring surveys for adult VELB were conducted in stands of elderberries with emergence holes previously detected during the winter surveys. A three- or four-person crew walked slowly through the elderberry stands, searching the leaves, flowers, and stems of each shrub, sometimes using binoculars. Spring surveys were conducted during the late April to late May period when adult beetles emerge from their larval galleries. Where adult beetles were collected, data were taken on characteristics of the VELB specimens, the substrates on which they were found, weather conditions, elderberry phenology, and vegetation structure. All collected VELB specimens were deposited in the University of California, Berkeley, Essig Museum.

Results

Elderberries as Potential Habitat

The winter surveys over 3 study years (i.e., 1985, 1986, and 1987) covered a total of 1,943 hectares in 66 polygons of riparian vegetation (Table 1). Average sizes of surveyed polygons varied among three sections of the study area. In the Sacramento-Colusa reach, 25 polygons averaged about 15 hectares per polygon; in the Colusa-Chico Landing reach, 23 polygons averaged 30 hectares per polygon; and in the Chico Landing-Red Bluff reach, 18 polygons averaged 50 hectares per polygon. This pattern reflects the fact that riparian vegetation below Colusa is confined to narrow strips within tightly constraining levees. From Colusa to Chico Landing, setback levees encompass large areas of riparian vegetation, and above Chico Landing, the absence of levees is associated with the largest stands of riparian vegetation.

Sixty-three of the 66 polygons surveyed throughout the study contained stands of elderberry shrubs (Table 1). Two of the three polygons without elderberries were located in the Sacramento-Colusa reach, possibly reflecting higher intensities of maintenance on narrow berms within the levees below Colusa.

VELB Emergence Holes

VELB emergence holes were found in 42 (64 percent) of the 66 polygons covered by the winter surveys (Table 1). Percentages of polygons with detected emergence holes increased from 28 percent below Colusa to 94 percent above Chico Landing. Evidently, habitat use by VELB has been wide-spread throughout the upstream portions of the study area.

Table 1 - Aggregate survey results for 3 study years.

					Specimen Characteristics			Substrate Characteristics			
River Mile	Collection Date	Time of Day	Weather	Temp.	Sex	Activity During Observation	Height During Observation (c)	Stem Diameter (m)	Total Height (m)	Exposure of Shrub	Overstory
84.3 West	5/3/85	1200	Clear, gentle breeze	77 °F	Male	Walking, flying	2.1	7.6	6.0	Sun	Open
84.3 West	5/3/85	1226	Clear, gentle breeze	77 °F	Male	Walking	1.5	5.1	2.0	Sun	Open
126.5 West	5/3/85	1558	Clear, no wind	75 °F	Female	Resting	0.9	2.5	1.2	Part shade	Open
235 West	5/5/8S	1105	Clear, no wind	78 °F	Male	Flying, resting	2.1	5.1	4.6	Sun	Open
138.7 West	4/29/87	1100	20% clouds, no wind	70 °F	Female	Resting	2.1	10.2	3.0	Shade	Mixed riparian
138.7 West	4/29/87	1130	20% clouds, no wind	75 °F	Male	Resting	1.8	1.9	3.0	Shade	Mixed riparian
169.5 West	4/29/87	1540	50% clouds, slight breeze	80 °F	Male	Resting	3.0	14.0	6.0	Sun	Open
177.7 East	5/7/87	1045	20% clouds, no wind	85 °F	Female	Resting	2.4	10.2	6.0	Sun	Open
179.4 East	5/8/87	1022	20% clouds, no wind	80 °F	Male	Walking	1.2	10.2	4.6	Sun	Open
179.4 East	5/8/87	1350	30% clouds, no wind	90 °F	Female	Resting	0.08	11.4	4.6	Sun	Open

Stem Diameter at VELB Emergence Holes

Stem diameters at 49 current-year emergence holes detected in May 1987 are shown by size classes in Figure 1. Current-year holes were positively identified by the presence of fresh wood and frass (i.e., wood shavings usually mixed with excrement produced by the boring insect). No holes were detected on stems less than 2.5 cm in diameter, whereas the largest stem with a hole was 20 cm in diameter. Sixty-six percent of the holes were observed in stems less than 7.0 cm in diameter, and 34 percent were observed in stems greater than this size.

Stem Height at VELB Emergence Holes

Stem heights were estimated at 627 VELB emergence holes observed during 1986 and 1987 surveys. Nearly 70 percent of the observed emergence holes were at heights at or below 1.2 m on elderberry stems (Figure 2). Approximately 10 percent were detected at heights above 1.8 m.

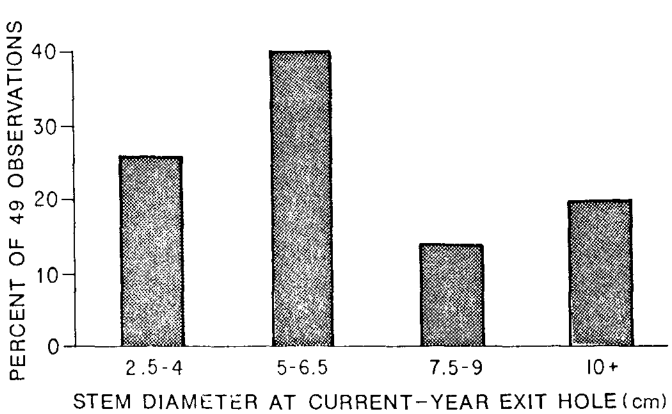

Figure 1- Frequency distribution of stem diameters at current-year holes detected in May 1987.

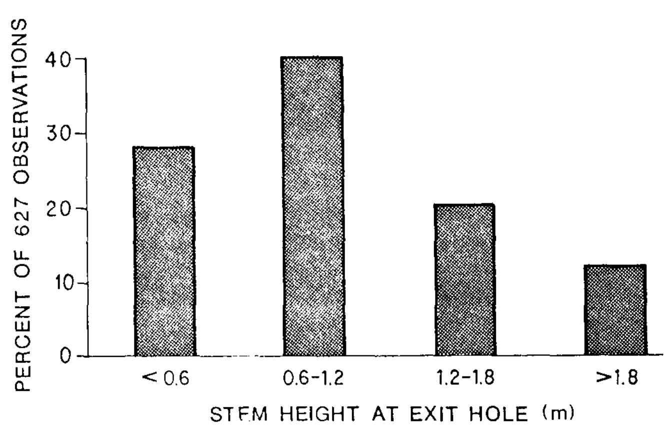

Figure 2- Frequency distribution of stem heights at VELB exit holes detected in 1986 and 1987.

Table 2 – Descriptions of collections of adult VELB specimens.

Reach	Winter Surveys						Spring Surveys			
	Area Surveyed (ha)	Polygons Surveyed	Polygons with: Elderberries		Polygons with: VELB Exit Holes		Area Surveyed (ha)	Polygons Surveyed	Polygons with Adult VELB	
			No.	Percent	No.	Percent			No.	Percent
Sacramento-Colusa (RM 60-145)	383	25	23	92	7	28	40	4	3	75
Colusa Chico Landing (RM 145-195)	688	23	22	96	18	78	523	16	3	19
Chico Landing-Red Bluff (RM 195-243)	875	18	18	100	17	94	274	13	1	8
TOTAL	1,946	66	63	95	42	64	837	33	7	21

Characteristics of Elderberry Clumps with VELB Exit Holes

A total of 367 elderberry clumps (i.e., groups of stems apparently arising from the same root stock) with VELB emergence holes were observed during the three winter surveys. Elderberry clumps with holes were found in young-growth riparian stands of young cottonwoods and willows on low-terrace areas of the Sacramento River floodplain (15 percent of 360 clumps); riparian stands of mature and senescent cottonwoods, generally on low-terrace areas, often with woody vines of wild grape (35 percent); mature riparian stands of mixed tree species including cottonwood, boxelder, walnut, or valley oak, often with woody vines of wild grape, on high-terrace areas (35 percent); and both high- and low-terrace areas with no overstory (14 percent of clumps).

Adult VELB Collections

Ten VELB adults were collected at seven different locations on five different dates in spring 1985 and spring 1987 (Table 2). The adult beetles were collected in seven of the 33 polygons surveyed during spring (Table 1). Three of the four polygons below Colusa provided VELB collections, indicating the importance of narrow riparian strips with elderberries as active VELB habitat.

Adult VELB were collected in 3 of the 16 polygons surveyed during spring between Colusa and Chico Landing. Nine of these 16 polygons were surveyed during late spring 1986, when no VELB were found anywhere in the study area, possibly due to effects of the February 1986 flooding along the Sacramento River, unusual weather conditions, and patterns of elderberry phenology during spring 1986. Above Chico Landing, adult VELB were collected in only 1 of the 13 polygons (Table 1). The low collection rate here also reflected the regionwide lack of collections in 1986.

More details on study results can be found in the report by Jones & Stokes Associates (1987).

Discussion

VELB Rarity

During this study, approximately 70 person-days of field time were spent searching habitat containing VELB emergence holes. This effort resulted in collections of only 10 adult VELB, showing that VELB is a rare insect. Our low rate of collection may have been influenced by two other factors in addition to the species' rarity. Visual searches for VELB adults are difficult within suitable habitat because elderberry shrubs are tall and because VELB adults are generally more active in higher portions of shrubs (e.g., 5 of 10 adults were collected at heights of 2 m or more). Many shrubs are inaccessible because of dense understories or overhanging vines of wild grape, blackberry, and poison-oak. In addition, VELB adults are not greatly mobile, they do not concentrate on elderberry flowers, and they do not often fly about, even in hot weather.

VELB Distribution on Sacramento River Floodplain

VELB emergence holes were detected in elderberries in most riparian stands surveyed, indicating that VELB are widespread, although rare, in suitable riparian habitat along the Sacramento River. The relatively small proportion of current-year emergence holes suggests that the population is limited at any one site by factors other than habitat availability.

Within the Sacramento River floodplain, VELB does not appear to be restricted to particular kinds of riparian vegetation or floodplain topography. VELB emergence holes were found in nearly all situations, ranging from isolated elderberry clumps in savannalike areas to continuous stands beneath tall overstories, areas with or without extensive woody understory vegetation, and on both low- and high-terrace floodplains.

VELB requires established elderberry plants of mature size and age. No emergence holes were found on stems less than 2.5 cm in diameter, consistent with the presumed 2-year period that VELB larvae are thought to inhabit elderberry shrubs. Stems of less than 2.5 cm in diameter may be inhabited by VELB larvae but grow greatly in diameter within the 2-year period. Annual cutting, burning, or herbicide treatment of elderberry shrubs would preclude VELB occupancy.

Role of Birds

If birds forage after VELB larvae, they may be an important factor regulating VELB populations. Bird holes were found at nearly every site where VELB emergence holes were found. A key need for monitoring VELB populations is to determine the role of birds in creating holes in elderberry stems, in enlarging or reworking VELB emergence holes, and in preying on VELB larvae. Easily distinguished bird holes were at least as common as VELB holes at many sites and were far more abundant than VELB holes at some sites. We dissected several elderberry stems with bird holes and found evidence of tunneling by insect larvae, presumably VELB, in the pith.

In searching for evidence of VELB, we recorded only clearly identifiable Cerambycid emergence holes and rejected holes that appeared to be created or enlarged by birds. If birds commonly enlarge holes originally bored by emerging VELB, they would obscure them as VELB emergence holes. Thus, the VELB population along the Sacramento River may be larger than is currently indicated by frequencies of emergence holes.

Sizes and Ages of Elderberries Used by VELB

Nearly 70 percent of current-year exit holes found in May 1987 were in stems 2.5-6.5 cm in diameter at the emergence hole. None were in stems less than 2.5 cm in diameter. Because of the rapid growth rate of young elderberries, stems less than about 6 cm in diameter may have grown from new shoots within the 2-year period of VELB larval occupation.

The best strategy for VELB habitat management is to maintain mixed stands containing all ages and sizes of elderberries. Our data suggest that VELB larvae are able to inhabit a broad range of ages and sizes of elderberries over a minimum size threshold of about 2.5 cm basal stem diameter. Where VELB habitat restoration or enhancement is being considered, a mixture of sizes of elderberries should be established to increase habitat area and quality.

Conclusions

The currently known range of VELB extends through the San Joaquin- Sacramento Valley from the Merced River in Merced County northward to near Red Bluff on the Sacramento River in Tehama County. Our study extended the known range northward by about 120 air miles and 183 river miles, from the City of Sacramento to Red Bluff. Other recent studies have extended the known distribution to at least 6 rivers in the San Joaquin Valley and along the American River through the City of Sacramento.

The currently known range is based on observations of either adult VELB or VELB emergence holes in elderberry shrubs. In our winter surveys along the Sacramento River, 95 percent of all surveyed stands of riparian vegetation contained elderberry shrubs, and VELB emergence holes were detected in 64 percent of the surveyed stands. During our spring surveys in stands with emergence holes, we collected adult VELB in 7 of the 34 stands surveyed.

Acknowledgments

We thank Jack E. Williams, U.S. Fish and Wildlife Service, Sacramento Endangered Species Office; William Shepard, California State University, Sacramento; Paul A. Rude; A. Miriam Green; and Clinton Kellner for contributing substantially to the success of this study.

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PRACTICAL TECHNIQUES FOR VALLEY ELDERBERRY LONGHORN BEETLE MITIGATION[1]

Greg Sutter, Jeurel Singleton, Jim King, and Ann Fisher [2]

The valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) *is* a live-wood pith-boring beetle of the family Cerambycidae. Elderberry (*Sambucus* spp.) shrubs are the beetle's exclusive host plant. The valley elderberry longhorn beetle (VELB) is classified as a threatened species by the U.S. Fish and Wildlife Service. The VELB is sporadically distributed in the Sacramento and San Joaquin Valleys from Red Bluff to Fresno, California.

This poster presentation describes mitigation measures for VELB habitat loss that has resulted from public and private development at sites along the Sacramento and American Rivers.

Mitigation Techniques and Project Examples

When designing a mitigation program for VELB, it is essential to consider the ecological characteristics of both the VELB and the elderberry host plants, site conditions at both the impact site and the mitigation site if offsite mitigation is used, and the importance of proper timing when dealing with natural systems.

The best way to mitigate project impacts is to build protection of existing elderberry habitat into the project. This is difficult in urban settings where public use and activities reduce the potential for long-term survival and regeneration of elderberry shrubs.

Transplanting Mature Shrubs

Where preservation of habitat in place is not possible, mitigation programs can include habitat enhancement offsite. Transplanting mature elderberries occupied by VELB to a new site is one way to mitigate by offsite habitat enhancement. Unlike offsite mitigation using elderberry seedlings or rooted cuttings, the transplanting of mature plants, if successful, can also translocate VELB larvae within stems to the new site. Successful transplanting of mature elderberry plants when the plants are dormant (approximately November through the first two weeks of February)

Foliage and stems should be pruned to reduce the shoot:root ratio and thus reduce transpirational load until the root system reestablishes. In addition, transplanted shrubs should be irrigated on a schedule that will gradually wean them from artificial moisture supplies. The large-diameter plant material pruned from mature elderberries also should be moved to the transplant site because larvae inhabiting the prunings may emerge as VELB adults during the spring emergence period and lay eggs on the transplanted elderberries.

As mitigation for a large land development project, mature elderberry plants were moved by Jones & Stokes Associates to a parcel deeded to the county as an addition to the American River Parkway. Approximately 80% of the transplanted plants were surviving after the first growing season.

Revegetating with Seedlings or Rooted Cuttings

Elderberry seedlings or rooted cuttings also can be used for offsite habitat enhancement or compensation. An ideal offsite mitigation plan would use young plants in combination with transplanted mature plants.

The easiest way to grow young plants for revegetation is from seed. If seed is not available, cuttings can be taken either in the dormant season as hardwood cuttings or in the spring as softwood cuttings.

Rooted cuttings planted by the California Department of Water Resources in the American River Parkway as mitigation for a floodway vegetation removal program are in their second growing season after planting. The plants were irrigated regularly through the first growing season (every 10 days to 3 weeks). The watering was reduced in the second season, and no watering will occur in following years. The plants had a high survival rate of about 90% after the first growing season, and at the end of the second year well over 50% are still thriving.

[1]Presented at the California Riparian Systems Conference, September 22-24, 1988, Davis, California

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Figure 1- Adult VELB emergence hole in an elderberry stem.

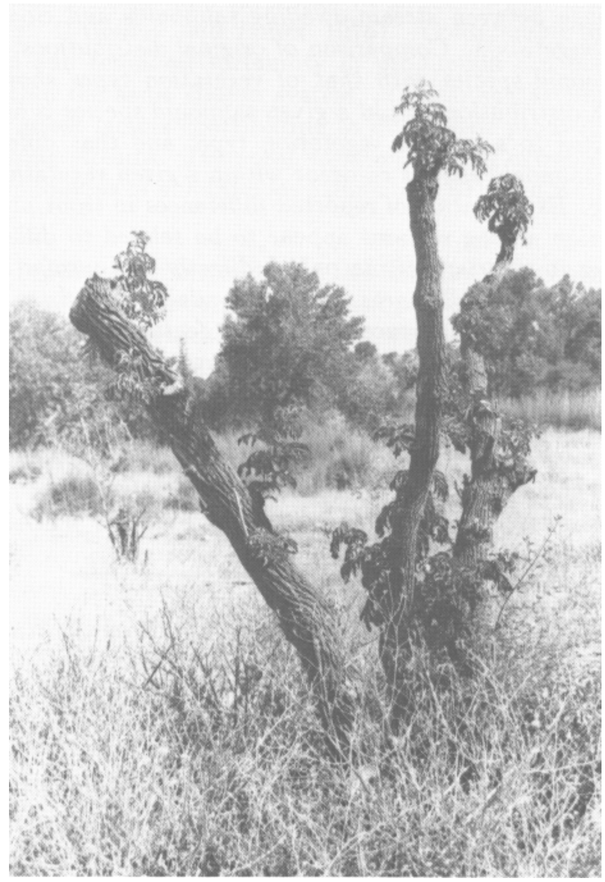

Figure 2- A mature elderberry plant heavily pruned for transplanting with many new sprouts after planting.

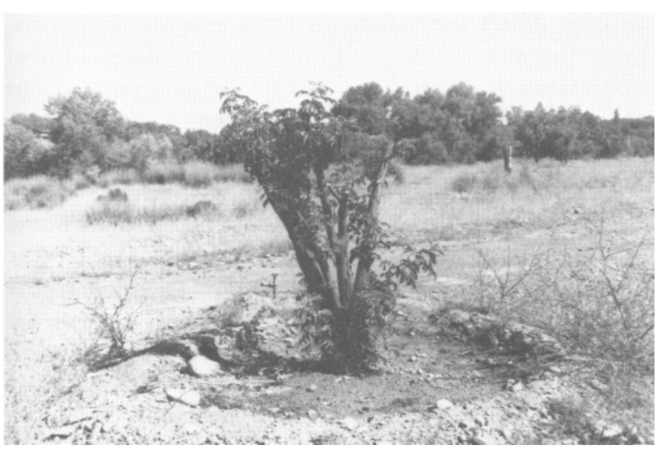

Figure 3- A transplanted elderberry shrub with vigorous new growth. Notice the large watering basin.

Figure 4- Rooted elderberry cuttings ready to be planted.

HOW TIGHT IS THE LINKAGE BETWEEN TREES AND TROUT?[1]

Margaret A. Wilzbach[2]

Abstract: This paper explores the tightness of the linkage between stream-dwelling salmonids and riparian vegetation. Comparison of original distributions of salmonid species with that of vegetation types shows that distribution within a given salmonid species is not limited to a specific vegetation type, and that different salmonid species co-occur within a given vegetation type. Examination of reported differences in trout production among streams appear to be related to differences in riparian setting only indirectly and insofar as these reflect differences in prey availability and, to a lesser extent, differences in habitat features. Variability in trout production estimates are minimized when comparisons are species-specific and normalized for temperature differences among streams. Within a riparian vegetation type, the relationship between trout production and successional age of the streamside vegetation is often inverse.

Much of the research of the past decade on the land-water interface was triggered by Hynes' (1963) proposal that stream biota highly depends on the terrestrial setting and by Ross's (1963) observation that the distribution of many genera and species groups of stream invertebrates is closely correlated to the distribution of terrestrial vegetation types. All 14 (now 18) species of the genus *Pychnopsyche* (Limnephilidae), for example, occur entirely within the deciduous forest formation of eastern North America. Their distribution overlaps nearly perfectly with that of sugar maple (*Acer saccharum*), one of the dominant trees in the climax forest. Ross suggested that the coincident distributions occur because of the unique conditions imposed upon stream fauna by the nature of the forest itself.

This paper describes a study to determine if a linkage exists between stream-dwelling salmonid fishes and the surrounding terrestrial vegetation, explores native distributions of salmonid species with reference to the distribution of vegetation types, and evaluates the relationship between the riparian setting and trout population parameters.

Native Distributions of Salmonids in Relation to Vegetation

The native range of the salmonid family is the Holarctic realm, including northern latitudes of North America and Eurasia. Restricting consideration to the subfamily salmoninae, common genera include the chars, *Salvelinus* spp., the trouts, *Salmo* species, and the largely anadromous Pacific salmon, *Oncorhynchus.* In no case is the distribution of any of these genera delimited by the distribution of a specific vegetation type.

The distribution of individual species also is not generally delimited by the distribution of vegetation types. For example, the original distribution of brook char (*Salvelinus fonlinalis*) was eastern North America from the Hudson Bay drainage and Labrador south to the southern Appalachian Mountains and west to parts of the Great Lakes basin and headwaters of the Mississippi drainage (MacCrimmon and Campbell 1969). This distribution coincides exactly with the hemlock and northern hardwoods region (Braun 1950), but it also encompasses other regions within the deciduous forest and boreal and tundra formations. The distributions of single species often extend beyond the range of a vegetation type among the trouts of western North America. Cutthroat trout (*Salmo clarki),* which were the most widely distributed of any western trout, occurred on both sides of the Continental Divide in the uppermost headwaters of the Columbia and Missouri river basins and in the Colorado River, Rio Grande, and Great Basin systems (Behnke 1972), across a range of vegetation types that included Pacific conifer forest, the Rocky Mountain forest complex, the Sierra Nevada forest complex, and the northern desert formation. In most geographical areas, the cutthroat trout do not form discretely differentiated populations, and variability among disjunct populations within a single drainage may be as great as the variability among drainage basins (Behnke 1972). Thus it is difficult to argue that any specific vegetation type posed a set of unique conditions that acted to limit the distribution of this salmonid.

Some *Salmo* species, notably within the golden trout complex (e.g. *Salmo aguabonita, S. gilae, S. apache*) do have very restricted distributions. *Salmo aguabonita* occurred originally in the Kern basin in California (Schreck and Behnke 1971), *Salmo apache* in the upper

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Salt River and headwaters of Little Colorado River, Arizona, and *Salmo gilae* probably only in high gradient headwater streams of the Gila River in New Mexico (Lee and others 1980). Probably the vegetation surrounding the streams within these restricted ranges was originally fairly uniform in composition. Given the very broad geographic distribution of most freshwater salmonid species across a range of vegetation types, however, there is little reason to think that the relationship between the distribution of these trouts and the corresponding vegetation is causal in nature.

Present Distribution and Production of Salmonids in Relation to Vegetation

Salmonids, particularly the rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), and brook char, have been extensively introduced to stream and river systems throughout the world (MacCrimmon 1971, MacCrimmon and Campbell 1969, MacCrimmon and Marshall 1968). The native range of the rainbow trout in western North America has been extended via introduction to every continent except Antarctica. The brown trout, native to Europe and Eurasia, has become established in all but 10 states in the U.S. and in 9 of 10 Canadian provinces.

In contrast to most stream invertebrates, salmonids and freshwater fishes in general are much more plastic in their responses to environmental conditions (Hynes 1970). Salmonids are obviously able to become established in streams that are surrounded by a broad array of vegetation types. An inescapable conclusion is that the composition of the surrounding vegetation of itself has not limited the ability of a salmonid population to inhabit a stream or river system.

Are any relationships apparent between composition of the streamside vegetative setting and trout population parameters other than distribution? These are not obvious. Similar production values have been reported among stream sites that differ in the nature of their vegetative setting. For example, the production of brook trout in Lawrence Creek, Wisconsin, a primarily open cropland stream bordered by some shrubs, was reported to be 18.1 (McFadden 1961) or 11.7 (Hunt 1974) g m-2 yr-1. In Valley Creek, Minnesota, which flows through northern hardwood forest, the annual production of brook trout was measured at 16.3 - 19.1 g m-2, dropping to 7.9 g m-2 in a year in which the stream experienced heavy siltation (Waters 1982). Similarly, the annual production of wild brown trout in a British Lake District stream, Black Brows Beck, which flows through oak dominated woodland, is within the same range (10 g m-2, LeCren 1969) as that of brown trout in a Danish stream (11.3 g m-2 for 2 yrs, Mortensen 1985), Bisballe Baek, which is open with scattered alder and willow along its banks. Among sites with the same riparian setting, differences can be found in production (e.g., O'Conner and Power 1976). Considerable spatial and temporal variability in production can occur within the same stream system, confounding attempts to assess factors contributing to differential production among streams. Temporal variation can be extreme in populations of anadromous salmonids (Hall and Knight 1981).

Productivity incorporates two distinct components: 1) a weight component determined primarily by growth, and 2) a numerical component which represents the balance between births vs. deaths and immigration vs. emigration (Allen 1969). These two components and the factors regulating them may interact, but each is also affected by independent influences. Growth rate is dependent on both environmental and on genetic factors (LeCren 1965). The maximum size a fish will reach is determined by food availability, which may be density related. The rate at which maximum size is approached is under at least some genetic/physiological control. Brown trout are thought to show a higher temperature-specific growth rate than brook trout (which may explain why they tend to displace brook trout so readily in the eastern U.S.) - and thus productivity can be only fairly compared within species.

Growth rate of salmonids is also influenced to a very large degree by temperature (Elliott 1976). Assuming prey are available for consumption, higher growth is obtained at higher temperatures up to the optimal growth temperature; above this temperature, growth will again decline. Differences in trout production are minimized once one normalizes for temperature. For example, in a comparison of streams ranging from chalk streams in southern lowland Britain to brown water, upland streams in Scotland, Edwards and others (1979) found that the high growth rates of brown trout in chalk streams could be explained almost entirely on the basis of ambient temperature and in particular by the homeothermous nature of the temperature regime. In the Horokiwi stream in New Zealand, from which the highest trout production values have been reported (55 g m-2 yr-1, [Allen 1951]), the mean of monthly temperatures was about 2°C higher than any of the British streams described by Edwards and others (1979). This temperature increase may have contributed to the higher production values. Allen (1985) found that brown trout from the Horokiwi stream grew more rapidly than similar sized brown trout from Britain that were held at the same temperature and fed to satiation. He suggested that there may have been genetic selection for more rapid growth and a higher temperature limit.

Factors affecting the density component of productivity are not as straightforward. A fair amount of evidence suggests that for the adult segment of the population, the physical configuration of the stream channel limits the number of fish that can be supported (e.g. Hunt 1971, White 1975). The assumption, although often untested, that trout standing crop can be predicted from habitat variables such as pool area or volume, bank cover, etc. has formed the basis of a burgeoning development of habitat models. Except under conditions of heavy fishing pressure, the density of adult freshwater fish populations is often fairly stable, which can be partly attributed to the long life span of reproductive stages. This may not hold for juvenile stages, which are extremely variable, and the principal cause of variation in overall population abundance. Much of the growth and up to 98 percent of the mortality takes place in the post-hatching, pre-maturity part of life (LeCren 1965). The factors responsible for this are the least understood and most problematic aspects of fish population dynamics. It is not at all clear, for example, whether any increase in the density of fry will be translated into an increase in the density and/or biomass of the adult population. Certainly future research on forestry-fishery interactions need to focus on this stage.

Functional Links Between Riparian Vegetation and Salmonid Populations

The above considerations aside, it is reasonable to conclude that food availability, temperature, and physical aspects of the channel are three of the major determinants of productivity. These determinants are strongly affected by the nature of and functional roles played by riparian vegetation, even though trout distribution patterns and productivity cannot be tied in a direct fashion to the composition of the streamside vegetation.

Temperature Effects Associated with Riparian Vegetation

In terms of its effect on stream temperature, the most important distinction to make among types of riparian vegetation is whether the vegetation provides an open or a closed canopy. In headwater streams this distinction will separate grasses and herbaceous vegetation from some deciduous and coniferous trees, depending upon stream width. In very small streams, even grasses may effectively shade the channel, especially if sideslopes are steep and banks undercut. In summertime, the principal source of heat to a small stream comes from direct solar radiation (Beschta and others 1987); canopy closure may reduce incoming radiation by 85 percent (Brown 1983). Canopy closure may also prevent heat loss in the winter that can occur by evaporation, convection, and long-wave radiation. Trout have been observed to feed actively during the winter, but the energy gain from feeding is often sufficient only for maintenance and not growth. An increase in winter temperatures, however, may promote greater growth. Increases in summer maximum temperatures following canopy removal generally range from about 3 to 10°C in the U.S. (Beschta and others 1987). In mountainous streams the increase in maximum summer temperatures does not usually approach the tolerance limits for resident salmonids; this is often a very significant problem in low gradient, low elevation sites. Even in mountainous streams, however, increases in the temperature regime may shift fish community composition to favor species other than salmonids (Karr and Schlosser 1978). For example, Reeves and others (1987) found that temperature affected the outcome of competitive interactions between steelhead trout and redside shiner (*Richardsonius balteatus*). Trout production at cool temperatures was the same in the presence and absence of the shiner; at warmer temperatures (19-22°C), trout production decreased 54 percent in the presence of the shiner.

Influence of Riparian Setting on Food Availability to Trout

The open or closed nature of the canopy also has an important effect on food availability to trout, for at least two reasons. First, light intensity appears to affect the foraging efficiency of trout. Wilzbach et al. (1986) found a strong log-linear relationship between trout foraging efficiency and surface light in an Oregon Cascade Mountain stream. Second, degree of canopy opening plays a major role in determining the food resource base for the invertebrate prey community and its consequent composition. The resource base of small woodland streams is heterotrophic, i.e. dependent upon organic matter elaborated in the surrounding terrestrial system (e.g. Cummins 1974, Cummins and others 1984). In these streams, shredders which feed on coarse particulate organic matter derived from the terrestrial zone comprise a large and often dominant component of the invertebrate community (e.g. Cummins and others 1981, Petersen and others 1988). In larger stream or river systems and in small streams lacking a canopy, in-stream algal production increases and scrapers which use this food resource may largely replace the shredder component. A distinction between scrapers and shredders is an important one because shredders rarely comprise a significant part of trout diets. As a general rule, salmonids feed upon invertebrates as they drift in the water column. Shredders are not often found in the drift, except at times of emergence or in very early life stages, at a size below which salmonids typically detect prey items. Many scrapers, especially heptageniid and some ephemerellid mayflies, are more commonly collected in drift samples. The most common prey items in trout diets, however, belong to the functional feeding group of collectors, including baetid mayflies, many chironomid midges, and blackflies which feed on fine particulates derived from litter or algal detritus by filtering or gathering. These exhibit an even greater propensity to drift, often on a predictable diurnal schedule.

In relation to its effect on food availability, the other important distinction to make among different types of riparian vegetation is the turnover time of its litter inputs to the stream. These can be roughly broken down into fast or slow. The fast litter category includes many herbaceous plants, shrubs characteristic of recovery stages from a disturbance (such as alder, dogwoods, viburnums, and salmonberry), as well as some types of deciduous trees such as basswood, elm, and black cherry. The slow litter category includes grasses and sedges, shrubs such as the rhododendrons, conifers, and such deciduous trees as oaks and beeches. If litter is derived predominantly from 'fast' plants, there will be a rapid turnover of coarse particulate organic matter (CPOM) relative to the time of input and a rapid generation of fine particulates (FPOM), including a significant portion derived from shredder feces. If litter comes from `slow' plants, there will be a delayed turnover and generation of CPOM and FPOM. Quickly decomposing litter supports a fall-winter population of shredders and collectors feeding on this allochthonous detritus. Slowly decomposing litter supports delayed spring-summer populations of shredders and collectors.

The combination of turnover time of the litter and the open or closed nature of the canopy may predict the availability and productivity of the food base for salmonids. Food availability can be considered as the sum of density of prey multiplied by prey turnover and the fraction of the community that regularly drifts (i.e. collectors and some scrapers). An open canopy stream should produce a greater availability of food for trout than would closed canopy streams, irrespective of the turnover time of the litter inputs, because of the year-round sustained yield of scrapers and availability of high quality algal-derived detritus as the food base for collectors. Predominantly fast litter inputs should provide greater food availability than slow litter inputs because they would favor collector development in the autumn and winter during times of lower algal production which in turn would support lower scraper populations and provide less algal detritus. Thus in general, the expectation should be that food availability increases in streams from closed canopy, slow litter/closed canopy, fast litter/open canopy, slow litter/open canopy, fast litter.

Streams with an open canopy and fast litter are characteristic of early stages in a successional sequence. The succession will lead over time to a closed canopy with fast litter if mature vegetation is deciduous, and providing that the climax vegetation is not oak, sycamore, or beech; or to a closed canopy with slow litter where the mature vegetation is evergreen, oak, sycamore, or beech. Differences in food availability are the most likely explanation for the inverse relationship that has often been observed between trout production and successional age of the streamside vegetation (Murphy and others 1981, Murphy and Hall 1981, Hawkins and others 1983, Bisson and Sedell 1984, Wilzbach 1984).

Riparian Influence on Channel Configuration and on Cover

The riparian setting influences channel configuration through its effect on bank stability, and through the provision of woody debris into the stream channel, which affects local hydraulic conditions and sediment deposition (Sullivan and others 1987). Both overhanging vegetation and its root systems, and in-channel debris may provide cover for salmonids. Bank stability is enhanced by dense root systems, and distinctions can be made among riparian vegetation according to root mass density. Deciduous trees have deeper root systems than coniferous trees. Herbaceous plants and shrubs, particularly those characteristic of pioneer stages, develop large, dense root systems very quickly. These often act to constrict channel width by preventing erosion; this forms the basis of White and Brynildson's (1967) suggestions for improvement of trout habitat by replacing streamside trees with shrubs. However, during extremely highwater discharges, long term bank stability and location may be better served by tree root systems than by shrubs. In Sequoia National Park, streams can be observed flowing between giant sequoia trees that are in the range of 1000 yrs. old.

The role of woody debris in influencing channel configuration and the biological properties associated with woody debris have been recently reviewed by Sullivan and others (1987) and Bisson and others (1987). Briefly, in-channel debris acts to form pools and to control sediment and organic matter storage. Its importance to salmonids lies primarily in pool formation and backwater areas for rearing, and in the provision of cover from high flow or from predators. Distinctions to make among riparian vegetation with respect to these functions include the amount and size of debris that is available for input to the channel, and the decomposition time of the wood in the channel. Coniferous trees are able to supply larger amounts of wood than most deciduous trees and, in general, have slower decomposition rates.

There is an interesting thing to note about cover. A ranking of cover by the amount supplied and its duration within the stream channel proceeds in the opposite direction from a ranking of food availability as described earlier. Cover should be greatest in streams with closed canopies and slow litter, and should decrease in order of closed canopy, fast litter/open canopy, slow litter/to open canopy, fast litter. This is a further indication that salmonid production generally tracks food availability rather than cover, and suggests either that food availability is of greater importance to salmonid production than cover, or that we haven't fully deciphered the interaction between food and space. Laboratory experiments on the relative roles of food abundance and cover in determining the distribution and emigration of cutthroat trout support the suggestion that food overrides cover in importance (Wilzbach 1985).

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GEOMORPHIC AND RIPARIAN INFLUENCES ON THE DISTRIBUTION AND ABUNDANCE OF SALMONIDS IN A CASCADE MOUNTAIN STREAM[1]

Kelly M. S. Moore and Stan V. Gregory[2]

Abstract: Abundance of resident cutthroat (Salmo clarki) *and rainbow* (Salmo gairdneri) *trout was generally 1.5 to 3.5 times greater in unconstrained reaches than in constrained reaches of Lookout Creek, a fourth-order tributary to the McKenzie River, Oregon. The presence of adult rainbow trout depressed juvenile abundance in pools with little habitat complexity but had no effect in pools with more heterogeneous structure. The greater abundance of trout in unconstrained reaches was related to habitat structure, the influence of the riparian canopy on stream productivity, and the effect of channel morphology on stream hydraulics. Valley floor landforms are major determinants of channel complexity and habitat structure, providing a hierarchical geomorphic context for interpreting riparian influences on patterns of abundance and distribution of salmonids within a basin.*

The viability of cutthroat trout (*Salmo clarki*) populations in steep Cascade Mountain streams is dependent on the recruitment of juveniles within a stream reach and the quality of rearing and refuge habitat. Recruitment is particularly important because cutthroat trout in these streams are residents that may complete their life history within a 20- to 100-m reach (Miller 1957; Wyatt 1959; Aho 1977). Factors that influence recruitment include availability of suitable habitat and the presence of predators. Age 0 trout initially occupy the margins of the stream channel and move to faster-deeper habitats as they grow. Habitats at the lateral boundary of the main channel are structured by the interaction of streamflow with boulders, wood debris, and the geomorphic constraints of the valley floor.

Valley floor structure can influence stream ecosystems by influencing channel morphology and by regulating energy input and processing (Gregory and others 1989). Mechanisms of this influence become apparent when drainage networks are organized hierarchically by reach type, channel unit, and habitat subunit. Reach types are delineated by the type and degree of local constraint imposed by the valley wall at the channel margin. Reaches are constrained by bedrock intrusions, landslides, earthflows, and alluvial fans. Streams within constrained reaches tend to be relatively straight, single-channels with little lateral heterogeneity. Unconstrained each types are characterized by complex, often braided channels with extensive floodplains.

The stream channel in both constrained and unconstrained reaches is composed of longitudinal sequences of channel units with distinct hydraulic and geomorphic structure (Grant 1986) that are longer than one channel width and identifiable as pools, riffles, rapids and cascades. Channel units are divisible into habitat subunits less than one channel width in length. The subunit scale of hydraulic and geomorphic features corresponds to descriptions of fish habitat frequently used in ecological research. Subunits at the stream margin (lateral habitats such as eddies and backwaters) are characterized by low velocity, heterogeneous substratum, abundant detritus, and structural protection from high discharge. This combination of physical and biotic conditions provides gradients of depth and velocity, cover, and access to invertebrate food that make lateral habitats particularly suited to the requirements of young-of-the-year cutthroat trout (Moore 1987). The importance of off channel pools, side channels, and tributaries for both rearing and winter habitat has been well documented (Bustard and Narver 1975; Tschaplinski and Hartman 1983; Hartman and Brown 1987). These studies have focused on the importance to juvenile salmonids of habitats adjacent to the main channel. However, the effects of habitat complexity, in the context of valley floor geomorphology, has not been examined.

In an earlier study of riparian influence on cutthroat trout populations, Moore and Gregory (1988a) observed that the abundance of age 0+ fish was generally proportional to the area of lateral habitat in third-order, Cascade Mountain streams. In a manipulation of subunit structure, Moore and Gregory (1988b) found that increasing lateral habitat from 12 percent to 24 percent of total stream area resulted in 2.2 times greater density of age 0+ cutthroat trout. Juvenile trout populations were virtually eliminated in stream sections where lateral habitat was reduced. In the present study, the objective was to examine the relationship between juvenile trout and lateral habitat subunits at the stream reach and channel unit levels of organization. Also, the abundance of adult trout relative to reach type was considered as were possible effects of physical structure on interactions between juvenile and adult fish.

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Methods

Observations of fish populations and measurements of stream structure were made in Lookout Creek, a fourth-order stream in the H.J. Andrews Experimental Forest in the Cascade Mountains, Oregon, USA. In constrained reaches, this stream flows through 450-yr-old stands of conifers dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). In unconstrained reaches, conifers are less abundant and near-stream vegetation is dominated by willow (*Salix* sp.) and red alder (*Alnus rubra*) Stream reaches were mapped and characterized in terms of a constriction ratio. Constriction ratio equals the width of valley floor less than 3 meters above low stream flow divided by the active channel width. At Lookout Creek, the least constrained reach (constriction ratio = 5.6) is located in a depositional area above an earthflow-constricted reach and has a wide valley floor and multiple secondary channels. The most constrained reach (constriction ratio = 1.3) has a single channel flowing through a steep walled canyon at the toe of an earthflow. Mapping evaluated the degree of constraint on the stream and also measured geomorphic channel units and habitat subunits for 6.2 km of Lookout Creek. Habitat complexity in channel units was defined arbitrarily, based on the distribution of subunits. If one subunit class comprised more than 70 percent of the channel unit area, the unit was considered to have low complexity. If the channel unit had high subunit richness and evenness (four or more subunit classes, each comprising at least 15 percent of the area), the unit was considered to have high complexity. Differences in channel unit and subunit habitat area was examined with a Kruskal Wallis test of ranked classes (Sokal and Rohlf 1981).

Fish populations in Lookout Creek were censused by snorkeling observation during the summer of 1987. All reaches, channel units, and habitat subunits were examined. Divers recorded the species, length, and habitat use of every fish observed. Cutthroat and rainbow trout, Sculpin (*Cottus* spp.) and dace (*Rhinichthys* sp.) are the only fish present in the study reaches. The distribution of habitat sub-units within each reach was measured during summer base flow in 1987 and during winter base flow in 1988.

Results

The pattern of habitat utilization was the same in each of the reaches of Lookout Creek. After emergence, juveniles established territories in lateral habitats exclusively and remained there for at least six weeks. The abundance of juvenile cutthroat trout in Lookout Creek was greater in unconstrained and semi-constrained reaches than in constrained reaches. Abundance also increased along a downstream to upstream gradient, but, except for the extreme downstream reach, the density of juveniles was always greater in less constrained reaches than in adjacent reaches with comparatively greater constraint (fig. 1).

Age 1+ and older fish had a distribution that was similar to that of juveniles, but the pattern was modified by the presence of large structural elements (boulders and wood) in the most constrained reach (fig. 2). The greatest density of fish was generally in the unconstrained reaches. However, one constrained reach had a particularly high abundance of adult trout. This reach was at the toe of an active earthflow that has introduced numerous large boulders (> 2 m diameter) to the channel. These boulders created channel roughness that entrained large woody debris and modified stream structure to create a variety of habitat types within the reach. Deep pools and backwater habitats were particularly abundant in this reach.

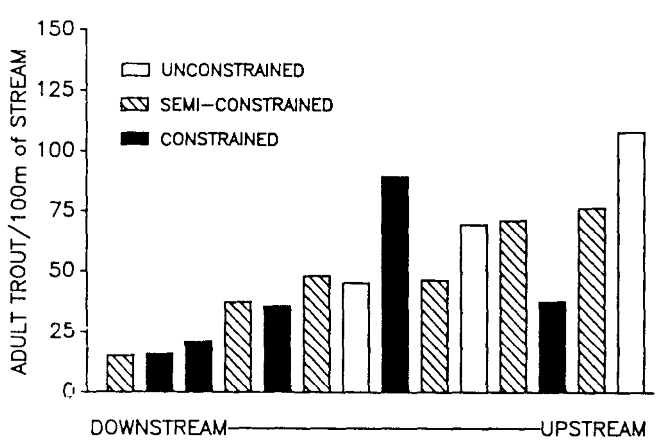

Figure 1 – Abundance of juvenile cutthroat trout in sequential reach types of Lookout Creek during the summer of 1987. Reach types are classified by the degree of constraint on the active stream channel. Abundance expressed as number of fish per 100 m of stream length.

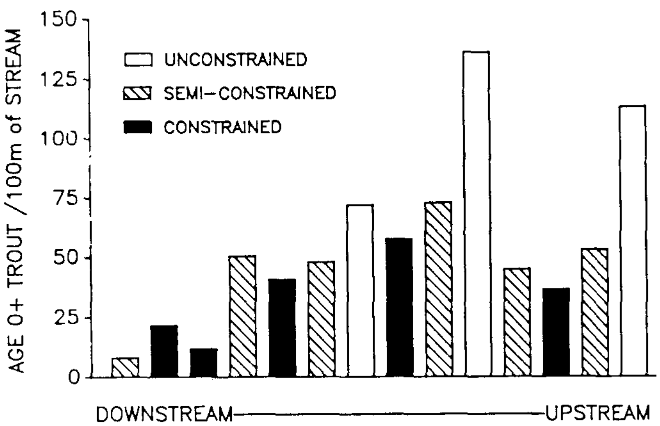

Figure 2 — Abundance of adult cutthroat trout in sequential reaches of Lookout Creek during the summer of 1987.

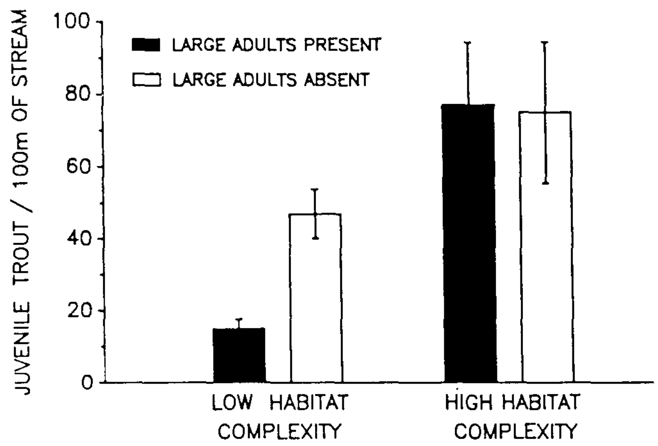

Figure 3 — Density of adult and juvenile cutthroat trout in channel units of Lookout Creek. Density expressed as number of fish per 100m^2 of wetted channel area.

The pattern of fish abundance in the study reaches was influenced by the distribution of channel units within each reach and the differential utilization of channel units by both adults and juveniles. The density of adult cutthroat and rainbow trout was greatest in pool channel units (fig. 3). Juvenile cutthroat trout were found in all channel unit types, but had the greatest densities in riffle and secondary channels. The differences in juvenile abundance between constrained and unconstrained reaches was not attributable to simple differences in channel unit structure between reaches. The area of secondary channels was greater in unconstrained reaches than in constrained reaches (9.0 percent and 2.3 percent respectively, $P < 0.05$). There was no difference in the area of riffle channel units in different reach types ($P > 0.10$). The average proportion of total stream area in pool channel units was greater in constrained reaches (37.7 percent) than in unconstrained reaches (21.7 percent).

Unconstrained reaches had more complex channel unit and subunit structure than did constrained reaches. Channel units were shorter and the sequence of channel unit classes were more varied in unconstrained reaches than in constrained reaches. Channel units in unconstrained reaches had a greater percentage of area in lateral habitat subunits ($P < 0.05$) and had a more heterogeneous distribution of subunit habitats. In September, when stream discharge was 18 cfs, habitat distribution was expressed as the average percentage of channel unit area within each reach:

Subunit	Reach Type[1] Constrained	Unconstrained
Hydraulic Jump	4.2	2.0
Chute	12.4	9.9
Riffle	16.5	20.1
Tranquil (Pool)	39.4	32.4
Lateral Eddies and Backwaters[2]	9.6	6.2
Exposed Channel	17.9	19.4
	100.0	100.0

[1] Constrained n=88, unconstrained n=78,
[2] $P < 0.05$, Kruskal Wallis test

Unconstrained reaches also had a greater diversity of habitats and increased availability of refuge habitat during floods. Equivalent measurements taken at higher flows (approximately 200 cfs), indicate that fast-water habitat subunits (hydraulic jumps and chutes) dominated the subunit distribution of channel units in constrained reaches. A hydraulic jump is defined by the dominance of very turbulent, supercritical flow. Chute subunits are areas of localized flow convergence, characterized by velocities at the threshold of supercritical flow. Although the area of fast-water subunits also increased at high streamflow, in unconstrained reaches the relative distribution of subunits did not change and the area of lateral habitat subunits increased nearly 60 percent.

In pool channel units, increased habitat complexity altered the patterns of juvenile abundance when large rainbow trout were present. The structure of pool channel units was variable both between and within reach types. Habitat complexity in pools was generally greater in the unconstrained reaches but complexity was strongly affected by the distribution and abundance of boulders and large wood debris within the channel unit (fig. 4). In pools with low habitat complexity, juvenile abundance was lowest in the presence of large adult trout ($p < 0.01$, Kruskal Wallis test, fig. 5). In pools with high habitat complexity, juvenile abundance was similar regardless of the presence or absence of large adults.

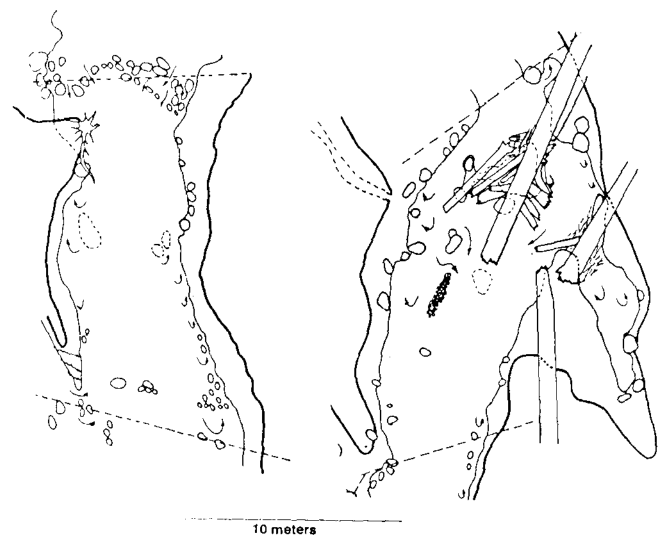

Figure 4 – Examples of pools with low (left) and high (right) levels of habitat complexity. Darker lines show margins of the active channel, lighter lines show the edge of the wetted channel, boulders and wood. Both pools are located in unconstrained reaches of Lookout Creek. Pools with lowest habitat complexity were similar to the pool on the left but had fewer small boulders along the margins.

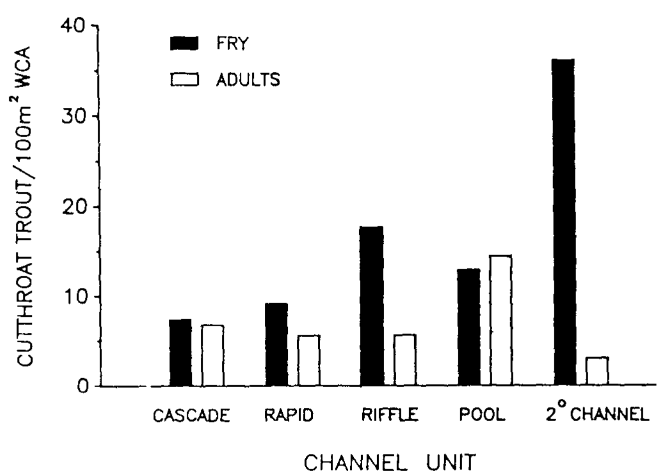

Figure 5 – Comparison of juvenile abundance in pools with low and high levels of habitat complexity and the presence or absence of large (length > 22 cm) rainbow trout. Habitat complexity was evaluated by a combination of subunit diversity, depth, and abundance of large boulders and wood. Error bars are +/- one SE, N = 10.

Discussion

Populations of juvenile cutthroat trout are apparently regulated by reach-level effects on stream habitat structure and stream productivity. Habitat structure and productivity, in turn, are both influenced by the geomorphic structure and interactions between the stream, the valley floor, and the adjacent hillslopes. The relationship between reach type and habitat structure (particularly lateral habitats) plays a key role in recruitment to trout populations. The strong correlation between lateral habitat area and number of age 0 cutthroat trout in a reach ($r = 0.983$; Moore and Gregory 1988b) underscores the importance of lateral habitats in the early life history of these fish. In the Cascade Mountains, cutthroat trout emerge during a period of declining streamflow after the winter rainy season. However, velocity in main channel habitats easily exceeds the swimming capacity of 20-30 mm long cutthroat trout. If the margins of the stream channel are abrupt and have either deep water or fast current, juvenile cutthroat trout will be displaced downstream until they reach suitable habitats. In addition to the losses from a particular reach, downstream movement also increases exposure to predators and potentially reduces the abundance of fry throughout the stream section.

Adult trout abundance was also related to reach type, but was additionally influenced by the availability of channel units (pools) with complex structure. The maintenance of complex structure in stream channels results in the development of channel units with a variety of habitat subunits. The greater abundance of cutthroat trout in the unconstrained reaches of Lookout Creek is apparently a function of the effects of riparian vegetation and geomorphic complexity on the structure of appropriate habitats.

Because unconstrained reaches of Lookout Creek have a more open canopy, more light energy is available, and primary production is greater than in the constrained reaches (Gregory and others 1989). Greater light intensity and increased production in the unconstrained reaches may, in addition to habitat effects, contribute to the greater abundance of fish in these reaches. Previous research has demonstrated that cutthroat trout population density and biomass are greater in recently logged (open clearcut) stream sites than in streams with mature coniferous stands (Aho 1977; Murphy and Hall 1981; Murphy and others 1981). The abundance of macroinvertebrates and the availability of drifting prey may be greater in reaches with open riparian canopies because of the effect of increased light on primary production, detritus quality, and prey capture efficiency (Gregory 1980; Wilzbach and others 1986). These studies have emphasized the influence of riparian setting on the production of food and related trout growth. Interpretation of these results, however, could be enhanced by an assessment of habitat structure and geomorphic setting.

Much of the organization of trout populations appears to be derived from the effects of reach level geomorphology on local levels of habitat. Intraspecific interactions play a smaller, but demonstrable role in regulating the distribution of juveniles. Both of these processes are further modified by the effects of riparian vegetation on habitat structure and food production. This pattern is consistent with models of community regulation that incorporate variable levels of physical disturbance and abiotic control (i.e., Menge and Sutherland 1987). Stream systems provide gradients of physical harshness and complexity of habitat structure that are appropriate for analysis with the Menge- Sutherland model (Schlosser 1982; Peckarsky 1983). In this study, gradients of physical harshness occur in at least two dimensions, longitudinal changes associated with reach type and lateral differences in habitat structure. Unconstrained reaches can be considered less harsh because the energy of flood events is dissipated across the broad valley floor. The physical processes that regulate the initial recruitment of trout result in greater abundance in these areas. Following the establishment of an age class, however, habitat complexity, interactions with possible predators, and system productivity have subsequent influence on the structure of populations.

The importance of valley floor habitats has been frequently demonstrated in large river systems with complex fish communities. In large rivers, lateral habitats of the floodplain riparian zone include side channels, oxbow lakes, marshes, ponds, and tributary streams. Fish production and community richness are strongly correlated with the area of floodplain in a given reach (Welcomme 1985). Channelization of these systems has resulted in decreased habitat heterogeneity, decreased production, and decreased trophic complexity as well as lower standing stock and richness of fish communities (Hortle and Lake 1983). In Cascade Mountain streams, fish community structure is much less complex than in large, low-gradient, river systems. Floodplain geomorphology and lateral habitats, however, have an analogous function in the structuring of fish populations. Community organization in both large and small streams can be better understood by considering the effects of the geomorphic structure of channel units, the stream reach, and the valley floor.

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MONTANE RIPARIAN HABITAT AND WILLOW FLYCATCHERS: THREATS TO A SENSITIVE ENVIRONMENT AND SPECIES[1]

Susan D. Sanders and Mary Anne Flett[2]

Abstract: Mountain meadows provide critical habitat for California's dwindling population of Willow Flycatchers (Empidonax traillii) and for many other breeding birds. Most meadows in the western United States are managed for livestock production or other consumptive uses rather than for wildlife. The potential threats to Willow Flycatchers and their habitat are discussed, and suggestions to protect and enhance mountain meadow habitat for this and other riparian species are offered.

California's montane meadows have received relatively little attention from wildlife biologists and conservationists concerned with riparian habitat protection. For example, only two papers presented at the first California Riparian Systems Conference (Warner and Hendrix 1984) discussed mountain meadows, compared to 24 concerning Central Valley riparian systems. Mountain meadows deserve attention from riparian researchers because these wetlands support rich biological communities, and because they provide valuable scenic and recreational resources to California's expanding human population. Montane meadows also contribute a high proportion of the forage on forest grazing allotments and wilderness areas (Ratliff 1982). Land managers need information about the effects of grazing on biological resources in order to resolve these potentially conflicting uses of mountain meadows.

Montane meadow systems are the stronghold of California's population of Willow Flycatchers, an obligate riparian species whose range and numbers have dramatically diminished. Our particular concern is the status and habitat requirements of Willow Flycatchers in California, and the potential threats to Willow Flycatchers and other inhabitants of montane meadows from livestock grazing and Brown-headed Cowbird *(Molothrus ater)* parasitism. We make management recommendations to protect and enhance habitat for Willow Flycatchers and an assemblage of riparian bird species breeding in Sierra Nevada high elevation meadows in our conclusions.

We define meadows here as open wetlands characterized by hydrophytes, mesophytes, and dry herbland of the subalpine and alpine zone (Ratliff 1984). We focus on wildlife resources rather than floristic distinctions, and therefore we do not follow the finer meadow classifications delineated by Ratliff (1982) and Benedict (1984).

Perazzo Meadows and Lacey Valley, the sites at which we conducted most of our field research, occur along the Little Truckee River in Sierra County, California, approximately 32 km northwest of Truckee. These sites are at 2010 m on the east slope of the Sierra Nevada in Tahoe National Forest. Perazzo Meadows and Lacey Valley are very large, wet meadows dominated by grasses, rushes (*Juncus* spp.), and sedges (*Carex* spp.). The riparian zone consists of willow shrubs (*Salix lemmonii* and *S. jepsoni*) that parallel streams and old oxbows in the meadow. Lodgepole pine (*Pines contorta* var. *murrayana*) forest surrounds the meadows.

Our discussion of Willow Flycatcher habitat requirements and potential threats to the species is based largely on field work conducted from mid June to late August in 1986 and 1987 at Perazzo Meadows and Lacey Valley. In addition to these studies, we surveyed meadows throughout the Sierra Nevada in June and July of 1986, searching for Willow Flycatchers and correlating their presence with habitat variables. The results of these surveys, discussed in detail by Harris and others (1987), also contribute to our analysis of Willow Flycatcher distribution, status, and habitat affinities.

Status of Willow Flycatchers in California

Willow Flycatchers have been extirpated as breeding birds from most of their former California range (Grinnell and Miller 1944; Flett and Sanders 1987; Harris and others 1987; Serena 1982). A few remaining populations inhabit isolated meadows of the Sierra Nevada. The largest of these mountain meadow populations occurs along the Little Truckee River drainage, which supports approximately 25 singing males. This species also occurs at lower elevations along the Kern, Santa Margarita, and San Luis Rey Rivers (Remsen 1978; Serena 1982; Unitt 1987). Recent surveys indicate a population of approximately 145 singing males in California (Harris and others 1987).

The loss of lowland riparian woodlands is probably the principal reason for the reduction of California's

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Willow Flycatcher population and the contraction of its range (Remsen 1978; Serena 1982). Nest parasitism by Brown-headed Cowbirds and livestock grazing may have also contributed significantly to population reduction (Gaines 1977, Serena 1982; Beedy and Granholm 1985; Sharp 1986; Taylor 1986; Taylor and Littlefield 1986). Other factors responsible for Willow Flycatcher declines in the Sierra Nevada may include loss of meadows due to reservoir and hydroelectric development, lodgepole pine encroachment on meadows, and habitat loss on wintering grounds (Serena 1982).

Habitat Requirements

Three features emerge as critical components of Willow Flycatcher habitat: large meadow size, water and willows. In the Sierra Nevada, Willow Flycatchers inhabit broad, flat meadows that are generally larger than 8 hectares, and that contain scattered clumps of willows (Harris and others 1987). They typically shun willow thickets on steep terrain, or narrow bands of willows bordered by conifer forest.

Water is an essential element on Willow Flycatcher territories. Twenty out of 22 territories at our study sites encompassed old oxbows, small secondary channels, or the Little Truckee River (Sanders and Flett 1988). All territories included areas with saturated soils, at least early in the season. Serena (1982) found that the portions of the meadows used by Willow Flycatchers were at least 40 percent wet. She also found that within meadows that contained dry areas, Willow Flycatchers occurred in the wettest sites.

In the Sierra Nevada, Willow Flycatchers are found only in meadows that contain willows (Harris and others 1987). All 22 Willow Flycatcher territories in our study site consisted of willow clumps separated by clearings. Willow cover on these territories averaged approximately 40 percent.

Willow Flycatchers build their nests in willows, and use these shrubs for foraging and singing perches, leaf and twig gleaning, and for cover. To provide suitable nesting habitat the willows should be at least 2 m in height, with a foliage density of approximately 50-70 percent. Nests generally are built at approximately 1 m in height, with about 1 m of willow cover above the nests (Sanders and Flett 1988).

Livestock Grazing

Direct Effects. Cattle can directly disturb Willow Flycatchers and other species nesting in montane meadows by knocking over nests in willow thickets or by crushing the eggs of ground-nesting birds. Stafford and Valentine (1985) and Valentine (1987) report that 4 of 20 nests monitored over a 4 year period were destroyed by cattle. Livestock also destroyed four nests shortly after the young fledged.

Cattle did not destroy any Willow Flycatcher nests in our study sites, although Perazzo Meadows contained approximately 150 cattle in 1986, and up to 360 in 1987. However, our data show that Willow Flycatchers invariably place their nests near the edge of willow clumps or along livestock trails, making them potentially vulnerable to disturbance by cattle (Flett and Sanders 1987).

In addition to Willow Flycatchers, at least 16 other bird species breeding in mountain meadows could be directly affected by cattle. Willow-nesting species include Yellow and Wilson's Warble (*Dendroica petechia and Wilsonia pusilla*), White-crowned Sparrow (*Zonotrichia leucophrys*), Song Sparrow (*Melospiza melodia*), and Red-winged Blackbirds (*Agelaius phoeniceus*). Ground nesting birds in mountain meadows are particularly vulnerable to trampling by livestock. These species include Canada Goose (*Branca canadensis*), Mallard (*Anas platyrhynchos*), Cinnamon Teal (*A. cyanoptera*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), Killdeer (*Charadrius vociferus*), Spotted Sandpiper (*Actitis macularia*), Common Snipe (*Gallinago gallinago*), Wilson's Phalarope, (*Phalaropus tricolor*), Savannah Sparrow (*Passerculus sandwichensis*), and Lincoln's Sparrow (*Melospiza lincolnii*).

The potential for livestock to trample or upset bird nests depends on the overlap between the nesting season and presence of the livestock. Most species are incubating eggs or nestlings by late June, and are therefore particularly vulnerable to livestock disturbance from then until early July. Willow Flycatchers, however, are unusually late breeders. At our study sites they established territories around mid to late June. The first eggs were not laid until the second or third week of June. The latest of the young fledged by mid-August; most species fledged two weeks to one month earlier.

Indirect effects. Livestock indirectly affect Willow Flycatchers and other species nesting in willows by altering the vegetation and hydrology of montane meadows. Cattle and sheep consume the lower branches and shrub layers of streamside vegetation and consume or trample young riparian plants (Taylor 1986). Even grazing for only a few days or weeks has been observed to adversely affect regeneration of woody vegetation (Crumpacker 1984). Obligate riparian species are more affected by grazing than other bird species (Mosconi and Hutto 1982). Duff (1979) reports a large increase in the number of passerine birds after excluding cattle from a riparian area. This increase was due to the reestablishment of the middle story of willows.

Livestock grazing can also reduce water quality, compact soils, and accelerate streambank erosion (Thomas and others 1979; Platts 1984). Streambank erosion due to overgrazing can eventually result in incising and gullying of streambeds (Ratliff 1984). Gullying can lower the water table of formerly moist meadows (Van Haveren and Jackson 1986), thus drying the soils and altering the meadow's vegetative composition.

Taylor and Littlefield (1986) documented the adverse effects of cattle grazing on Willow Flycatchers and Yellow Warblers at Malheur National Wildlife Refuge in Oregon. They censused these two species along riparian transects with different grazing histories. Taylor and Littlefield found that transects that had been ungrazed for forty years supported significantly more Willow Flycatchers and Yellow Warblers than grazed transects. Willow foliage volume and density was significantly higher in the ungrazed transects. Heavily grazed transects had very few willows and no Willow Flycatchers or Yellow Warblers. Taylor and Littlefield also presented 12 years of U.S. Fish and Wildlife Service Breeding Bird Survey data, indicating a significant relationship between increased Willow Flycatcher numbers and decreased grazing intensity.

Cowbird Parasitism

Brown headed Cowbird nest parasitism has been suggested as a cause of the Willow Flycatcher's decline in California (Remsen 1978). Their decline in central and coastal California coincides roughly with the spread of cowbirds in the 1920's and 1930's (Gaines 1977, Garrett and Dunn 1981). Friedmann (1963) reported 150 instances of Brown-headed Cowbird parasitism of Willow Flycatchers, 41 of which were reports from southern California.

Studies by Harris (in prep.) in 1987, at The Nature Conservancy Kern River Preserve, revealed intense parasitism by Brown-headed Cowbirds on Willow Flycatcher nests. The Kern River Preserve is a willow-cottonwood riparian woodland at an altitude of 750 m. At least 13 and possibly 16 of 19 Willow Flycatcher nests at the Kern River Preserve were parasitized by cowbirds. The losses due to parasitism resulted in a low egg-to-fledgling success rate of 24 percent.

While cowbird parasitism seems to be a major contributor to nesting failures of lowland populations of Willow Flycatchers, there is less evidence of cowbird parasitism in the higher elevations of the Sierra Nevada. One out of 22 Willow Flycatcher nests at our study sites was parasitized by a Brown-headed Cowbird. The single cowbird fledged successfully, but its three Willow Flycatcher nestmates did not survive. The only other record of Willow Flycatcher nest parasitism in the mid to high elevation Sierra Nevada was from the Lake Tahoe region in 1960 (Gaines 1977).

Stafford and Valentine (1985) suggest that the peak of Willow Flycatcher egg-laying in the high-elevation Sierra Nevada often occurs after the peak of the cowbird breeding season. King (1954), studying parasitism in the state of Washington, also noted that the peak of egg deposition by Willow Flycatchers occurred after the height of the cowbird egg-laying season passed. He found only 2 of 44 Willow Flycatcher nests parasitized. On the other hand, studies of Willow Flycatcher populations living at high elevation (2,500 m) sites in northcentral Colorado documented high parasitism rates (Sedgewick and Knopf 1988). At least 40 percent (11 out of 27) of the Willow Flycatcher nests found during that study were parasitized by Brown-headed Cowbirds.

Cowbird parasitism on Willow Flycatcher nests is a potential threat at high elevations and clearly is a serious problem at lower elevations in California. Laymon (1987) suggests that reducing or eliminating livestock grazing in mountain meadows could increase the reproductive success of Willow Flycatchers. Elimination of grazing allows grass to grow too tall to be suitable cowbird foraging habitat and removes the large grazers with which cowbirds associate.

Conclusions and Management Recommendations

Wet meadows of the Sierra Nevada are critical resources for the rare Willow Flycatcher and for many other breeding birds. These meadows are typically managed for livestock production, often to the detriment of wildlife. The following recommendations provide guidelines for protecting and enhancing mountain meadows that support Willow Flycatchers. These management recommendations would also confer benefits to a diverse array of riparian birds breeding in montane meadows.

- Eliminate or Delay Grazing — To avoid the direct and indirect impacts associated with livestock, grazing should be reduced or eliminated in meadows and riparian areas that support Willow Flycatchers. One alternative to eliminating grazing entirely is to delay putting cattle on high elevation meadows until mid-August, after Willow Flycatchers have fledged. Another alternative is to exclude cattle from the vicinity of streams and riparian vegetation by fencing, providing an alternative source of water for livestock by means of stocktanks. These recommendations have the added benefit of protecting nests and habitat for at least 16 other species of birds that breed in mountain meadows.

- Acquire Habitat — Montane meadows and riparian areas that support Willow Flycatchers should be protected and managed as a primary resource on public lands. Occupied and potential sites on private lands should be protected by conservation easements with landowners or by land purchases. In particular, efforts should be made to permanently protect the meadow system along the Little Truckee River. These meadows support the second largest known Willow Flycatcher population in the state, and the largest Sierra Nevada population.

- Avoid Developments Adjacent to Montane Meadows — Cowbirds frequently feed in disturbed areas where high energy foods are concentrated, including residential housing with bird feeders, campgrounds, corrals, and garbage dumps (Airola 1986). Such developments should be kept away from riparian areas to minimize the impacts of the cowbirds on Willow Flycatchers and other species nesting in willow thickets of mountain meadows. Excluding residential and housing developments near meadows would also reduce the potential for disturbance from humans, dogs, cats, and off-road vehicles, all of which could have significant impacts on birds breeding in mountain meadows.

- Revegetate and Restore Montane Meadows — The response of Willow Flycatchers to revegetation and meadow restoration should be explored as part of a comprehensive plan of habitat protection and enhancement. Restoration of Willow Creek in Modoc County provides a promising model of such efforts (Clay 1984). In addition, Valentine (1987) makes some specific suggestions for restoring meadows that support Willow Flycatchers.

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POPULATION TRENDS AND MANAGEMENT OF THE BANK SWALLOW (*RIPARIA RIPARIA*) ON THE SACRAMENTO RIVER, CALIFORNIA[1]

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Abstract: Annual monitoring of Bank Swallows (Riparia riparia) *along the Sacramento River, California has been conducted since 1986 to determine population trends, evaluate impacts from bank protection and flood control projects, and implement and monitor mitigation efforts. The population of Bank Swallows in a 50-mile river reach remained static over 3 breeding seasons from 1986 to 1988 despite ongoing bank protection projects. The proportion of burrows occupied by breeding swallows and the mean number of young/nest with young in a nesting colony was not significantly different between 1986 and 1988. Six experimental mitigation sites constructed in 1988 were successfully used by breeding Bank Swallows.*

Studies of the Bank Swallow in California began in 1986 after Remsen (1978) reported a population decline which he attributed, in part, to state and federal bank protection and flood control projects. On the Sacramento River, these projects occur on eroding riverbanks, and they involve removal of riparian vegetation, reshaping vertical riverbanks, and placing rock revetment (riprap) on the bank to prevent erosion.

Bank Swallows require vertical banks in silty, loamy, and sandy soils close to water for nesting (Freer 1977; Garrison and others 1987; Spencer 1962). Actively eroding riverbanks provide these nesting requirements, therefore, riprap projects and Bank Swallow nesting habitat requirements are incompatible. Five known nesting sites on the Sacramento River have been destroyed by riprap projects since population monitoring began in 1986. Garrison and others (1987) and Humphrey and Garrison (1987) found that a significant amount of Bank Swallow nesting habitat on the Sacramento River could be lost with riprap construction. Over 50 percent of California's Bank Swallow population occurs on a 210-mile stretch of the Sacramento River (Laymon and others 1988).

This paper will report (1) trends in the Bank Swallow population on the Sacramento River from 1986 to 1988, (2) impacts of riprap projects to the population, (3) preliminary results from experimental mitigation efforts, and (4) management activities. This paper utilizes data from earlier papers (Garrison and others 1987; Humphrey and Garrison 1987; Laymon and others 1988) and additional data collected in 1988.

Study Area and Methods

Our study was conducted on the Sacramento River between Chico Landing, Butte County, River Mile (RM) 195, and Colusa, Colusa County, RM 144. This river reach is lined by riparian forests typical of the Central Valley of California (Warner 1984) and agricultural lands. Dominant riparian trees are cottonwood (*Populus fremontii*), red willow (*Salix laevigata*), black willow (*S. lasiandra*), box elder (*Ater negundo*), and valley oak (*Quercus lobata*). Agricultural lands include orchards and row crops. The Sacramento River is an alluvial river with natural levees and a meandering channel, however, man has greatly altered the natural fluvial processes occurring in the river (Scott and Marquiss 1984).

Surveys were conducted by boat from early April to early June from 1986 to 1988. Colony locations were plotted on 1:24,000 scale black-and-white aerial photographs and described to the nearest 0.1 RM. The study area was divided into 4 river reaches (RM 144-155, RM 156-170, RM 171-185, RM 186-195) to assess colony dynamics. At all 43 colonies in 1988, 29 of 30 colonies in 1987, and 21 of 31 colonies in 1986, the number of burrows was counted with a tally counter. Visual estimates were made at the remaining colonies in 1987 (1 colony) and 1986 (10 colonies) (see below). Burrow counts from each colony were rounded to the nearest 10 burrows. Burrows counted had dark entrances (> 2 cm deep) when viewed from a distance of 5-25 meters. We counted all burrows in active sections of banks and did not count old burrows from inactive sections. Bank Swallows flying into burrows were used to determine activity, and we observed colonies for 15-60 minutes to assess whether or not a colony or section of colony was active.

There are several considerations when quantifying Bank Swallow populations using burrow counts. First, it is sometimes difficult to distinguish freshly dug burrows of the current nesting season from those remaining

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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from previous years which may not be used for nesting. However, we observed swallows nesting in old burrows, a practice also reported by others (Hickman 1979; Peterson 1955; Svensson 1986). Some old burrows were clearly unusable because the habitat was unsuitable due to vegetation coverage or lack of a vertical bank. In addition, inactive burrows from previous years were often filled with spider webs, vegetation, or collapsed soil. Also, portions of the bank with old burrows suitable for nesting were inactive for unknown reasons.

Not all burrows in a colony are used for nesting (Freer 1977; Garrison and others 1987; Hickman 1979; MacBriar and Stevenson 1976; Svensson 1986). However, burrows counts are an obvious measure of colony size and are data that are inexpensive to collect and repeatable. In addition, each burrow is dug by at least one swallow, and burrow digging is part of their breeding behavior (Beyer 1938; Peterson 1955). In this study, burrow counts are supported by data on the proportion of burrows occupied in a colony by nesting birds.

Burrow number was estimated at 1 of 30 colonies (3 percent) in 1987 and 10 of 31 colonies (32 percent) in 1986. Garrison and others (1987) reported that these estimates in 1986 underestimated the actual number of burrows in a colony by an average of 6 percent. Underestimates were due to inaccuracy in the estimates and burrow additions and/or losses after the estimates were made. Timing of burrow counts, particularly in the early spring when burrows are dug, results in variability in burrow numbers (Jones 1987). However, both complete counts and estimates change with burrow additions and losses. For this study, complete counts and estimates were combined in 1987 and 1986 to estimate population abundance.

The proportion of burrows occupied by nesting birds was estimated at 15 randomly selected colonies of 31 colonies in 1986. Equivalent data were collected at 11 of 43 colonies in 1988. In 1988, 6 of the 11 colonies were in manmade sites constructed as experiments to test the feasibility of mitigation, and the remaining 5 colonies were in natural sites that were randomly selected. Percent occupancy did not differ (Mann-Whitney Test, $U = 8.0$, $P = 0.247$) between manmade and natural sites in 1988 so data were combined.

Within a colony, a sample of burrows (n = 16-100) was checked using a flashlight and an angled dental mirror attached to an extendable automobile radio antenna. Burrows checked were in groups of 5-15 spaced approximately 2 m apart across the face of the colony, and these burrows generally were in accessible sections of the nesting bank. Burrows with eggs, young, a nest, or an adult in incubating or brooding posture were considered occupied, and burrows of unknown status were excluded. The number of young in a nest were counted and the mean/nest with young was calculated as a measure of colony productivity.

Experimental mitigation attempts began in September 1987 with the construction of 1 site above a riprapped bank using soil from the colony which was destroyed when the bank was riprapped. A vertical face 1.3-1.7 meters tall was cut there in March 1988. Additionally, 5 vertical banks were constructed in March 1988 on existing riverbanks which were unsuitable for swallow nesting because bank faces were not vertical and/or covered with vegetation. These 6 sites were monitored from March to June 1988, and data collected were equivalent to that at natural sites. Garrison (1988) provides more details on the experimental mitigation sites.

A Kruskal-Wallis test was used to determine differences in populations in the 3 breeding seasons from 1986 to 1988. The Mann-Whitney 2-sample test was used to determine differences in percent occupancy and mean number of young/nest with young between 1986 and 1988 and between natural colonies and colonies at experimental mitigation sites in 1988. Percent occupancy and mean number of young/nest with young were calculated from 4 and 3 colonies at the same locations in 1986 and 1988, respectively. A Chi-square test was used to assess differences in patterns of colony abundance among the 4 identified river reaches and colony site dynamics (Zar 1974). Significance was set at $P < 0.05$.

Results and Discussion

Population Trends

The Bank Swallow population was not significantly different during the 3 breeding seasons from 1986 to 1988 (Kruskal-Wallis Test, $H = 2.20$, df = 2, $P = 0.333$) (table 1, fig. 1). The number of colonies did not differ significantly (Chi-square Test, $x2 = 1.38$, df = 6, $P < 0.95$) between years from 1986 to 1988 within 4 river

Table 1 -Total number of burrows and colonies, mean and standard error (SE) of burrows per colony, and percent change of Bank Swallow populations on the Sacramento River, California, 1986-88

	1986	1987	Pct. Change 1986 to 1987	1988	Pct Change 1987 to 1988
Total Burrows	13,780	12,090	-12	16,710	38
Colonies	31	30	-3	43	43
Mean + SE	440 ± 80	400 ± 70	-9	390 ± 80	-3

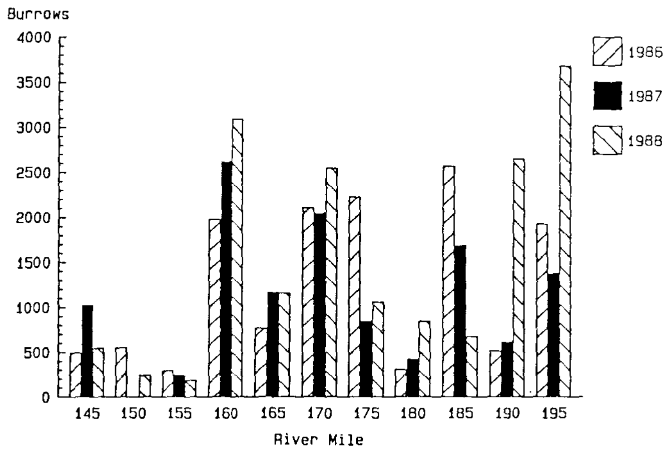

Figure 1—Number of burrows at Bank Swallow colonies by 5-river-mile sections on the Sacramento River, California, 1986-88.

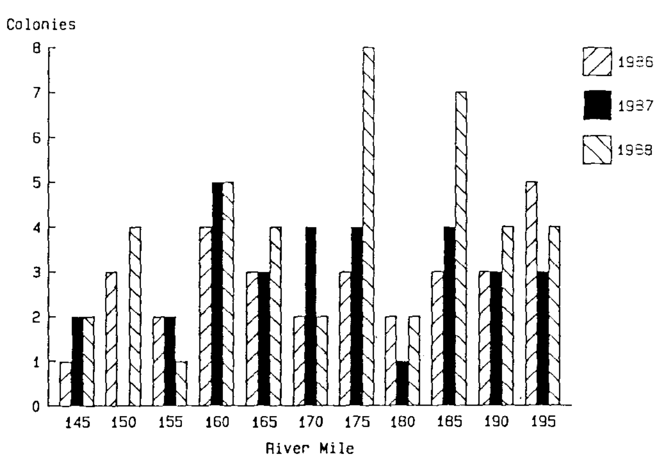

Figure 2—Number of Bank Swallow colonies by 5-river-mile sections on the Sacramento River, California, 1986-88.

Table 2 - Use patterns of Bank Swallow colonies on the Sacramento River, California, 1986-88

	Years	
Use Pattern[1]	1986-87	1987-88
Active site used the previous year	22 (56)[2]	21 (40)
Active site not used the previous year	8 (21)	22 (42)
Inactive site used the previous year	9 (23)	9 (17)
Total[3]	39 (100)	52 (99)

[1] Pattern based on comparing use at a colony site in one year (e.g., 1987) with use the previous year (e.g., 1986).

[2]Number in parentheses are percentages.

[3]Total different than number p (colonies located in a given year because of addition of inactive sites.

reaches in the study area (table 1, fig. 2). Colony site dynamics was assessed by categorizing colonies from the 3 study years into 1 of 3 groups based on site use over a 2-year period. For example, colony site dynamics in 1986 and 1987 was based on activity for those two years. A consistent pattern of colony site dynamics existed between the periods 1986 to 1987 and 1987 to 1988 (Chi-square Test, $X^2 = 4.87$, df = 2, $P < 0.10$) (table 2).

The abundance and distribution of the Bank Swallow population within the study area remained relatively uniform over the 3-year period from 1986 to 1988. However, the size of individual colonies fluctuated, several sites were abandoned, several abandoned sites were later reoccupied, and new sites were established. The fact that the population remained relatively constant despite considerable site dynamics indicates that Bank Swallows are adapted to dynamic environments such as the Sacramento River where the location of suitable nesting sites may change periodically.

Proportions of colony sites used two successive years, abandoned following an active year, or used following an inactive year were statistically equal for the period 1986 to 1987 and 1987 to 1988. Despite the lack of statistical significance, twice as many colony sites in 1987 to 1988 (42 percent) than 1986 to 1987 (21 percent) were active following an inactive season.

Bank Swallow habitat is greatly influenced by high flows and erosion which create freshly exposed vertical riverbanks. This occurred most extensively in 1986 along the Sacramento River. In contrast, 1987 and 1988 were dry years characterized by relatively low river flows and reduced erosion. Suitability of nesting habitat was reduced at many previously occupied sites because riverbanks sloughed.

Although not statistically significant, the data suggest Bank Swallows occupy a greater proportion of nesting sites without previous use during dry years than wet years. In dry years, suitable habitat may be more widely distributed in smaller size habitat patches because of localized sloughing. The greater number of colonies and smaller mean colony size in 1988 compared to 1987 and 1986 provides supporting evidence. Additional data from other wet years are needed to fully answer this question.

Between 1986 and 1988, percent occupancy (Mann-Whitney Test, U = 78.5, P = 0.813) and the mean number of young/nest with young (Mann-Whitney Test, U = 17.5, P = 0.062) were equal. Therefore, colony occupancy by breeding birds and their productivity was the same in a wet year (1986) and a dry year (1988). In fact, percent occupancy was slightly greater in 1988 when some burrows remained from previous years:

Variable (Mean ± SE):	1986	1988
Percent occupancy	46 ± 5 (n=15 colonies) Range = 6-83	47 ± 4 (n=11 colonies) Range = 30-64
Number of young/ nest with young	2.7 ± 0.2 (n=9 colonies) Range = 2.1-3.	3.2 ± 0.2 (n=8 colonies) Range = 2.5-3.9

Impact Assessment

Since 1986, 5 colony sites within the study area have been riprapped. Because of the relatively constant population abundance and uniform distribution, it appears that there were not any adverse impacts from 1986 to 1988. Any adverse impacts may have been hidden by the ability of the Bank Swallow to adjust to changes in the abundance and distribution of suitable nesting sites. Several factors provide supporting evidence.

First, in 1988, Bank Swallows occupied 2 new sites just downstream from 2 sites riprapped in 1987. Second, all 6 mitigation sites constructed in 1988 were occupied. Third, the 5 colony sites impacted by riprap were relatively small colonies (< 410 burrows). Adverse impacts may be more likely to occur when large colonies (> 1000 burrows) are riprapped. In late 1988, another colony at RM 190.5 Left (2330 burrows) was riprapped, and population monitoring in 1989 may help answer this question.

Lastly, habitat necessary to maintain a uniform population over the 3-year study period may still be present. The number of nesting colonies increased from 31 in 1986 to 43 in 1988 indicating that habitat was available for a relatively constant population. However, future riprap projects will continue to eliminate available habitat. In turn, this could reduce the amount of available nesting habitat which would limit the ability of Bank Swallows to respond to environmental perturbations by establishing new colonies. We lack data on the abundance and distribution of suitable nesting habitat. However, our observations suggested that the majority of suitable nesting sites were occupied.

Preliminary Results from Experimental Mitigation

All 6 experimental sites were occupied by breeding Bank Swallows in 1988 (total = 1,150 burrows, mean ± SE = 190 ± 43, Range = 70-340). Percent occupancy was not significantly different (Mann-Whitney Test, U = 8.0, P = 0.247) between experimental sites (mean ± SE = 43 ± 6, n = 6 colonies, Range = 30-63) and natural colony sites (mean ± SE = 53 ± 4, n = 5 colonies, Range = 44-64). In addition, the mean number of young/nest with young was not significantly different (Mann-Whitney Test, U = 7.0, P = 1.000) between the experimental sites (mean ± SE = 3.1 ± 0.2, n = 5 colonies, Range = 2.5-3.9) and natural colony sites (mean ± SE = 3.2 ± 0.2, n = 3 colonies, Range = 3.0-3.6). Therefore, the experimental mitigation sites apparently were equivalent to natural colony sites in occupancy and productivity by providing the proper habitat conditions.

The 1,150 burrows at the 6 experimental sites approximately double the 690 burrows (most recent counts) lost at the 5 riprapped colonies. However, because of the ephemeral nature of Bank Swallow nesting colonies, we do not feel that simply replacing losses of burrows and individual colony sites is mitigation. Successful mitigation includes the maintenance of (1) population abundance and distribution along the river, (2) productivity and occupancy at natural and manmade sites, and (3) abundance and distribution of available habitat. Data from 1988 are the first of a 3-year monitoring program, and additional experimental sites will be constructed in 1988. However, at least the mitigation techniques tested thus far appear feasible.

There are several critical factors, however, influencing the ultimate success of the mitigation techniques tested to date. Many potential mitigation sites are on private lands requiring permission for construction and monitoring. In 1988, private landowners granted permission at 6 of 8 (75 percent) proposed sites. However, 9 of the initial 17 (53 percent) recommended sites were eliminated because of access and safety concerns, high costs, or habitat suitability questions, and the landowner was never contacted.

Also, 4 of the initial 13 (31 percent) sites recommended for habitat improvement (i.e., cutting a vertical face on existing riverbanks) were subsequently occupied in 1988 by nesting Bank Swallows without any habitat improvement. This result indicates that some of the recommended and constructed sites may not have provided any mitigation value because the birds could have nested there anyway. In addition, maintenance and monitoring commitments are necessary for the life of the project if mitigation is to succeed in compensating for habitat losses. Lastly, riprap projects also eliminate potential mitigation sites on existing riverbanks.

Management Activities and Recommendations

Bank Swallows have received considerable interest by agencies, environmental groups, and the public since our studies began in 1986. Population data have been gathered from 3 successive breeding seasons, the species is a candidate for listing as a threatened species in California, experimental mitigation has been implemented with a 3-year monitoring program, and concerned state and federal agencies are cooperating. Despite these efforts, the Bank Swallow's future in California is far from secure. Riprap projects are continuing on the Sacramento River where the species is most abundant, and habitat is being permanently lost each year. We are unsure whether mitigation efforts can fully offset losses because many factors beyond our control affect the success of mitigation.

Annual monitoring should continue on the Sacramento River and include the entire population on the river, and a management plan should be developed to ensure the species' long-term viability. Establishing habitat preserves where Bank Swallow habitat as well as other riparian values are protected may ultimately be the most effective way of managing and preserving the species. Experimental mitigation efforts must be continued, and additional research is needed on habitat requirements and site tenacity.

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A PROPOSED HABITAT MANAGEMENT PLAN FOR YELLOW-BILLED CUCKOOS IN CALIFORNIA[1]

Stephen A. Laymon and Mary D. Halterman[2]

Abstract: This paper presents data from a 2-year survey of yellow-billed cuckoos (Coccyzus americanus) *in California and develops a plan from the survey and the conservation biology literature to prevent extirpation in the state. The plan includes recommendations of 23 sub-populations and a total population in California of 625 pairs. Sites for habitat restoration are recommended.*

The yellow-billed cuckoo (*Coccyzus americanus*) *is* an endangered species in California and is a de-facto endangered species west of the Rocky Mountains (Gaines and Laymon 1984, Laymon and Halterman 1987). The species was once common in the Western states but has been extirpated from much of its previous range including southern British Columbia, Washington, Oregon, Idaho, Utah and Nevada (Laymon and Halterman 1987, Roberson 1980).

In 1977, a survey for cuckoos throughout California found a population of 122 to 163 pairs, including 35 to 68 pairs in northern and 87 to 95 pairs in southern California (Gaines and Laymon 1984). Further habitat loss along the Colorado River from 1978 to 1985 led to a resurvey in 1986 and 1987. Summary results of that survey are presented in this paper. Based on these results, we redefine suitable habitat for yellow-billed cuckoos. From this new definition and from conservation biology theory we propose a habitat management plan for the yellow-billed cuckoo in California.

Study Area and Methods

The survey was conducted from northern Kern and Inyo counties south in 1986 and from southern Kern and Mono counties north in 1987. We also surveyed the Arizona side of the Colorado River and the lower Bill Williams River in 1986. During the 1977 survey, we conducted surveys at all sites where cuckoos were found regardless of current habitat quality. We also surveyed sites where cuckoos were suspected of nesting since 1977 and at potential habitat that we encountered while in the field. The survey method consisted of playing tape recorded contact calls of the cuckoo 10 times at 1-minute intervals at points 150 to 200 m apart on transects along and through the habitat.

Results

Predictions of Yellow-billed Cuckoo populations

At each site we predicted the number of pairs of cuckoos that we expected, based on the extent and quality of habitat (table 1). All predictions made away from the Colorado River, including the Bill Williams River, were based on suitable habitat which we defined as a minimum of 10 hectares (ha) of broad-leafed forest at least 100 m wide (Gaines 1974), and at least 1 ha of dense nesting habitat per pair. Along the Colorado River, where no suitable habitat remained, we made predictions based on marginal habitat, which we defined as a minimum of 4 ha of broad-leafed forest at least 50 m wide, and at least 0.5 ha of dense nesting habitat.

In northern California, we found 2230 ha of suitable habitat and predicted a total of 75 pairs of cuckoos in the Sacramento Valley (southern Sacramento County north to northern Tehama County), 10 pairs in the San Joaquin Valley (northern San Joaquin County south to central Kern County) and 3 pairs in other scattered locations (table 1). In southern California we identified 540 ha of suitable habitat and predicted a total of 28 pairs. Along the Colorado River, we identified 370 ha of marginal habitat and predicted that 17 pairs would be found. Along the lower Bill Williams river, we identified 200 ha of suitable habitat and predicted that 25 pairs would be found on the Bill Williams River delta.

The prediction based on 3340 ha of existing suitable and marginal habitat indicated that a total of 125 pairs of cuckoos should breed in California and that an additional 32 pairs should breed in western Arizona. This prediction ignored factors relating to patch isolation.

Survey Results

A total of 19 pairs and an additional 24 unmated males (UMM) were found in northern California, all

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Table 1 - Pairs of Yellow-billed Cuckoos predicted based on existing suitable habitat and the number of cuckoos found during surveys.

Locality	habitat patches	ha of habitat	# pairs predicted	pairs detected	UMM[1] detected
NORTHERN CALIFORNIA					
Sacramento River	22	1380	62	18	19
Feather River	3	360	9	1	5
Butte Sink	1	120	4	0	0
Stanislaus River, San Joaquin & Stanislaus Co	5	200	5	0	0
Merced River, Stanislaus & Merced Co	1	20	1	0	0
Kings River, Fresno Co	2	40	1	0	0
Kaweah River, Tulare Co	1	40	2	0	0
Lewis Ck, Tulare Co	1	30	1	0	0
Salinas River, Monterey Co	2	40	2	0	0
Subtotal	38	2230	87	19	24
SOUTHERN CALIFORNIA					
Kern River (X 1985-87)	1	200	10	7	3
Prado Flood Control Basin, Riverside & San Bernadino Co	2	120	6	1-4	0
Santa Clara River, Los Angeles Co	3	40	2	0	0
Mojave River, San Bernadino Co	3	80	4	0	1
Owens Valley, Inyo Co	3	60	3	0	1
Tecopa, Inyo Co	2	40	3	1	0
Subtotal	14	540	28	9-12	5
COLORADO RIVER REGION					
North of Needles, CA	2	80	2	0	0
North of Earp, CA	1	15	1	0	0
North of Blythe, CA	3	50	3	1	1
Picacho Region, CA	2	20	2	0	1
Laguna Dam Region, CA	2	20	2	1	0
Topock Swamp, AZ	2	50	4	2	1
Bill Williams River, AZ	1	280	25	25-30	0
Cibola Region, AZ	3	60	3	2	1
Subtotal	16	575	42	31-36	4
Total California	61	2955	125	30-33	31
Total CA & w AZ	67	3345	157	59-67	33

UMM[1] = unmated male

in the Sacramento Valley. (table 1). In southern California, 9 to 12 pairs and 5 UMM were found. An average of 7 pairs were found at the Kern River from 1985 to 1987 (range = 3 to 10). The Colorado River and the Bill Williams River had a population of 31 to 36 pairs and 4 UMM. The total population of cuckoos in California is estimated at 30 to 33 pairs and 31 UMM. The current estimated population in California and western Arizona is 59 to 67 pairs and 33 UMM.

Magnitude of recent declines

This survey shows a dramatic decline when compared with the 1977 survey (table 2). This decline ranges from a high of 95 pct along the Colorado River to a low of 46 pct to 72 pct in northern California. Only the small populations of the Prado Flood Control Basin and the Feather River have not declined since 1977. All other populations have declined dramatically (Laymon and Halterman 1987). The total decline in California was 73 pct to 82 pct with the population dropping from 122 to 163 pairs in 1977 to 30 to 33 pairs in 1987.

Discussion

Causes of Recent Declines

Declines found during this survey can be attributed to 4 causes: 1) habitat loss, 2) habitat fragmentation, 3) stochastic extinctions and 4) low colonization rates. Habitat loss is the major problem on the Colorado River. Most cottonwood-willow habitat, the preferred nesting habitat of the yellow-billed cuckoo, was lost due to sustained inundation caused by high river flows from 1983 to 1986 (W.C. Hunter, pers. comm.). Cottonwoods were especially hard hit since they are intolerant of prolonged inundation. The 2 largest patches of cottonwoods remaining are a fairly open, dry 25-ha experimental reforestation plot at Cibola and a 4-ha patch along the All-American Canal 5 km west of Laguna Dam. Some relatively extensive patches of willow-cottonwood forest are still present on the lower Bill Williams River, but approximately 50% of the cottonwoods have also been lost there. Hunter and others (1987) estimates over 4,000 ha of cottonwood- willow habitat were found along the Colorado River in the mid- 1970's. This has been reduced to 200 ha of which most occurs on the lower Bill Williams River.

Table 2 - Decline of Yellow-billed Cuckoos in California and western Arizona from 1977 (Games and Laymon 1984) to 1986-87.

Location	1977 (pairs)	1986-1987 (pairs)	Decline (pct)
Northern California	35-68	19	46-72
Southern California	87-95	11-14	84-88
California	122-163	30-33	73-82
Colorado River	122	6	95
Western Arizona	119	29-34	71-76
California & western Arizona	240-282	59-67	72-79

Prior to the loss in 1983, cuckoos on the Colorado River nested in small patches of cottonwood-willow habitat, sometimes less than 1 ha in extent. In 1981 and 1982 several pairs nested on the 25-ha Cibola revegetation site. They have not been found there, or in most small patches, since 1983. This suggests that these sites were marginal habitat and were not capable of supporting viable populations. The cuckoos in these small, dry sites were probably not reproducing consistently, and the sites were only occupied when cuckoos in suitable habitats were reproducing successfully and provided an overflow. When the suitable habitat was lost in 1983, the marginal habitat was depopulated. Similar patterns of decline have been found for forest interior species in eastern forests as the forests become fragmented (Robbins 1979).

Extinctions due to stochastic events also have a high probability in small, isolated populations. It is also difficult for colonizers to locate these isolated islands of riparian habitat. The combination of these factors make it unlikely that these sites, capable of supporting 1 to 5 pairs, would be occupied every year. Reduction of cuckoos on the Colorado River also provides fewer potential colonizers for sites to the northwest.

Since 1977, cuckoos are thought to have nested at the following scattered locations: 2 sites in the Owens Valley; the Amargosa River near Tecopa; Mojave River; 2 sites on the Santa Clara River; San Luis Rey River; Prado Flood Control Basin; and the Kern River. In 1986 we found breeding pairs at only 3 of these 9 isolated locations; Tecopa, Prado Flood Control Basin, and the Kern River. Of these, only Prado Flood Control Basin and the Kern River appear to have nesting cuckoos every year.

The Tecopa site, located 265 km NW of the Bill Williams River, has been surveyed yearly since 1977 (Jan Tarble, pers. comm.). This site has suitable habitat for 2-3 pairs but has reached this potential only twice in 10 years, and has been unoccupied during 6 of these years. This illustrates the dangers of extinctions of small populations and shows that the contribution of these isolated sites to the overall population of cuckoos is indeed small.

The Sacramento River still appears to have sufficient habitat to maintain a self-sustaining population of cuckoos. However, the population is now much lower than its potential. There are several possible explanations: 1) the survey was conducted at a population low; 2) the population is dependent upon colonists from the SE; 3) male cuckoos return to the same site to breed each year, while females do not, i.e. the number of pairs varies year to year while the number of males remains relatively constant; and 4) the current definition of suitable habitat in inadequate.

New Definition of Nesting Habitat

Away from the Colorado River, a relationship exists between size of habitat patch and the proportion of patches that are occupied by either pairs or unmated males. Of the 21 sites 20 - 40 ha in extent, only 2 were occupied (9.5%), while of the 17 sites 41 - 80 ha in extent, 10 were occupied (58.8%), and of the 7 sites >80 ha 100% were occupied. This trend towards increased occupancy with increased size is significant ($t=3.63$, $p<0.001$). Along the Colorado River of the 13 sites 20 - 40 ha in extent, 6 were occupied (46.2%), and the only site >80 ha was occupied.

Table 3 — Habitat suitability of yellow-billed cuckoos in California.

Habitat Suitability	Habitat Type	Area (ha)	Width (m)
Optimum	Willow-Cottonwood	>80	>600
Suitable	Willow-Cottonwood	41-80	>200
Marginal	Willow-Cottonwood	20-40	100-200
Marginal	Mesquite	>20	>200
Unsuitable	Willow-Cottonwood	<15	<100
Unsuitable	Mesquite	<20	1/
Unsuitable	Salt Cedar	2/	1/

These findings indicate that a new definition of suitable nesting habitat for yellow-billed cuckoos is needed in California. Riparian habitats in California range from unsuitable to optimal. Additional criteria such as canopy closure may be important. However, until detailed studies of microhabitat use are completed, it is safest to emphasize dominant tree species, total area and area width (table 3). Dominant tree species is important since cuckoos are only known to breed in willow-cottonwood and mesquite habitats in California. Willow-cottonwood habitats are greatly preferred. The mesquite habitats may be occupied only after the willow-cottonwood habitats are saturated.

Total area is derived from the proportion of occupancy of each area class and from literature showing lower nesting success (Chasko and Gates 1982, Gates and Gysel 1978) for open cup nesting birds near edges of large habitat fragments and in smaller habitat fragments. Wilcove (1985) shows that increased nest predation reaches up to 600 m into the forest interior. This indicates that reserves smaller than 100 ha are less valuable than larger reserves (Wilcove and others 1986). The width factor also is derived from the adverse effects of edge. The more circular a preserve is, the less these effects will come into play (Diamond 1975, Temple 1986).

Using this new definition of yellow-billed Cuckoo habitat, the previously defined suitable habitat is divided into 3 categories. At present in California, away from the Colorado River, there are 2768 ha of riparian habitat that could be used by cuckoos, of this 26 pct is marginal, 36 pct is suitable and 38 pct is optimal. Along the Colorado River, including the Bill Williams River there are 572 ha of habitat of which 51 pct is marginal and 49 pct is optimal.

Management Plan

A management plan for yellow-billed cuckoos in California requires more than habitat preservation. All existing habitat should be preserved regardless of present habitat quality; however this probably will not insure the survival of the species in the state. In addition, much habitat restoration is needed before recovery of the cuckoo is complete, but how much and where? Any number that is derived is a result of a trade off between number of patches, patch size and patch isolation as pointed out by Shaffer (1985).

Using simulation modeling, it has been demonstrated that populations of <10 pairs are very unstable and always become extinct in a short period of time (Richter-Dyn and Goel 1972; Roth 1974). In addition Shaffer (1981) theorized that with more realistic models this minimum number would increase. A minimum of 25 pairs in a subpopulation with interchange to other subpopulations should be reasonably safe from extinction by stochastic events. This should be a minimum goal for any major subpopulation. This goal has been adopted by The Nature Conservancy for their habitat management plan for the yellow-billed cuckoo on the Kern River Preserve. At present, no subpopulations >25 pairs exist in California. The Bill Williams River in Arizona population meets this criteria.

The number of subpopulations needed is the second issue. Using simulation models, Roth (1974), shows that variance of mean subpopulation size decreases as the number of subpopulations increases. The Sacramento River subpopulation is close to 25 pairs if it is assumed that the entire river is considered 1 subpopulation. A subpopulation should be defined as the cuckoos breeding in a discrete area with relatively contiguous habitat. A 3 km break between the habitat patches might be sufficient to delineate a subpopulation and an 8 km break surely would be sufficient. Using an 8 km break, the Sacramento River from Red Bluff to Colusa now encompasses 6 subpopulations. The population goal for this area would be a minimum of 150 pairs of cuckoos (25 pairs X 6 subpopulations). This would require a total of 3000 ha of suitable or optimal habitat and would require restoration of 1830 ha (table 4).

Since the Sacramento Valley population is isolated, additional subpopulations will be needed to connect this population to the ones to the south and east. We recommend the establishment of one subpopulation on the Feather River, and five in the San Joaquin Valley. In addition, we recommend the establishment of three subpopulations in southern California (table 4). The establishment of seven new subpopulations is needed on the Colorado River. This is especially critical since the populations further north may be dependent on this area for immigrants. A minimum of 23 subpopulations of at least 25 pairs each would provide habitat for a minimum of 625 pairs. This number, while only a fraction (i.e. <5%) of the original population of cuckoos in California, should: 1) provide protection from extinction by stochastic events, 2) provide sufficient genetic diversity (Soule and Simberloff 1986), 3) cover much of the cuckoo's original range and habitats in

Table 4 – Minimum management goals for subpopulations pairs and reforestation of suitable habitat for yellow-billed cuckoos in California and western Arizona.

Locality	Subpopulations	Pairs	Current Suitable (ha)	Reforestation Suitable (ha)
Northern California				
Sacramento River	6	150	1170	1830
Feather River	1	25	120	380
Stanislaus River	1	25	120	300
Cosumnes River	1	25	0	500
Merced River	1	25	0	500
Kings River	1	25	0	500
Mendota Pool	1	25	0	500
Sub Total	12	300	1410	4510
Southern California				
Kern River	1	25	200	300
Prado Dam	1	25	120	370
Mojave River	1	25	40	450
Owens River	1	25	0	500
Sub Total	4	100	360	1620
Colorado River				
Needles-Parker	4	100	330	1750
Parker-Blythe	2	50	0	1000
Blythe-Yuma	3	75	0	1500
Sub Total	9	225	330	4250
Total	25	625	2100	10,380

California, and 4) provide sufficient colonists to occupy small, outlying sites. In order to accomplish this goal a total of 10,380ha of suitable or optimal habitat must be restored. While this is no small undertaking, it will certainly require less expertise, engineering and money than did the channelization and flood control projects that aided in the destruction of the once vast riparian forests of California.

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CHARACTERISTICS OF LEAST BELL'S VIREO NEST SITES ALONG THE SANTA YNEZ RIVER[1]

Thomas E. Olson and M. Violet Gray [2]

Abstract: Due primarily to alteration of riparian vegetation and nest parasitism by brown-headed cowbirds (Molothrus ater), *the least Bell's vireo* (Vireo bellii pusillus) *has undergone a tremendous decline in range and numbers since the 1920's. In 1987, we sampled vegetation at 32 nest sites to characterize nesting habitat of least Bell's vireos in the Santa Ynez River drainage. Most next (59.4%) were located in willows* (Salix spp.) *or mugwort* (Artemisia douglasiana) *at heights of less than 1 m. Vireos selected sites with relatively dense vegetative cover in the vicinity of the nests. Herbaceous species and dead plant material comprised much of the nesting cover.*

The least Bell's vireo nests in California and northwestern Baja California, and winters in southern Baja California. It is one of four recognized subspecies of Bell's vireo (*Vireo bellii*) (American Ornithologists' Union 1983). Nests are usually constructed in dense, willow-dominated riparian vegetation within 3 m of the ground.

Although formerly a common to abundant breeding species in the Central Valley and other low-elevation riparian zones in California, the least Bell's vireo has undergone a dramatic decline in abundance and distribution. Despite a substantial decrease in numbers that began as early as the 1920s, this species was still widely distributed within California in the 1940s, extending northward to Red Bluff, Tehama County (Grinnell and Miller 1944). Since that time, the number and breeding range of least Bell's vireos have steadily decreased, with all northern California populations believed to be extirpated by 1970 (Goldwasser and others 1980). The decline has been attributed primarily to: (1) alteration and destruction of riparian vegetation that comprises suitable breeding habitat; and (2) nest parasitism by brown-headed cowbirds. Because of this decline, the least Bell's vireo is a state-and federal-listed endangered species.

The population in California in 1985 was estimated at approximately 300 pairs, based primarily on surveys conducted during the previous 12 years by Gaines (1974, 1977), Goldwasser (1978, 1981), Goldwasser and others (1980), and Gray and Greaves (1984). Nearly 20 percent of that total occurred along the Santa Ynez River in Santa Barbara County.

Continued residential and industrial development in southern and central California has increased the demand for water projects that could result in further alteration of least Bell's vireo nesting habitat. Information about this endangered species must be developed to resolve current and future conflicts between the demands of an increasing human population and habitat requirements of the least Bell's vireo. Such information will be necessary to mitigate adverse effects to vireos. The objective of this study was to characterize nest sites of least Bell's vireos and to describe trends in use of nesting habitat within the Santa Ynez River drainage.

Study Area and Methods

We sampled vegetation at 32 least Bell's vireo nest sites in 1987 along the Santa Ynez River in Santa Barbara County (fig. 1). The study area was located approximately 10 km north of Santa Barbara and included the eastern end of Gibraltar Reservoir, a 3-km portion of the Santa Ynez River upstream from the reservoir, and Mono Creek from its confluence with the Santa Ynez River to the Mono Debris Basin.

Approximately 240 ha of suitable vireo breeding habitat occurred in the study area. Riparian vegetation types included cottonwood forest, willow woodland, riparian scrub, and dry wash. Dominant overstory species were Fremont cottonwood (*Populus fremontii*), arroyo willow (*Salix lasiolepis*), and red willow (*S. laevigata*). Common species in a diverse understory included mugwort (*Artemisia douglasiana*), mule fat (*Baccharis salicifolia*), and willow (*Salix* spp.) shrubs. Adjacent vegetation types were primarily chaparral, with smaller areas of oak woodland. Unlike most areas where least Bell's vireos nest in California, this study area was completely publicly owned and administered (United States Forest Service and the City of Santa Barbara). As such, little disturbance occurred in the study area and surrounding buffer areas.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Figure 1— The study area was located along Gibraltar Reservoir, the Santa Ynez River, and Mono Creek in Santa Barbara County, California.

Vegetation was sampled at 18 successful and 14 unsuccessful least Bell's vireo nest sites using methodology modified from James (1971). Similar methodology has been used in other studies of least Bell's vireos. Successful nests were defined as those from which at least one young vireo fledged. At each nest site, a 0.04-ha circle was established, centered on the nest. In addition, two 20-m by 2-m transects were established across the circle. These transects were oriented parallel and perpendicular to the main stream channel and were divided into 10 cells, each 2 m by 2 m. All vegetation sampling was done after nesting activity had ceased.

Data collection was completed in three parts: At the nest, within the 0.04-ha circle, and along the 20-m by 2-m transects. The species and height of the nest substrate plants were recorded, as well as the height of the nest above the ground.

Within the 0.04-ha circle, the species, height, and diameter at breast height (DBH) of all trees (DBH ≥ 7.5 cm) were noted. The physical and vegetative characteristics of the habitat were diagramatically sketched and qualitatively described.

Along the two transects, we determined stem density by counting the number of stems of forbs, shrubs, and young trees (DBH < 7.5 cm) within each cell. Vertical foliage density was measured along the transects by placing a 4-m sampling rod at the edge of each cell farthest from the nest. Plant species (leaves or stems) impinging upon the sampling rod were recorded as "foliage hits" in five height intervals: 0-0.2 m, 0.2-1.0 m, 1.0-2.0 m, 2.0-4.0 m, and >4.0 m. Hits in the latter interval were visually estimated. Foliage density in each height interval at a given nest site was represented by the total number of hits at 20 stops (sampling points).

Results

In 1987, least Bell's vireo nests in the study area were generally located in vegetation characterized by riparian species. Nineteen (59 percent) nest sites, however, occurred on flood plain terraces 2-5 m above the level of the main river channel. Those nests were located 10-200 m laterally from the nearest edge of the channel and were situated in vegetation cover that also included upland species, such as summer mustard (*Brassica geniculata*), coast live oak *(Quercus agrifolia),* star thistle (*Centaurea soltitialis*), and annual grasses. In contrast, only 10 (31 percent) nests were located within 3 m of the main river channel.

Eleven different plant species were used as nest substrate (table 1). Nineteen of 32 nests (59.4 percent) occurred in 4 species: arroyo willow, red willow, narrowleaf willow (*Salix exigua*), and mugwort. The remaining 13 (40.6 percent) nests were located in 7 different species. The species of substrate plant used did not influence nesting success (x^2, P > 0.50).

Most nests were situated at relatively low heights. Mean nest height was 70.6 ± 3.5 cm (table 2). There was no difference between mean nest height of successful (66.3 cm) and unsuccessful (72.8 cm) nests (*t*, 0.20 < *P* < 0.40). Although nearly half of all nests were located in willow species which are capable of developing into large canopy trees, mean total height of all nest substrate plants was only 2.8 ± 0.4m. Vireos used a variety of growth forms as nest substrate, including shrubs, upright trees, and trees previously downed in floods that continued to grow horizontally. Mean height of substrate plants did not differ between successful (2.6 m) and unsuccessful (2.9 m) nests (*t, P* > 0.50). Nest height expressed as percent of total height of the nest substrate plant varied considerably. The mean was 32.5 ± 3.0 percent, with a range of 4-78 percent. Mean values for successful (32.4 percent) and unsuccessful (32.6 percent) nests were similar (*t, P* > 0.50).

Table 1 – Plant species used by least Bell's vireos as nest substrate, Santa Ynez River, 1987.

Species	Number of nests		All nests	Percent of total
	Successful	Unsuccessful		
Arroyo willow *Salix lasiolepis*	4	2	6	18.9
Red willow *S. laevigata*	3	2	5	15.6
Narrowleaf willow *S. exigua*	3	1	4	12.5
Mugwort *Artemisia douglasiana*	1	3	4	12.5
Mule fat *Baccharis salicifolia*	2	1	3	9.4
Fremont cottonwood *Populus fremontii*	0	3	3	9.4
California blackberry *Rubus ursinus*	2	0	2	6.2
Summer mustard *Brassica geniculata*	1	0	1	3.1
Star thistle *Centaurea solstitialis*	1	0	1	3.1
Coast live oak *Quercus agrifolia*	0	1	1	3.1
California wild rose *Rosa californica*	0	1	1	3.1
California blackberry *Rubus ursinus*-mugwort *Artemisia douglasiana*	1	0	1	3.1
Total	18	14	32	100.0

Table 2— Height of nests and substrate plants, Santa Ynez River, 1987.

Nest Characteristic	Mean Sue-cessful (n=18)	Mean Unsuc-cessful (n=14)	Mean All nests (n=32)	Range for all nests
Height of nest above ground (cm)	66.3	72.8	70.6	37-118
Total height of substrate plant (m)	2.6	2.9	2.8	0.8-12.2
Nest height as pct of substrate plant height	32.4	32.6	32.5	4-78

Although the density of foliage within different height intervals at the nest sites was relatively constant, greatest density at successful and unsuccessful nests occurred from 0.2 to 1.0 m (fig. 2) Below 1.0 m, mugwort and summer mustard contributed most to foliage density. Above 1.0 m, foliage density was comprised mostly of mule fat, Fremont cottonwood, and willows. Similar to foliage density, plant species richness was somewhat greater in the 0.2-1.0 m interval than in other intervals. Overall number of species encountered within various height intervals at all nest sites included 20 at 0-0.2 m, 22 at 0.2-1.0 m, 18 at 1.0-2.0 m, 14 at 2.0-4.0 m, and 7 over 4.0 m.

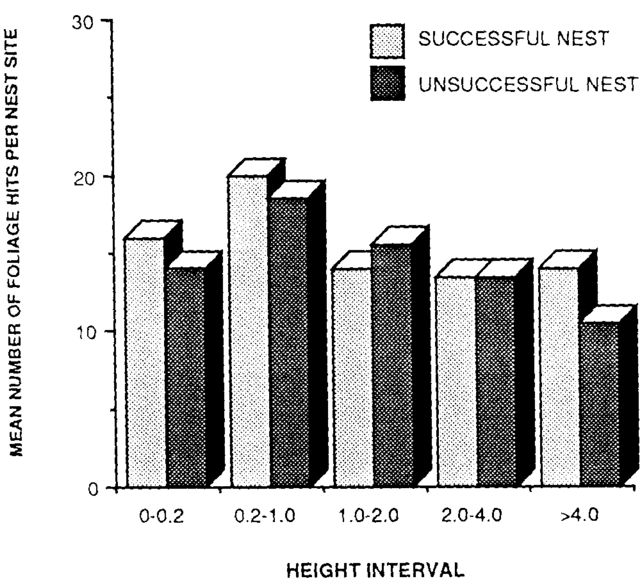

Figure 2– Vertical foliage density at successful and unsuccessful nest sites as expressed by the mean of foliage hits per nest site, Santa Ynez River, 1987.

Density and species richness of foliage at various height intervals were similar between successful and unsuccessful nests. However, mean species richness in the 0.2-1.0 m interval was greater at successful nest sites (5.2) than at unsuccessful nest sites (4.1) (*t*, $0.02 < P < 0.05$), perhaps indicating better nesting cover at the former sites. An apparent difference noted in the >4.0 m interval (13.5 foliage hits per successful site, compared to 10.5 foliage hits per unsuccessful site) was not significant (*t*, $0.20 < P < 0.30$).

The mean stem density of herbs, shrubs, and saplings (< 7.5 cm diameter) at breast height for the 32 nest sites was 45,668 ± 619 per ha. The range of stem densities was considerable: 6,875-190,000 stems per ha. Mean stem densities at successful (42, 305 ± 4317 stems per ha) and unsuccessful (49, 991 ± 13,239 stems per ha) nests were not different (*t*, $P > 0.50$). Of 23 plant species recorded at breast height, 6 accounted for 79 (successful nests) to 89 (unsuccessful nests) percent of all sterns: mugwort, narrowleaf willow, mule fat, arroyo willow, white sweetclover *(Melilotus albus)*, and summer mustard (fig. 3). Thirty-four percent of the stems recorded at all nest sites were dead, primarily mugwort, with lesser amounts of mule fat, summer mustard, willows, and star thistle. The proportion of sterns that were dead did not differ between successful (33 percent) and unsuccessful (36 percent) nests (t, $P > 0.50$).

The density of trees (DBH > 7.5 cm) at nest sites averaged 376.5 ± 53.2 per ha, of which 309 (82 percent) were live. Densities of trees at successful (393.1/ha) and unsuccessful (355.4/ha) nest sites were not different (table 3; *t*, $P > 0.50$). Size of trees varied, with an average height of 8.3 m (range = 1.8-18.3 m) and a mean DBH of 15.5 cm (range = 8.0-50.0 cm). Although trees at successful and unsuccessful nest sites were similar in mean height, mean DBH differed. Trees at successful nest sites were significantly greater in mean DBH than at unsuccessful nest sites (*t*, $P < 0.01$). Dominant trees at all nest sites were red willow, arroyo willow, and Fremont cottonwood. Cottonwoods and sycamores were the tallest canopy species, and coast live oaks had the greatest mean DBH. Most nests were located under extensive overhead tree density; at 19 of 32 nest sites, more than 10 trees were present within the 0.04-ha sampling circle.

Discussion

Vegetative cover at least Bell's vireo nest sites in 1987 was comprised not only of riparian plants, but also of several upland species. Despite the use of varied sites, most nests were constructed near open water in washes and the main stream channel. Proximity to open water may be an important factor in food (insect) availability.

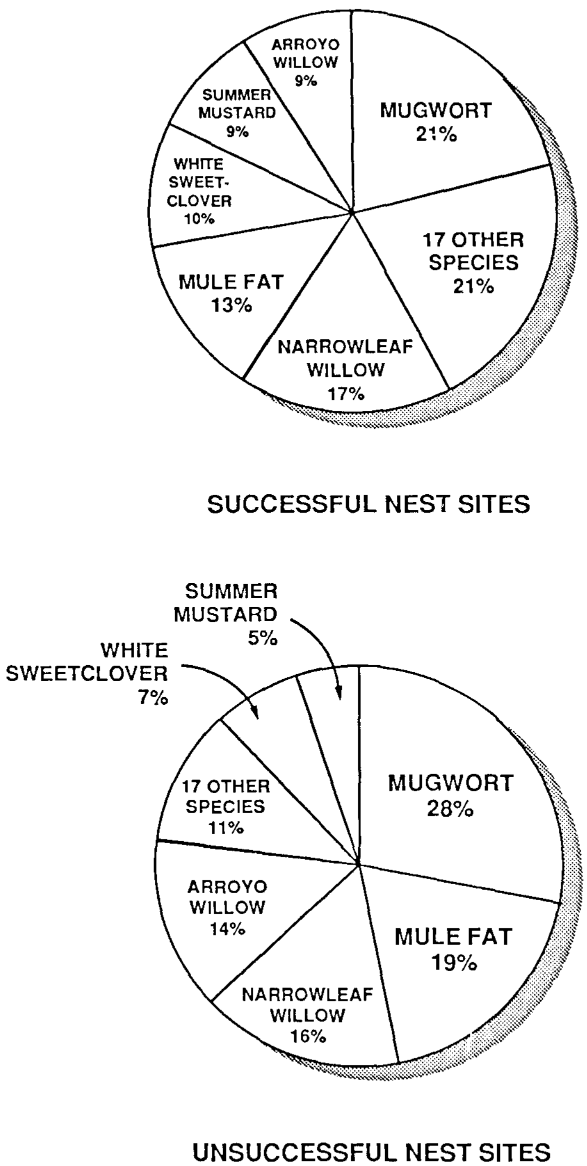

Figure 3– Stems encountered at breast height along 20-m by 2-m transects at successful and unsuccessful nest sites by species, Santa Ynez River, 1987.

We found that the use of plant species as nest substrate was not proportionate to their availability. Vireos selected 3 species of willows (arroyo, red, narrowleaf) as nest substrate over more dominant plants, particularly mugwort and summer mustard. Within the 0.2-1.0 m height interval (in which 30 of 32 nests were constructed), mugwort and summer mustard accounted for 54.4 percent of all foliage hits at nest sites, compared to percentages of 21.2 for the 3 species of willows and 24.4 for all other species. However, nearly half (47.0 percent) of all vireo nests were situated in willows. Nests constructed in mugwort and summer mustard accounted for only 18.7 percent of all 1987 nests. The remaining nests (34.3 percent) were in 6 other plant species. Using a statistical technique suggested by Neu and others (1974), we determined that the disproportionate use of plant species as nest substrate was significant (χ^2, $P < 0.01$) and that vireos preferred willows while avoiding mugwort and summer mustard (Bonferroni *Z* statistic, 90 percent family confidence coefficient). The selection of willows as nest substrate suggests a preference for rigid structural support for construction of nests.

Vireos in the study area appeared to construct nests and were more successful in a height interval that provided a high degree of vegetative cover. Thirty of 32 nests (94 percent) were located at heights between 0.2 and 1.0 m where foliage density and plant species richness were greatest. Height of nests, size of substrate plants and foliage density within the 0.2-1.0 m interval did not affect nesting success. We did, however, observe higher plant species richness in that interval at successful nest sites (average number of species = 5.2) than at unsuccessful nest sites (4.1) (*t*, $0.02 < P < 0.05$).

Mean height of nests in this study area during 1981 (the only other year in which comparable data were collected) (Gray and Greaves 1984) was 64 cm, similar to our findings. In contrast, mean nest heights elsewhere have been substantially higher, including 1.0 m at several northern San Diego County sites (Goldwasser 1981); 1.0 m at Camp Pendleton, also in San Diego County (Salata 1983); and 1.2-1.3 m at Prado Basin, Orange County (Zembal 1985, Collins and others 1986).

The variation in mean nest height among southern California populations of least Bell's vireos may support our finding of a preference for dense cover in the vicinity of the nest. Vegetation structure at some other study areas in California is different, possibly lacking a dense understory below 1.0 m (J. Greaves, pers. comm., 1988; Gray, pers. obs.). Overmire (1963) found that the midwestern subspecies of Bell's vireo (*Vireo bellii bellii*) nested in Oklahoma at greater heights in grazed areas where understory vegetation had been reduced. Mean number of stems per ha at breast height at Camp Pendleton (134,541) was nearly three times as great as that recorded in this study area (45,668), perhaps reflecting denser, more complex vegetation at a higher interval within the understory at the former study area. Other investigators have reported much lower mean stem densities, including 5500 stems per ha in San Diego County (Goldwasser 1981) and 9914 stems per ha at Prado Basin (Zembal 1986).

Table 3 - Density and size of trees at least Bell's vireo nest sites, Santa Ynez River, 1987[1].

	Successful nests (n=18)			Unsuccessful nests (n=14)		
	Number per ha	Mean height (m)	Mean DBH[2] (cm)	Number per ha	Mean height (m	Mean DBH[2] (cm)
Western sycamore	2.8	9.9	14.0			
Fremont cottonwood	123.6	10.2	19.0	128.6	10.2	16.7
Coast live oak	16.7	8.0	35.9	14.3	6.2	21.0
Narrowleaf willow	1.4	4.6	9.0			
Red willow	220.8	7.4	15.4	150.0	7.1	13.2
Arroyo willow	22.2	7.0	10.6	150.0	6.4	10.5
Other	5.6	9.1	24.0			
Total	393.1	8.4	17.2	355.4	8.1	14.3

[1]Based on occurrence of trees (DBH ≥ 7.5 cm) within a 0.04-ha circle, centered on the nest site.

[2]DBH = diameter at breast height.

Interestingly, overhead cover at most nest sites, especially in the 1.0-2.0 m interval, was not comprised entirely of live, woody plant material. Counts of stems/ha at breast height indicated that herbaceous species, particularly mugwort and white sweetclover, accounted for a substantial proportion of overhead cover (fig. 3). In addition, approximately 34 percent of all stems (herbaceous and woody) recorded at breast height were dead, as were 21 percent of the foliage hits in the 0.2-1.0 m height interval.

Overstory tree density which provides overhead cover also appears to be an important component of nesting cover. Nearly all nest sites were under some degree of overhead cover from trees of different size classes, especially red willow and Fremont cottonwood. Of 32 nest sites, 19 (59 percent) were under a dense canopy where ≥10 trees occurred within the 0.04-ha circle. Two other findings also suggest a need for overhead cover. First, within the nest substrate plant, nests were usually located in the bottom half (nest height averaged 32 percent of total height of plant). In addition, trees at successful nest sites were significantly greater in DBH than those at unsuccessful nest sites; trees in older age classes may provide more cover. A combination of cover in the vicinity of the nest and overhead cover may be important for protection from terrestrial and avian predators. Although foliage densities in the 0.2-1.0 m (vicinity of nest) height interval were similar for successful and unsuccessful nest sites, plant species richness differed. Successful nest sites contained a higher species richness between 0.2 and 1.0 m, perhaps indicating a higher degree of cryptic cover.

Conclusions

We conclude that several components of the Santa Ynez River riparian zone appear to be important for least Bell's vireo nesting habitat. These components include:

1. Minimally disturbed vegetation types adjacent to the riparian zone. Many nests were located at edges between riparian and upland vegetation types. These adjacent areas are often sites of foraging by adult and fledgling least Bell's vireos (Gray and Greaves 1984) and can act as a buffer zone between vireo breeding habitat and disturbed areas.
2. Complex vegetation, including high plant species richness and stem density below 2.0 m for actual and cryptic cover at the nest site. A substantial proportion of the vegetation in this height interval may be comprised of herbaceous species or dead material of woody and herbaceous species.
3. Shrubby willows in the understory to provide rigid structural support for nests.
4. A relatively high overstory tree density comprised mostly of Fremont cottonwoods and willows which provides a dense overstory canopy. A relatively higher proportion of the trees should be from older age classes.

Our results generally agree with those of other studies of least Bell's vireos. Goldwasser (1981) and Salata (1983) believed that structure and composition of vegetation below 3 and 4 m, respectively, were critical. Salata (1983) also reported the importance of a mix of tree size classes, with a mean height of 8 m. Gray and Greaves (1984) recommended protection of ground cover and low shrub layers. Additional research is needed to identify specific habitat requirements necessary for mitigation and revegetation plans.

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DESCRIPTION OF NESTING HABITAT FOR THE LEAST BELL'S VIREO IN SAN DIEGO COUNTY[1]

Bonnie J. Hendricks and John P. Rieger[2]

Abstract: *Least Bell's Vireo* (Vireo bellii pusillus) *nesting sites on three rivers in coastal southern California were characterized to provide data for a habitat restoration plan for this endangered species. In addition, riparian areas outside vireo territories were sampled to compare with nesting habitat. The parameters measured were percent cover, percent open ground, plant heights, plant density, height class frequency, species frequency, and species diversity. The vireo nest sites showed no significant differences from the non-nest riparian sites for any of the variables studied. The nest sites on the San Diego River had lower native plant density and diversity than nest sites on the Sweetwater and San Luis Rey rivers. There were no significant differences in nesting habitat between the Sweetwater and San Luis Rey. We suggest using the data from all three rivers in designing revegetation sites for the Least Bell's Vireo in coastal San Diego County if data on the specific watershed being revegetated can not* be *obtained.*

The Least Bell's Vireo (*Vireo bellii pusillus*) is an endangered riparian bird which occurs primarily in coastal southern California. Habitat loss and cowbird parasitism are the primary causes for its rapid population and distribution decline (USFWS, 1985).

Riparian habitat restoration is part of the active management plan for the recovery of the Least Bell's Vireo. As development pressures continue in the current vireo range, restoration is being required almost on a routine basis for project impact mitigation. Effective restoration of vireo habitat requires a more thorough knowledge of the habitat than presently exists. In the only published paper on Least Bell's Vireo habitat, Gray and Greaves (1984) described the habitat in Santa Barbara County with data on plant species frequency, frequency of vegetative height classes, and stems per hectare. We wanted to broaden the vegetative description of the habitat and include several rivers from San Diego County. In addition, our study was designed to yield data that could be more easily adapted for use in a revegetation plan.

Our primary goal, to characterize the nesting habitat of the Least Bell's Vireo in San Diego County for the design of restoration projects, prompted us to ask the following two questions: (1) are there differences in vireo nesting habitat among three of the major rivers in San Diego County, the Sweetwater, San Diego, and San Luis Rey? (2) are there differences in vegetation between vireo nesting areas and riparian areas outside vireo territories?

Methods

Selection of study plots

All Least Bell's Vireo nests monitored in 1986 on the Sweetwater, San Diego, and San Luis Rey rivers were assigned numbers, and a sample of ten were randomly chosen from each river (figs. 1, 2, 3, and 4). A 10 meter diameter circular plot was centered on each nest.

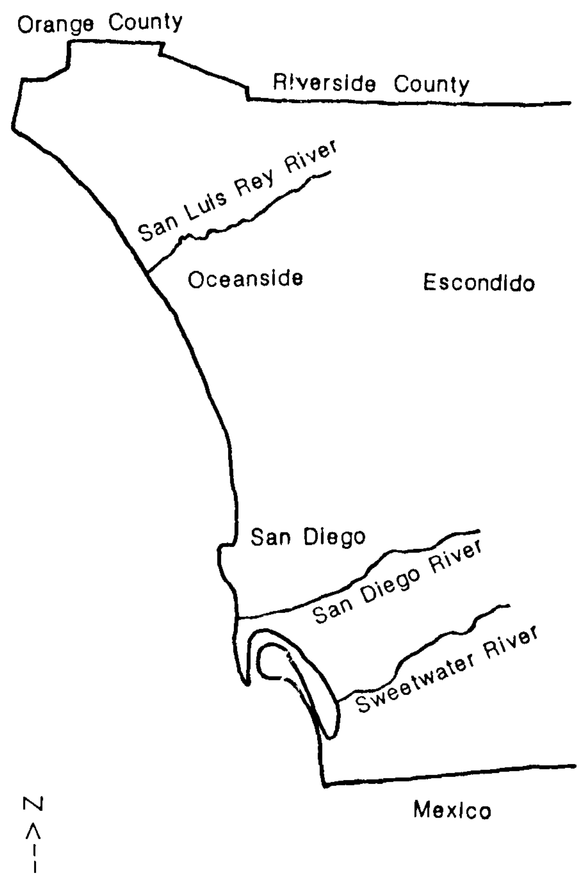

Figure 1— Coastal San Diego County, Calif. showing the location of the three river drainages studied.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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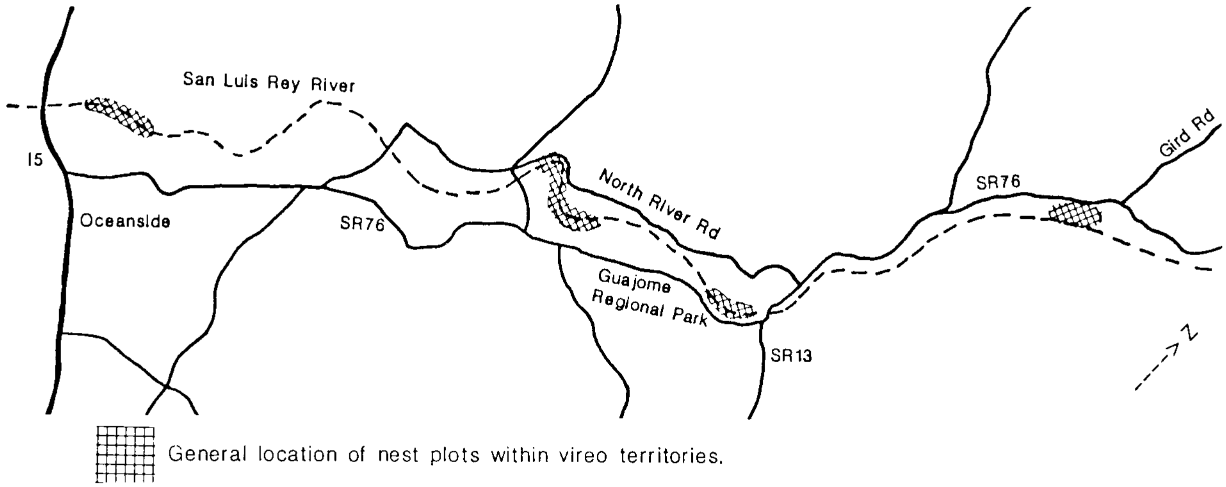

Figure 2- Location of study sites on the San Luis Rey River, San Diego County, Calif., 1986.

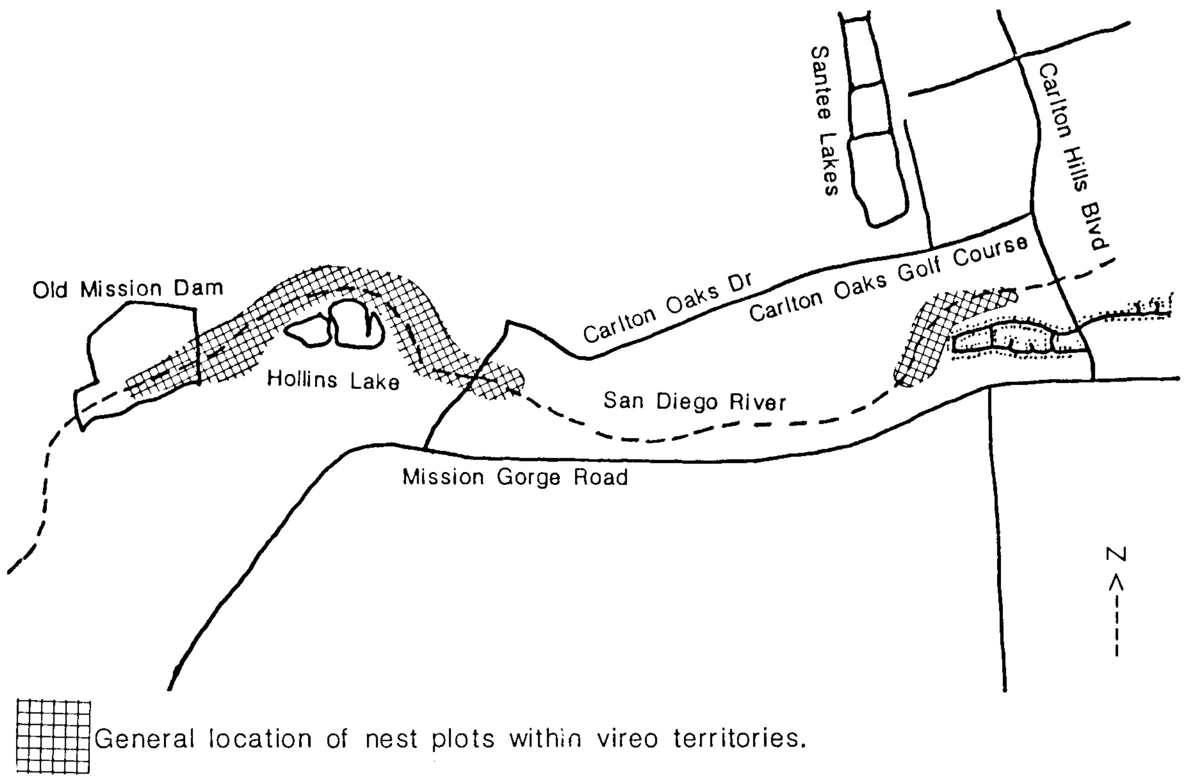

Figure 3- Location of study sites on the San Diego River, San Diego County, Calif., 1986.

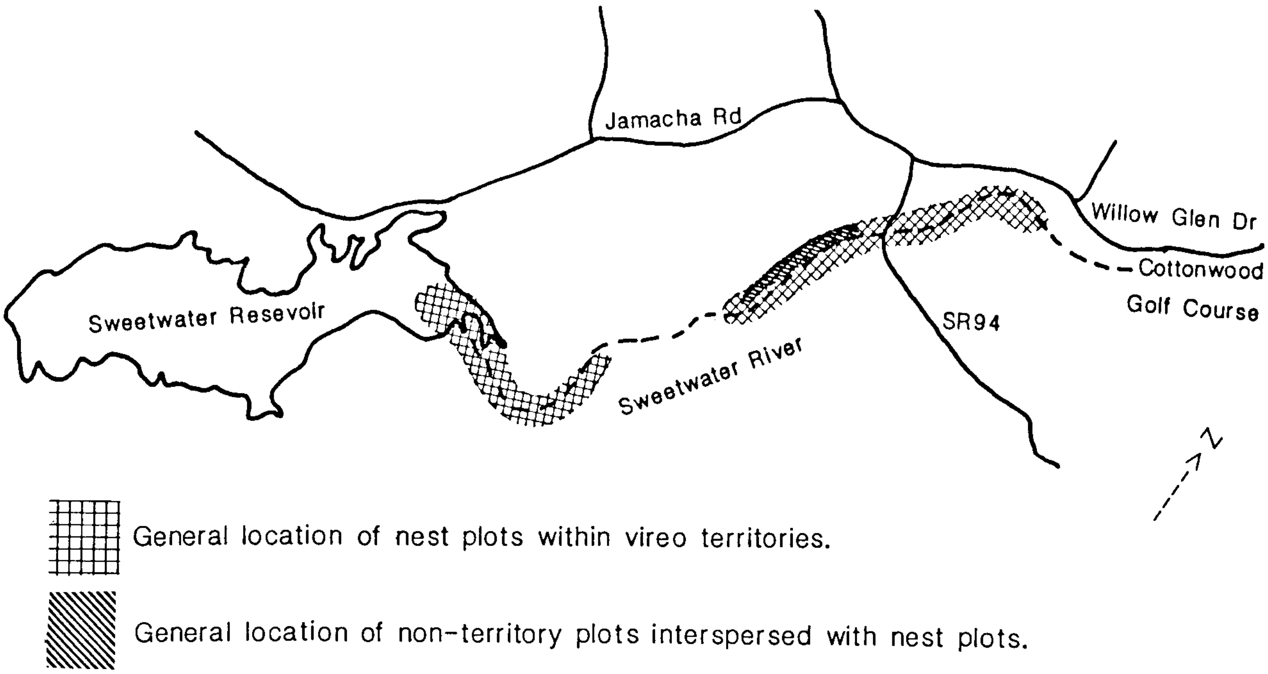

Figure 4— Location of study sites for nest and non-nest plots on the Sweetwater River, San Diego County, Calif., 1986.

Ten non-nesting areas with riparian vegetation and in close proximity to, but outside, vireo territories were identified on the Sweetwater River. Random numbers were used to locate one 10 meter diameter circular plot within each of the ten areas. The non-nest plots were interspersed with vireo nest plots (fig. 2).

The parameters measured were percent vegetative cover, percent open ground, height of plant stands, frequency of height classes, plant density, plant species frequency, and plant species diversity. Vertical structure of the vegetation is believed to be more important than species composition for nest site selection in the Least Bell's Vireo (Gray and Greaves 1984). Therefore, instead of making comparisons separately for each plant species, the species were grouped according to their growth form and whether they are native or exotic.

Percent cover

Each plot was mapped to scale, delineating the major vegetation stands found within it including open areas and watercourses. Stands often consisted of more than one plant species. Percent cover of native trees, shrubs, herbs, and exotic plants was calculated from the scale maps with a planimeter.

Plant heights

An average level of the plant tops within each relatively distinct plant stand was estimated and measured. Heights above 3.5 meters were estimated to the nearest 0.5 meter. Since exotic plants included different growth forms, to simplify the analysis of heights, native and exotic plants were combined and all species were grouped as trees, shrubs, or herbs.

The frequency of specific height classes was determined in addition to heights of tree, shrub, and herb stands. The height classes included: open ground, ground cover (< 0.6 meter), low canopy (3.1 — 6.0 meters), and high canopy (> 6.0 meters).

Plant density

All plants occurring within the plots were identified and counted. This enabled calculation of plant density by species and by plant growth form. However only density by growth form is reported here and includes native trees, shrubs, herbs, and exotics.

Plant species frequency and diversity

Percent frequency of plant species was calculated as the number of plots in which a species occurred divided by the total number of plots. Diversity represents the number of species per 10 meter diameter plot and was divided into natives and exotics.

Statistical methods

A randomized complete block analysis of variance was used for each of the vegetation parameters except species frequency and height class frequency. Plant growth form was the blocking factor for all analyses. The treatments in one set of analyses were the three San Diego county rivers (all plots centered on vireo nests). Vireo nest sites and riparian sites outside vireo territories (i.e. non-nest plots), both on the Sweetwater River, were compared in the second set of analyses.

All samples were tested for normal distributions with the Kolmogorov-Smirnov goodness of fit test, and homogeneity of variances with Hartely's F-max test. In some cases the data were logarithmically transformed to meet these criteria. When the logarithmic and square root transformations failed to normalize the distributions or render variances homogeneous, the data were ranked and the usual analysis of variance was performed on the ranks (Montgomery 1984). When this ranking test was used, the data were presented as medians instead of means and 25th and 75th percentiles instead of standard errors. Fisher's least significant difference test (Fisher's LSD) was used to make pairwise comparisons following the analysis of variance when treatment effects were significant. Alpha was set to 0.05 for all tests.

Results

Species frequency

The percent frequency of black willow (*Salix gooddingii*) and arroyo willow (*Salix lasiolepis*) was high on all three San Diego County rivers (table 1). Mulefat (*Baccharis glutinosa*) was overall the most frequently occurring plant in the study. There were no clear cut trends in percent frequency of species in nest plots versus non-nest plots or among rivers with one exception. Native herb frequency was low on the San Diego River relative to the other rivers.

Percent cover

Percent cover of trees, shrubs, herbs, and exotics was not significantly different among the Sweetwater, San Diego, and San Luis Rey rivers (3 x 4 ANOVA using ranks, df = 2 and 108, F = 0.64, p = 0.86) (fig. 5). High variability in percent cover resulted in no significant differences on the Sweetwater River between non-nest plots and nest plots (2 x 4 ANOVA using ranks, df = 1 and 72, F = 1.07, p = 0.31) (fig. 5).

Percent open ground in nest plots was not significantly different among the three rivers(one-way ANOVA, df = 2 and 27, F = 0.70, p = 0.50) (fig. 6). Although the percent open ground was about twice as high in the nest plots as the non-nest plots, they were not significantly different (student's t-test, df = 18, t = -1.45, p = 0.16) (fig. 6).

Plant heights

Heights of tree, shrub, and herb stands were not significantly different among rivers (3 x 3 ANOVA, log transformation used, df = 2 and 81, F = 0.31, p = 0.74) nor between vireo nest plots and non-nest plots (2 x 3 ANOVA log transformation used, df = 1 and 54, F = 0.45, p = 0.50) (fig. 7).

Table 1 - Percent frequency of plant species occurring in 10 m diameter plots on the Sweetwater (SW), San Diego (SD), and San Luis Rey (SLR) Rivers, San Diego County, Calif., 1986. Only species that occur in at least four out of the total 40 plots are shown.

Species	Non-nest SW	Nest SW	Nest SD	Hest SLR
NATIVES				
Trees				
Salix gooddingii	40	100	80	50
Salix lasiolepis	60	60	50	80
Populus fremontii	0	20	20	30
Salix hindsiana	0	0	10	40
Sambucus mexicana	30	10	0	10
Shrubs				
Baccharis glutinosa	80	80	100	80
Artemisia palmeri	10	40	0	70
Baccharis sarothroides	20	10	20	0
Herbs				
Artemisia douglasiana	20	30	0	90
Ambrosia psilostachya	10	40	20	40
Urtica holosericea	40	20	0	20
Ileterotheca grandiflora	0	20	0	30
Phacelia sp.	10	0	0	30
EXOTICS				
Trees or Shrubs				
Tamarix sp.	10	50	0	10
Nicotiana glauca	0	40	10	10
Arundo donax	10	0	10	20
Herbs				
Brassica nigra	20	30	50	70
Rumex sp.	40	10	60	30
Solanum sp.	40	20	40	10
Centaurea melitensis	40	30	30	0
Bromus sp.	10	10	30	50
Cyperus sp.	0	20	10	30
Apium graveolens	30	20	0	0
Foeniculum vulgare	10	10	30	0

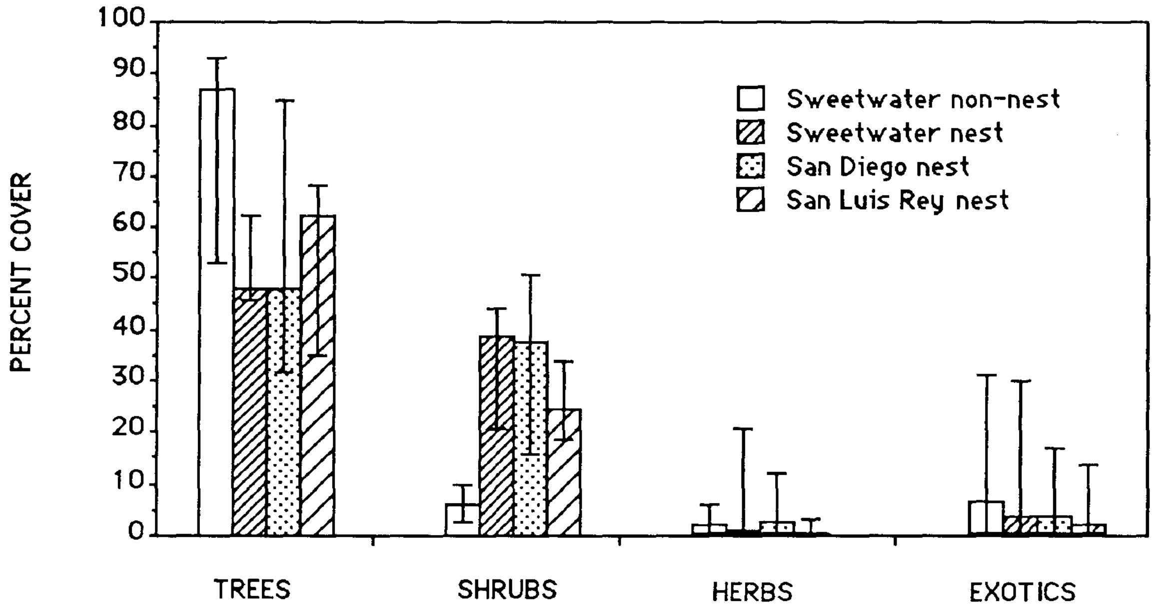

Figure 5– Median percent vegetative cover in vireo nest plots and non-nest plots on the Sweetwater River and in nest plots on the San Diego and San Luis Rey Rivers, San Diego County, Calif., 1986. Error bars are 25th and 75th percentiles.

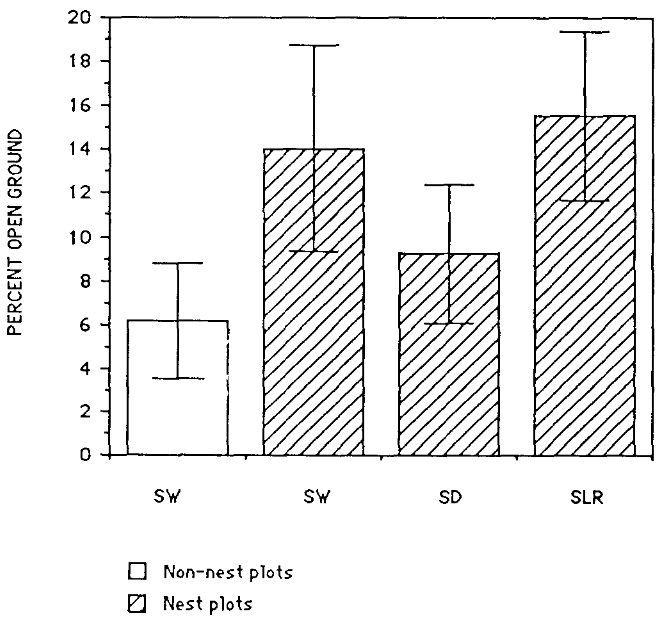

Figure 6– Mean percent open ground in vireo nest plots and non-nest plots on the Sweetwater River and in nest plots on the San Diego and San Luis Rey Rivers, San Diego County, Calif., 1986. Error bars are plus or minus 1 standard error.

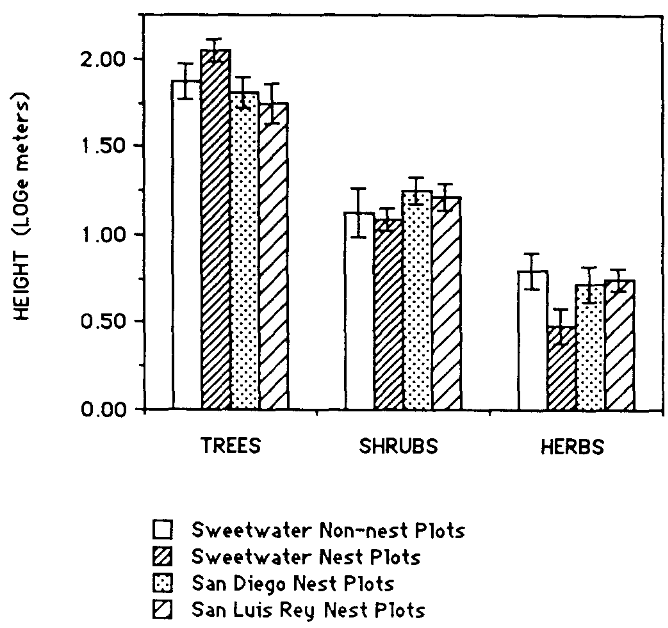

Figure 7– Mean log height of vegetation by growth form in vireo nest plots and non-nest plots on the Sweetwater River and in nest plots on the San Diego and San Luis Rey Rivers, San Diego County, Calif., 1986. Error bars are plus and minus 1 standard error.

The percent frequency of vegetative cover by height class is presented in Table 2. Ground cover was present more frequently in the San Luis Rey and Sweetwater nest plots than in the San Diego nest plots. Low shrub, high shrub, and low canopy layers were present in 80 to 100 percent of the plots on each of the three rivers, including non-nest sites. The frequency of a high canopy was variable among rivers.

Plant densities

Plant densities in the nest plots were significantly different among the three rivers (3 x 4 ANOVA using ranks, df = 2 and 108, F = 10.65, p<0.001) (fig. 8). Pair-wise comparisons using Fisher's LSD method revealed the following: (1) both native tree and shrub densities in nest plots were lower on the San Diego than on the San Luis Rey but were not different between the Sweetwater and either of the other two rivers, (2) plant density of native herbs was significantly lower on the San Diego than on the Sweetwater or San Luis Rey Rivers, (3) the densities of introduced plants did not differ significantly among the three rivers.

There were no significant differences in plant density between non-nest plots and nest plots for all growth forms (2 x 4 ANOVA, log transformation used, df = 1 and 72, F = 2.58, p = 0.09) (fig. 9).

Species diversity

Native plant species diversity in nest plots was significantly lower on the San Diego River than on both the Sweetwater and the San Luis Rey (3 x 2 ANOVA, df = 2 and 54, F = 4.26, p = 0.02) (Fisher's LSD test) (fig. 10). In contrast, there were no significant differences in the diversity of exotic plant species among rivers (Fisher's LSD test).

There was no significant difference in the number of native or exotic species per non-nest plot compared with nest plots (2 x 2 ANOVA, df = 1 and 36, F = 3.31, p = 0.09) (fig. 10). High variability among plots overshadowed the apparent difference between non-nest and nest plots in mean diversity of natives.

Table 2 — Percent frequency of height classes in 10 m diameter plots on the Sweetwater (SW), San Diego (SD), and San Luis Rey (SLR) Rivers, San Diego County, Calif., 1986.

Height Classes	NON-NEST SW	NEST SW	NEST SD	NEST SLR
Open	50	80	70	80
Ground Cover (< 0.6 m)	60	90	40	100
Low Shrub (0.6 — 1.5 m)	90	80	90	100
High Shrub (1.6 — 3.0 m)	80	90	90	100
Low Canopy (3.1 — 6.0 m)	90	80	100	90
High Canopy (> 6.0 m)	50	90	30	60

Discussion

Nest sites on the San Diego River had lower native plant density, native species diversity, and frequency of native herbs than nest sites on the Sweetwater and San Luis Rey. There were no significant differences in any of the vegetation parameters between the Sweetwater and the San Luis Rey. We believe that greater human presence is responsible for the lower native plant density and diversity on the San Diego River. There is generally more human disturbance in the riparian vegetation within the vireo's breeding range on the San Diego River because of a golf course, scattered camping sites, and partial channelization of the river. Even though the San Diego River is more disturbed, a relatively high population density of vireos occurs there (Jeff Newman, pers. comm.). Therefore it is appropriate to use data from all three rivers in a restoration model for vireo habitat in coastal San Diego County (table 3). However, whenever possible, it is best to use data on vireo habitat within the particular watershed being restored.

We found no significant differences between vireo nest sites and non-nest sites in all the vegetation parameters studied. Gray and Greaves (1984) also found no differences between nest and non-nest sites in stem densities, species frequencies, and height class frequencies. Also in agreement with their data was the wide variability among nest plots in vegetation structure. This high variability, and the similarity between areas occupied and not occupied by vireos, indicates that the vireo is a generalist nester, at least within willow-cottonwood woodland, with respect to: species frequency, cover, and plant density.

Table 3 — Means and standard errors of 30 Least Bell's Vireo nest plots on the Sweetwater, San Diego, and San Luis Rey rivers, San Diego County, Calif., 1986.

	Percent Cover	Plant Density (no/ha)	Plant Height (meters)
Natives[1]			
Trees	55.37 ± 21.73	2,750 ± 3,084	5.76 ± 1.84
Shrubs	34.95 ± 25.70	7,279 + 9,580	2.36 ± 0.84
Herbs	9.54 ± 18.24	5,577 ± 7,053	0.99 ± 0.56
Exotics	11.21 ± 16.72	10,016 ± 13,012	—
Open Ground	12.93 ± 12.36	—	—

[1]Natives and exotics are combined for mean plant heights.

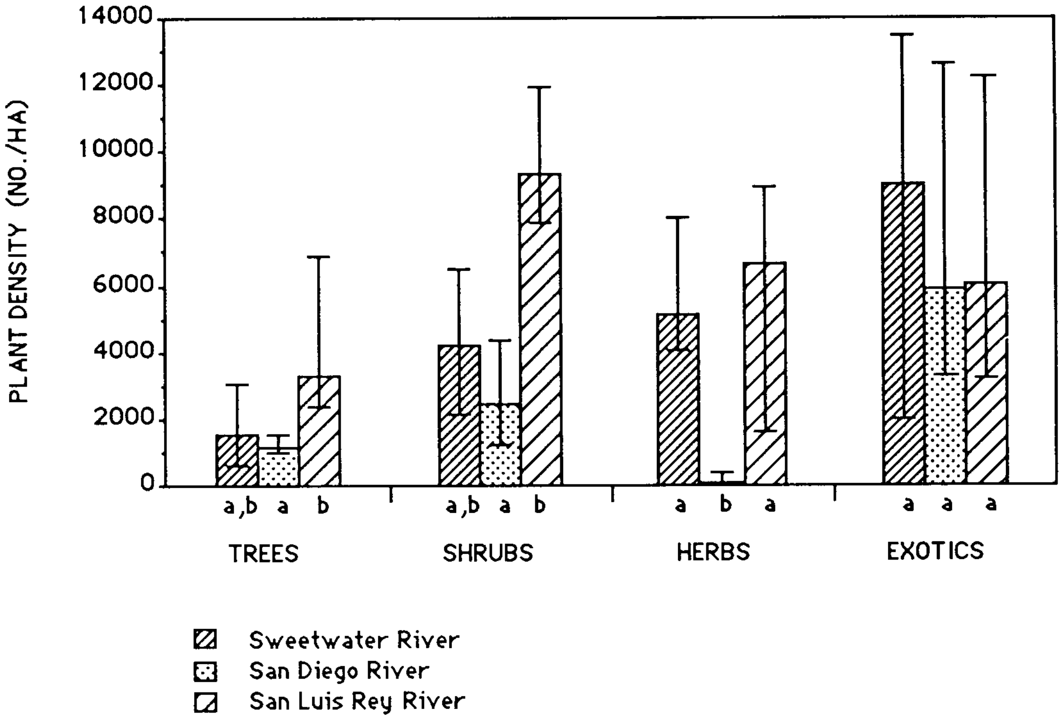

Figure 8– Median plant densities in vireo nest plots on the Sweetwater, San Diego, and San Luis Rey Rivers, San Diego County, Calif., 1986. Error bars are 25th and 75th percentiles. Medians with the same letter in the same group (i.e. trees) are not significantly different.

Although the vireo is a generalist nester in several ways, this does not lessen the importance of approximating natural riparian woodland as closely as possible when restoring vireo habitat. Our data can be used directly in designing a riparian revegetation area (Baird and Rieger, these proceedings). The height class frequencies in nest plots show that a restoration plan should include persistent low and high shrub layers and a tree canopy. Percent cover of growth forms, species frequencies, and plant densities should be used as a basis for (1) the percent areas to plant with native trees, shrubs, and herbs, (2) species composition, and (3) overall plant densities. A revegetation design based on plant density as opposed to stem density is more functional because the number of stems per plant is difficult to predict given the variability of branching patterns.

Characterization of the vireo's foraging habitat and other areas within their territories is the next step toward developing a holistic habitat restoration plan for this species. We strongly encourage the use of quantitative data from natural communities for designing the restoration of habitat for other endangered species.

Acknowledgments

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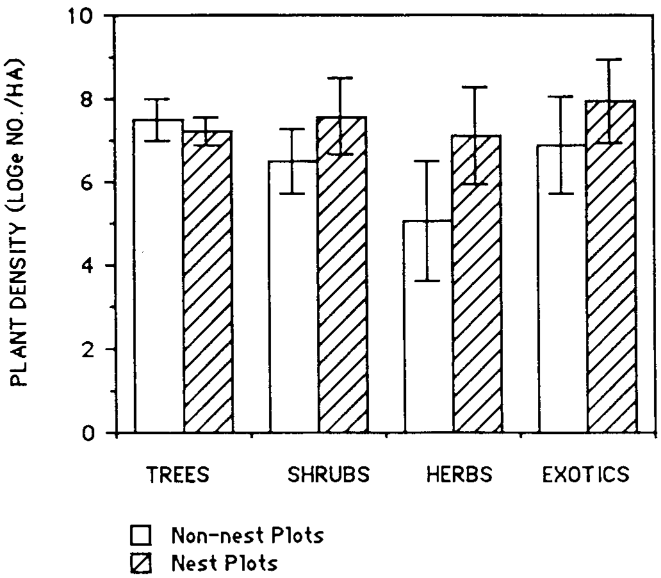

Figure 9— Mean log plant density in vireo nest plots and non-nest plots on Sweetwater River, San Diego County, Calif., 1986. Error bars are plus and minus 1 standard error.

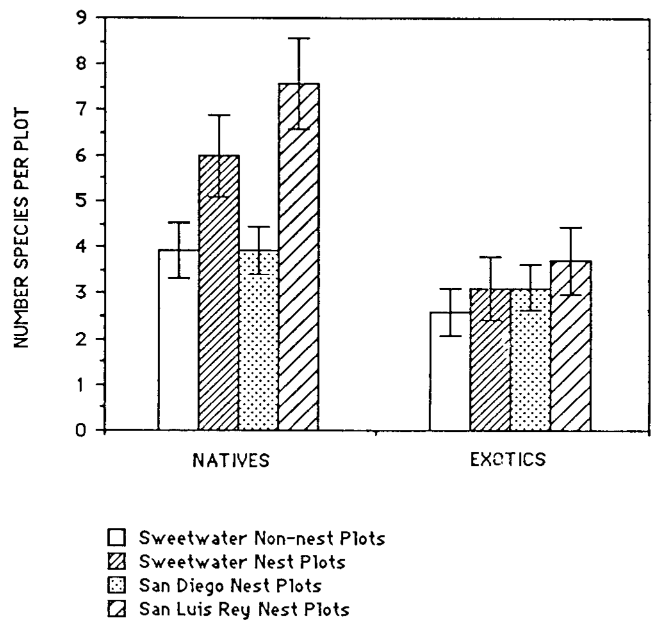

Figure 10— Mean number of species per plot in vireo nest sites and non-nest sites on the Sweetwater River and in nest sites on the San Diego and San Luis Rey Rivers, San Diego County, Calif., 1986. Error bars are plus and minus 1 standard error. Means with the same letter in the same group (i.e. natives) were not significantly different. Sweetwater nest plots were not significantly different from non-nest plots.

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MAINTAINING SITE INTEGRITY FOR BREEDING LEAST BELL'S VIREOS[1]

James M. Greaves[2]

Abstract: Least Bell's vireos (Vireo bellii pusillus) *exhibit a high degree of between-year fidelity to breeding area. Use of many sites in an isolated population in Santa Barbara, California, spans at least 10 years. Males and females show different types and degrees of tenacity to territories, as well as to some nest-sites. More than 60 percent male and nearly 30 percent female returning birds utilized the previous year's territories. While pair bonds remain strong throughout the breeding season for most birds, mate fidelity may be determined by such factors as population size and its sex ratio. Dimorphic behavioral traits such as these which are difficult to ascertain present researchers and managers with profound problems when studying the vireos and designing habitat alteration projects around the species' requirements.*

Facing a combination of natural forces that threaten its water supply at Gibraltar Reservoir, the City of Santa Barbara has undertaken several measures designed to alleviate some, if not all, of the problems it has begun reconstruction of the dam's base for earthquake safety, attempted to desilt the reservoir in order to halt its declining capacity, and is developing plans to either raise the dam to increase the reservoir or find alternate sources of water. In 1978, least Bell's vireos were discovered in habitats on alluvium in and adjacent to the reservoir (Gray and Greaves 1980). A detailed banding study of its life history and population dynamics was conducted from 1979-83 (Greaves 1987). Since its listing at the Federal level as an Endangered species in 1986, the city and U.S. Forest Service have continued to monitor the local population with annual censuses. In 1987, a second detailed study of the population was begun in order to assess its size and structure. Return rates of adult and first-year (FY) birds were determined, and nesting activities monitored to find rates of success and brown-headed cowbird (*Molothrus ater*) parasitism. The study will continue through 1996.

Study Area and Methods

The study area is located six miles north of the City of Santa Barbara in the Los Padres National Forest on both city and federal lands along a two-mile section of the Santa Ynez River, including a mile-long sediment-filled portion at the east end of Gibraltar Reservoir, and a two-mile section of Mono Creek extending northward from its confluence with the reservoir and the Santa Ynez River. In all, more than 240 ha. comprise the study area, composed of riparian and adjacent habitats ranging in width from 50 to more than 400 meters. For detailed descriptions of habitats and vegetation structures, see Gray and Greaves (1984), Greaves and others (1987), and Olson and Gray (1989).

In order to adequately ascertain population size and structure, I conducted a banding project, starting in 1987 and continuing through 1988, using various combinations of U.S. Fish and Wildlife Service aluminum and colored plastic leg bands. A drainage band (red for Santa Ynez River population) is required for each bird that is banded. Census methods followed those outlined earlier (Greaves 1987). Data were collected on the numbers of males and females present, age structure of the population, numbers of nests built, eggs produced, eggs that hatched, young fledged, and known-aged birds returning as potential breeders. Territories were areas with readily discernible and defended boundaries that were, generally, re-used from year to year. Nest sites were smaller locations within a territory, usually a single shrub or clump of weeds or shrubs. Successful nests were those that fledged at least one vireo chick.

I determined factors that affected breeding success, and made recommendations concerning predators, cowbirds, and human activities in the study area. Censuses of other birds were made in order to monitor changes over time in composition of the entire bird community, paying close attention to the numbers and locations of the three other vireo species, warbling (*V. gilvus*), Hutton's (*V. huttoni*), and solitary (*V. solitarius*), that shared the riparian habitats with the least Bell's vireos. Changes in the numbers and locations of these species were noted in order to determine if inter-generic competition might be influencing the apparently declining population of least Bell's vireos as compared to the previous study's estimate of the four species' composition within the bird community.

Results

For the two breeding seasons of this study, the population contained less than half the number of birds

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Independent Consultant, Santa Barbara, California.

found in the previous study (Greaves 1987). Numbers of males, females, pairs formed, young vireos produced, and cowbirds in the area were as follows:

	1987	1988
Vireo males present	25	22
Vireo females present	17	14
Vireo pairs formed	19	21
Vireo young produced	63	47
Cowbird males present	7	5
Cowbird females present	6	6
Cowbird eggs or young at/in vireo nests	1	2

In 1988, returning vireos were distributed as follows:

1987 vireos	Returned	# to same territory
Males banded (N=22)	12	10
Females banded (N=15)	9	3
Males unbanded (N=3+)	4	3
Females unbanded (N=2 to 4)	2	0
Nestlings/fledglings banded (N=61)	-	-
First-year (FY) males banded	7	0
First-year (FY) females banded	3	0
Nestlings/fledglings unbanded (N=2)	-	-
First-year (FY) males unbanded	(1)	0
First-year (FY) females unbanded	0	-

Ten of 61 banded 1987 fledglings returned to the study area in 1988. Three of these (two males, one female) were from one nest while two other males were from a nest in an adjacent territory along Mono Creek; all five found other birds with which to mate, including at least one other first-year (FY) male. The two males from the second nest above were paired sequentially with the same female, which had been banded as an adult in 1987. Two other FY males remained unpaired throughout 1988. None of the FY birds mated with siblings or their own parents. Their dispersal distances from site of fledging ranged from 0.2 to 1.6 miles.

In 1987, two females were suspected of being sequentially polyandrous (see Greaves, 1987, for discussion). In 1988, at least six females made seven mate changes by the end of June, either during the latter part of first brood feedings or fledging, or immediately after failure of previous nesting attempts. No adult birds were found dead in 1987. However, in 1988, two females were killed at their nests by unknown predators; one male (an FY bird) never re-mated, while the other later was successful in raising a brood with a female that had been previously successful elsewhere in the study area. One male disappeared from a viable nest, and his mate immediately joined an adjacent unpaired male and raised a brood from their first nest.

All 1988 territories were within the boundaries of territories found in 1987, all of which were used one or more times in the previous study (Greaves and others 1987). One male-initiated nest was begun on the same fork as was used by the same pair in 1987, but abandoned in favor of a site chosen by the female. Another 1988 nest was placed within a meter of a successful 1987 nest by a completely different pair than had nested there in 1987. Many 1988 nests were within five meters of former nests, some dating as far back as 1980.

After noting that one nest had been abandoned subsequent to parasitism in 1988 and another cowbird egg was found, desiccated, beneath a fledged nest, a limited cowbird removal program was undertaken along a quarter-mile section of the Santa Ynez River that was consistently (and, historically) used for mid-day feeding and flocking. Two two-hour periods were required to take seven of the eight cowbirds; the other was shot a mile upstream on the Santa Ynez River in a woodland adjacent to an active least Bell's vireo territory.

In mid-May 1988, five female and three male cowbirds were shot with a 20-gauge shotgun in a part of the study area in which they foraged during mid-day. No further least Bell's vireo nests were found to be affected by cowbirds subsequent to these few removals. Three weeks after the eight cowbirds were shot, a fledged cowbird was seen with a pair of yellow warblers (*Dendroica petechia*) and was also shot. In early July, two cowbird chicks were removed from nests in adjacent blue-gray gnatcatcher (*Polioptila caerulea*) territories, and a female cowbird was observed near one of the two nests. In addition, a cowbird egg had been found in the nest of a pair of common yellowthroats (*Geothlypis trichis*) in 1988; several other species' nests had been found parasitized from 1980-87, including Hutton's vireos, lazuli buntings (Passerina amoena), rufous-sided towhees (*Pipilo erythrophthalmus*), and song sparrows (*Melospiza melodia*).

Censuses of other bird species indicated that most species were in lower numbers in 1987 and 1988 than had been found in the previous study. However, in 1988, the number of solitary vireos seemed to increase (from less than a half dozen males in 1987 to 12 males in 1988), and hummingbirds, which were virtually absent during 1987, were abundant throughout 1988, including a tremendous number of Allen's hummingbirds (*Selasphorus Basin*) after mid-June, a species formerly seen only in early spring and late summer in much smaller numbers. Costa's (*Calypte costae)* and Anna's (*C. anna*) hummingbirds predominated, with no verified records in either year of the formerly common black-chinned hummingbird (*Archilochus alexandri*)(Gray and Greaves 1980).

While warbling vireos are widespread throughout the west, their occurrence in sizable populations has not been recorded often: the Gibraltar Reservoir study area contained nearly 100 pairs in the early 1980's (Gray and

Greaves 1980), but was found to have declined as dramatically as the least Bell's vireo had in 1987 and 1988, still out-numbering the latter by a 2:1 ratio. Hutton's vireos breed in a broader ecological area of the west, in more arid regimens, utilizing oak and chaparral woodlands, even when adjacent to riparian areas with sufficient vegetation. In the study area, all four species of vireo were found to use riparian vegetation for feeding, as well as nesting, their foraging and nesting niches separated to some extent by community characteristics, but more often along horizontal boundaries, with warbling vireos using the oak and willow-cottonwood canopies, the solitary and Mutton's using, respectively, interior and exterior edge and understory tree canopies between 4 and 20 feet, with least Bell's vireos nesting generally in weedy situations below 4 feet, in the openings in between thickets, within thickets, and within closed canopied woodlands. All four species foraged in all levels, but generally used the same levels within which they nested for food-gathering and tending fledglings. A more complete discussion of the variety of wildlife in the study area can be found in Gray and Greaves (1980) and Gray and others (1989).

Discussion

It is clear that the rates of return for male and female least Bell's vireos to the same and adjacent territories continue to follow those found in the past (Greaves 1987). While the percentage of females returning from 1987 to 1988 remained about the same (33 percent) as in the past study (31 percent), the percentage of males returning to the same territory (83 percent) in 1988 was far higher than that of males returning to the same territory (63 percent) in the previous study. The primary difference between the size of the study population from 1979-83 (annual mean of 46 males and 40 females) compared to the current population size (annual mean of 23 males and 15 females) may partially account for the difference in male tenacity to sites. With fewer conspecifics nearby and larger areas available for territories, the males may not have been under as much competitive pressure to vacate a territory or shift its center from 1987 to 1988 as they had in the past; females, on the other hand, may change mates or territories from year to year at about the same rate regardless of population size, tenacity based more on success or failure than on affinity to particular sections of the habitat.

Return rates for FY birds was about the same as in the previous study; 18 percent of 1979-82 fledglings, compared to 16 percent of 1987 fledglings, 16 percent being well within the range (11-32 percent) for the previous study. However, the male to female ratio in 1988 FY birds (7:3) was more than double the total encountered previously (25:23, range 3:4 to 8:5). Individual year samples appear to vary on the order of 2:1. The ratio in 1988 may be within a normally occurring range, since it is not significantly different from the ratio found in 1983 (8:5), a year in which the overall male to female ratio increased to nearly 57:43. Indeed, the smaller population found in 1983 from the previous four seasons, with its greater FY male to female ratio, may have been the first indication in the area that smaller populations would contain a higher percentage of males, such as found in 1987 and 1988.

As a population shrinks, fewer females returning to an area may be one of the first obvious changes: the ratio of males to females in 1983 was slightly less than that found in 1987 (60:40) and 1988 (61:39) but greater than had been previously encountered (51:49 to 54:46 from 1980-82)(Dames and Moore 1987). No data exist as to the male to female ratios for the years 1984-86, so it is difficult to ascertain whether or not the recent ratio is a continuation of a long-term trend or the result of other factors, such as the long drought begun in late 1986 and continued through the 1988 breeding season.

As the study population became imbalanced during the past study period, mate switching by females appeared to increase in frequency. Disturbances at nest sites by predators and cowbirds could account for some normal mate switching behavior, while researchers may account for some of the later increase, roughly paralleling the increase from 1987 when there was relatively little researcher disturbance until adults were banded later in the season to 1988 when there was contin-ued disturbance by researchers. Some evidence exists (Greaves 1987) to partially discount researcher disturbance as the sole cause of increased mate switching. Indeed, if the researcher were a primary cause of disturbance, many tenacious pairs should not have remained together through as many nesting attempts or breeding seasons following handling by the researcher. Cumulatively, however, the effects of predation, cowbirds, researchers, and drought may be sufficient to encourage an increase in the female's natural tendency to switch mates.

If, for instance, other disturbances, such as bulldozer, off highway vehicle, or hiker travel were to occur in an area, these additional pressures could be sufficient to cause areas to be permanently abandoned by females, followed then by the males. Indeed, vast areas within which male least Bell's vireos have been found just outside the study area that appear to contain sufficient habitat for breeding pairs, receive greater amounts of human impacts than the more isolated study area, and do not contain permanent, or consistently occupied territories. Often, only unpaired males are found, which do not remain more than a week in those locations.

The re-use of territories and specific nest sites by a pair of birds from one year to the next appears to be a common strategy among least Bell's vireos (Greaves 1987; Greaves and others 1987). Indeed, such behavior appears to extend to birds occupying adjacent, overlapping territories. In 1988, a pair of vireos built a nest within another unpaired FY male's defended territory. After their nest was predated, a previously successful female joined the unpaired male and they built a nest directly atop the other pair's failed nest, incorporating some of its material. In spite of the availability of nearby habitat for nest sites, the FY male and his new mate chose a site that had been recently used. Unfortunately, it was not an ideal location for a nest, and the female was killed by a predator while still laying eggs in the new nest. Only one other nest had ever been re-used: of 469 nests observed, it was a doubly successful nest for the male that defended it, raising two broods, each with a different female (Greaves 1987). Thus, while failure may preclude the likelihood that a nest or site will be re-used during a given season, often encouraging the birds to move great distances for subsequent nesting attempts, success appears to encourage the re-use, even from year to year, of specific locations, often to the exact fork on the host plant.

Thus, disturbances that cause nest failures may contribute to the tendency of females to switch mates. This would allow the female a greater array of nest site alternatives, but does not seem to increase the likelihood of success for that female or her mate during any given season. Indeed, monogamy proved to be a more reliable strategy during the previous study for increased nest success (Greaves 1987). A greater number of second successful nests arose from second nesting attempts by a monogamous pair than among those arising from sequential matings in the current study population as well.

There is insufficient past or present data from the study area to indicate any predator- or cowbird-related causes for the decline in the least Bell's vireo population. Drought has been mentioned as a likely explanation for the decline of many of the local species. Censuses conducted along the Salinas River in 1987 indicate that drought or adverse local weather conditions may have been the primary factor in depressing most riparian bird species during the 1987 breeding season (Greaves 1988). Simultaneous with the decline of least Bell's vireos in Santa Barbara has been a tremendous increase in the species in other populations in southern California. While it might be convenient to attribute all the decline of birds in the study area to drought, there are several other factors which should be considered, among which is the difference in the manner in which the Santa Barbara and other populations have been managed to ameliorate the effects of cowbirds.

Cowbird trapping programs have been conducted at several of the other southern California sites for at least four breeding seasons, while only in 1988 were adult cowbirds taken out of the habitat in Santa Barbara. The primary control method used in the past in Santa Barbara was the removal of cowbird eggs or chicks from any nests in which they were found. The cumulative effects of parasitism might have led to decreased successful reproduction by birds in nearby areas, as well as in the study area among birds not studied. Populations of most other species could have slowly declined during that period to their current levels. There appears to be no direct evidence on how the cowbird has caused any particular species or community of birds to decline or change over time. Only circumstantial evidence suggests that cowbirds have lowered populations in many southern and central California regions. By inference, the conclusion has been drawn that previously high rates of parasitism, along with the virtually failed reproductive efforts on the parts of least Bell's vireos in several of the populations, may account for the loss of adult vireos from the Santa Barbara area. With no young produced in other localities, it is apparent that the other populations cannot provide dispersers to colonize new, or repopulate older, areas with additional breeders. Conversely, in areas from which cowbirds have been removed in large numbers, many populations appear to be making remarkable recoveries. (Data on file, U.S.F.W.S., Laguna Niguel, California.)

In addition, the problem of population viability needs to be addressed. We currently do not know what constitutes a viable genetic pool among least Bell's vireos. The high rate of return among FY birds to the Santa Barbara study area might indicate the absence of other areas into which they might have dispersed for breeding. Combined with a dirth of breeders filtering into the area from other drainages, the effects could be the inter-breeding of siblings and of parents with their young. So far, there has been no evidence of either occurrence, in both the current as well as the past study at the site. Thus, the high return rate of FY birds might indicate that previous assumptions about return rates for FY birds need to be reconsidered. Other studies and their accompanying conclusions about survival rates among FY birds, such as that conducted by Nolan (1978), were made on small parts of larger populations, the boundaries of which were not as readily apparent as those found along the narrow riparian corridor in the several least Bell's vireo study areas. Four percent of previously fledged prairie warblers (*Dendroica discolor*) returned to breed within his study population, compared to a ratio (based on plumage characteristics) of 2:1 for after-second-year (ASY) to FY males, a ratio comparable to that encountered at Gibraltar Reservoir in 1988 when 14 ASY and 7 FY males were identified.

(Unpubl. data on file, Greaves.) Only with continued monitoring of all least Bell's vireo populations, will it be possible to discover whether a 16 percent survival rate is, as suggested by Nolan, rather high for FY birds in general, or whether, due to the inability of researchers to adequately cover the vast areas in which the warblers bred and ultimately dispersed, one might expected a higher number of young to survive to breeding, as appears to be the case among least Bell's vireos from the Santa Barbara area.

Until there is evidence of large numbers of FY birds from one drainage becoming breeders in other drainages, management objectives for least Bell's vireos should assume a high degree of isolation from each other of the more distant populations, especially where the distance is as great as that between Santa Barbara and its nearer large least Bell's vireo breeding centers nearly 150 miles to the south. Each population should be considered to be its own source of replenishing, future genetic material, and projects tailored to that interpretation of observed behavior. With a return to regular weather patterns, such as existed during the late 1970's and early 1980's, bird populations may re-establish themselves in former numbers. By continuing banding research and cowbird removal programs, we will provide a future data base from which to obtain answers to the questions raised above.

Conclusions and Management Recommendations

It is clear that males and females respond differently to factors in the environment that affect territoriality and site tenacity. Males establish and vigorously defend well-defined areas within the study area, while females move from one area to the next until they find mates whose territories contain the requisite habitat characteristics that they need for breeding. First-year birds constitute a sizable and important part of each population, and may be limited in their options of dispersal sites, preferring to return to their natal area in much higher than previously assumed numbers. Weather-induced changes in population may affect male: female ratios, and alter reproductive results sufficiently to temporarily depress breeding populations in one area while increasing them in other areas less affected by the adverse weather patterns. While there appears to be a correlation between cowbird removal and increases in local populations of least Bell's vireos, no direct evidence has been gathered to indicate that the entire California and Mexican population of least Bell's vireos has declined solely due to cowbird depredations.-

The above factors must be considered by managers when undertaking or mitigating projects that remove least Bell's vireo breeding habitats. Other objectives that should be considered by researchers and managers immediately include the following:

1. Declare Critical Habitat for those larger populations, where the Department of the Interior has delayed such designations for more than two years from its original mandate.

2. Continue research on dispersal and return rates for at least another five years, using banding studies wherever feasible.

3. Continue cowbird removal programs in all areas where least Bell's vireos breed to ensure that cowbirds do not have major impacts on reproduction of riparian avifauna.

4. Maximize habitat diversity along riparian corridors, creating or increasing buffer zones between natural settings and surrounding altered or degraded areas.

5. Conduct major revegetation programs on all major streams in California, using as guides data collected during studies of riparian systems throughout the southwest, paying close attention, for least Bell's vireos, to such studies as conducted by Olson and Gray (1989).

6. Eliminate all detrimental human activities in floodplains.

7. Recognize the importance of least Bell's vireo habitats to other riparian obligate and non-obligate species (Gray and others, 1989; Hunter and others 1987; Johnson and others 1987).

8. Recognize the importance of individual birds to the entire state-wide populations of endangered species, such as the least Bell's vireo. We should not wait until a species reaches the critical stage as that of the California condor (*Gymnogyps californianus*) or the extinct state of the dusky seaside sparrow (*Ammospiza maritima nigrescens*) before considering the individual bird inexpendable.

9. Protect and enhance isolated habitat islands within which apparently unpaired males may be encountered. With the tendency of females to wander between mates, isolated males may be important to tying together the apparently isolated sub-populations of the species. All smaller populations should be considered, therefore, to be dynamic parts of a larger state-wide or regional population, in spite of the current data suggesting that all populations may be reproductively isolated from one another.

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USE OF NON-RIPARIAN HABITATS BY LEAST BELL'S VIREOS[1]

Barbara E. Kus and Karen L. Miner[2]

Abstract: *The least Bell's vireo* (Vireo bellii pusillus) *is an endangered songbird inhabiting riparian woodlands in southern California. Although the species requires riparian habitats for nesting, vireos also occur in upland habitats adjacent to breeding areas. Vireos breeding at the Sweetwater River in San Diego County during 1986 and 1987 were observed using non-riparian areas for foraging and nesting. The use of non-riparian habitats, primarily areas of coastal sage scrub and chaparral vegetation, varied over the nesting cycle, and was related to territory location and habitat composition. These observations suggest that planning boundaries intended to protect resources essential for breeding vireos should include upland* areas *bordering riparian habitats.*

The least Bell's vireo (*Vireo bellii pusillus*), a southwestern subspecies of Bell's vireo, is a migratory songbird inhabiting riparian woodlands in southern California and northern Baja California. Once widespread and abundant (Cooper 1861; Anthony 1893, 1895; Fisher 1893; Grinnell and Swarth 1913; Grinnell and Storer 1924; Grinnell and Miller 1944), the species has undergone a dramatic decline during the last 4 decades according the U.S. Fish and Wildlife Service (USFWS 1988, leading to its designation by the Secretary of the Interior as endangered in 1986. The vireo's decline in numbers has been attributed to the loss and degradation of riparian habitat through out the species' range, as well as to the expansion in range of the brown-headed cowbird (*Molothrus ater*), a nest parasite (USFWS 1988).

Although characterized as a riparian breeding species, least Bell's vireos use non-riparian habitats within and adjacent to floodplains for foraging and other activities. Gray and Greaves (1984) were among the first to document the use of non-riparian foraging sites by vireos, reporting observations of birds foraging in chaparral areas near the Santa Ynez River in Santa Barbara County. Recent observations of vireos using non-riparian habitats at other sites suggest that this behavior may be widespread and that the availability of such areas may be important to nesting vireos. This paper reports on the nature and extent of use of non-riparian habitats by least Bell's vireos breeding at the Sweetwater River in San Diego County.

Study Site and Methods

Study Site

We studied least Bell's vireos at the Sweetwater River in southern San Diego County, California. The study site includes a 5-kilometer stretch of the river bounded to the east by the Cottonwood Golfcourse and to the west by the Sweetwater Reservoir. Approximately 566 hectares of riparian wood land occur within this reach, which is bordered primarily by upland areas of coastal sage scrub and chaparral habitats. The width of the riparian stand ranges from approximately 10 meters just east of the reservoir to over 250 meters to the west and east of this point (fig. 1).

Methods

Vireos were observed from mid-March through mid-August during 2 breeding seasons in 1986 and 1987. Surveys were conducted early in the spring to determine the number and location of all vireo pairs within the study area. Pairs were then visited weekly throughout the season, and their breeding activities monitored. Visits to individual territories lasted for periods of from 0.5 to 2.0 hours, during which observers recorded behavioral data about the birds, including the occurrence and location of territorial advertisement (singing), border disputes, foraging, and behaviors related to nest attendance. Any activities occurring in non-riparian habitats were described, noting the identity and behavior of the individual(s) involved, their distance from the riparian edge, and the habitat type and plant species in which they were observed. Four non-riparian habitat types were assigned by the presence of at least one of the following indicator species: coastal sage scrub: *Artemisia californica, Eriogonum fasciculatum;* chaparral: *Malosma laurina, Prunus ilicifolia, Adenostoma fasciculatum;* grassland: grass species; degraded riparian: sparse vegetation of *Salix* spp., *Sambucus mexicana,* and exotic trees and shrubs.

Vireo territories were mapped by plotting the locations of perches used by singing males on aerial photographs of the site, and connecting the outermost perch

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locations for each male. Home range boundaries were determined for some pairs by incorporating known territories with adjacent areas used by the pair, but not observed to have been defended by them. The sizes of territories and home ranges were calculated by tracing these areas with a planimeter. Territories were classified as "edge" territories if their boundaries coincided with of the edge the riparian woodland, or if the birds could reach adjacent non-riparian habitats without traveling through another vireo's territory. All other territories were classified as "central" territories.

The vegetation structure and composition of vireo territories were described by estimating the following variables:

RIPWIDTH: Width-class of riparian vegetation perpendicular to the drainage channel (<10, 11-50, 51-250, 251-1000 , >1000 meters).

AQUATIC: Percent cover of aquatic and/or emergent plant species.

OPENHERB: Percent cover of bare ground and herbaceous plant species.

SHRUB: Percent cover of shrubs (<3 meters high).

TREE: Percent cover of trees (>3 meters high).

UNDRSTOR: Proportion of TREE with shrub understory.

These habitat variables were visually estimated at the location of each territory by sampling a 10-meter-wide belt transect running perpendicular to the river channel, bounded by the riparian-upland edge. Cover estimates were made according to a modification of the Daubenmire Cover Scale (Daubenmire 1959, 1968) in which the intervals of the upper and lower cover classes were expanded to account for the relative inaccuracy of the estimation method used.

Results and Discussion

Distribution and Abundance of Least Bell's Vireos

A total of 46 breeding pairs were observed at the study site in 1986; this population increased to include 56 pairs in 1987. The densest concentrations of vireos occurred at the upper end of the Sweetwater Reservoir, and in the upper segment of the study area adjacent to the Cottonwood Golfcourse, although birds were distributed along the entire length of the drainage, including narrow stretches of riparian habitat bordered by steep canyon walls (fig. 1). Most of the territories occupied in 1986 were also occupied in 1987, possibly by the same individuals.

Use of Non-riparian Areas

Foraging

In 1986, one or both members of 15 vireo pairs (31 percent of all pairs) were observed foraging outside of their territories in non-riparian habitats at least once during the study period. Typically, individuals seen feeding outside of the riparian zone were males; however, females of at least six pairs also fed in non-riparian vegetation. Only one instance of a fledgling feeding outside of the riparian zone was observed.

Vireos tended to forage in areas adjacent to the riparian stands wherein their territories were located, traveling from 3 to as far as 61 meters to reach these sites:

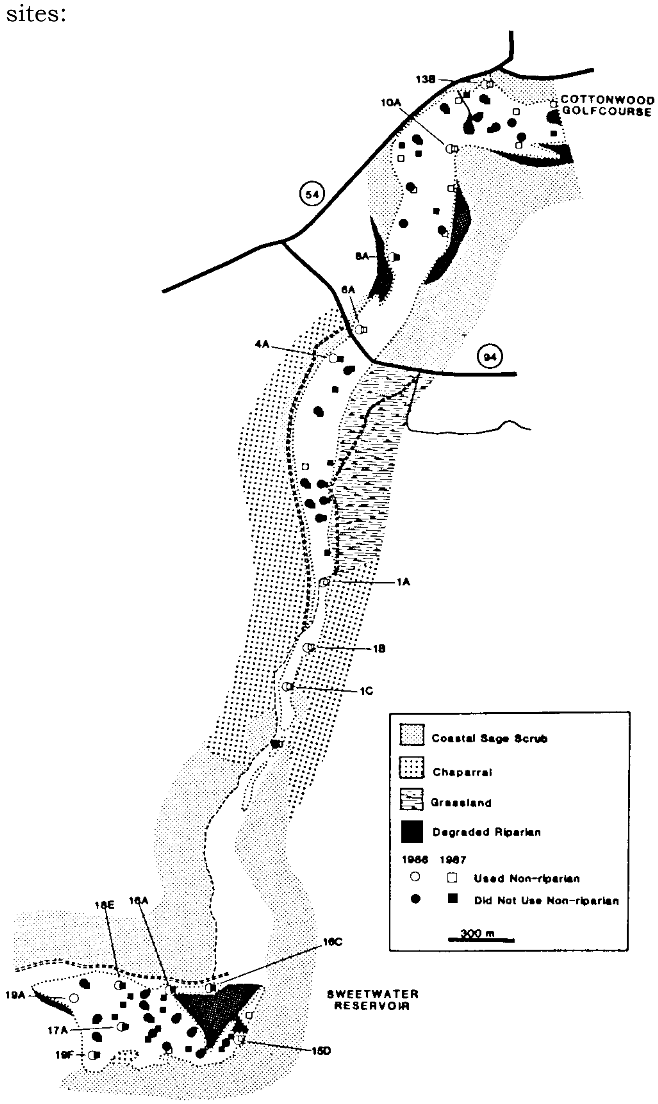

Figure 1– Territory locations of breeding least Bell's vireos at the Sweetwater River, San Diego County, California, in 1986 and 1987.

Pair	Type of Habitat[1]	Mean Distance from Territory (m)
1A	DR	6
	CHP	12
1B	CHP	25
1C	CSS	15
	CHP	16
4A	CSS	3
6A	DR	15
8A	DR	14
10A	DR	30
13B	DR	6
15D	CSS	--
16A	CSS	8
16C	DR	30
17A	CHP	27
18E	CSS	6
19A	DR	61
19F	CSS	19

[1] DR: degraded riparian, CSS: coastal sage scrub, CHP: chaparral.

While foraging in non-riparian habitats, vireos fed in species of plants not typically found within their territories. The most frequently visited species was *Malosma laurina,* which occurs in chaparral and coastal sage scrub habitats, followed by *Artemisia californica,* present primarily in coastal sage scrub areas, and *Sambucus mexicana,* which occurs in both coastal sage scrub and degraded riparian areas. Vireos were also observed foraging in an additional 12 species:

Species	Number of Visits
Malosma laurina	13
Sambucus mexicana	7
Artemisia californica	7
Baccharis sarathroides	3
Baccharis glutinosa	2
Brassica nigra	3
Salix spp.	2
Prunus ilicifolia	2
Nicotiana glauca	1
Salvia mellifera	1
Heteromeles arbutifolia	1
Silybum sp.	1
Platanus racemosa	1
Schinus molle	1

The use of adjacent areas by foraging vireos varied according to the stage of the nesting cycle (fig. 2). The largest number of non-riparian foraging bouts occurred when pairs had fledglings, although substantial numbers also occurred prior to egg-laying and during incubation. Birds rarely fed outside of their territories when raising nestlings.

When territory characteristics were compared among vireo pairs that foraged in adjacent non-riparian areas and those that did not, two overall differences emerged. First, birds using adjacent foraging sites tended to occur along the narrowest stretches of the river (fig. 3; Kruskal-Wallace statistic = 4.78, 1 d.f., P=0.028), and second, these birds had territories positioned on the edge of riparian stands (Kruskal-Wallace statistic = 6.40, 1 d.f., P=0. 011). These two factors are linked in their effect in that most centrally located territories occur in wide stands of riparian vegetation, while edge territories tend to be located along narrow stretches of the river. By far, the largest proportion of birds feeding outside the riparian zone were those possessing edge territories; only one of these 15 pairs occupied a central territory. Forty-five percent (14/31) of pairs with edge territories fed in non-riparian areas, while only 6 percent (1/17) of pairs with central territories did so, a difference which is significant ($x2$ = 16.4, 1 d.f., P<0.005).

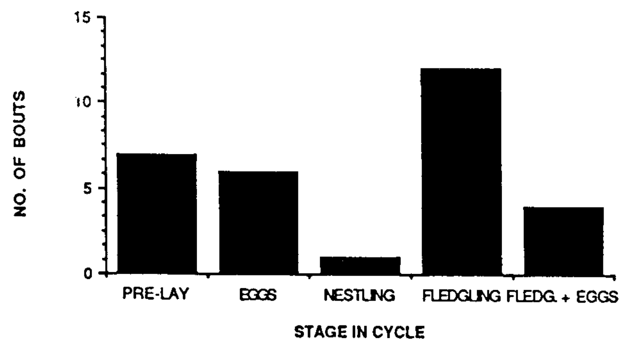

Figure 2– Frequency of non-riparian foraging bouts by least Bell's vireos during different phases of the nesting cycle.

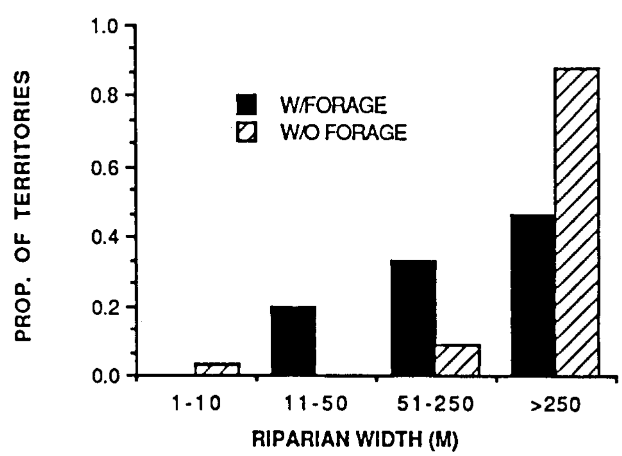

Figure 3– Proportion of territories of least Bell's vireos that used, and did not use non-riparian foraging areas, in riparian stands of different width.

Because the use of adjacent foraging areas was largely confined to pairs with edge territories, we compared the habitat characteristics of central and edge territories in an attempt to discern differences which might affect vireo foraging behavior. Territories differed in several regards with respect to their location in the riparian zone. Edge territories had significantly less tree (Kruskal-Wallace statistic = 8.87, 1 d.f., P=0.003; fig. 4a), and shrub cover (Kruskal-Wallace statistic = 7.70, 1 d.f., P=0.006; fig. 4b), and significantly more bare ground and herbaceous cover (Kruskal-Wallace statistic = 10.66, 1 d.f., P=0.001; fig. 4c), than did central territories. Since vireos feed primarily in trees and shrubs, the amount of this vegetation within a territory may be correlated with the amount of food available; thus, edge territories may have lower food resource densities than central territories. Edge territories also tended to be smaller in area than central territories (Kruskal-Wallace statistic = 2.88, 1 P=0.089); although this difference is not statistically significant, it supports the hypothesis that birds nesting in edge territories may have fewer overall resources than birds in centrally located territories, and that they may rely upon access to non-riparian foraging sites to supplement their resources.

Other Uses of Non-riparian Habitats

A closer examination in 1987 of the use of non-riparian areas by vireos revealed that these areas are not strictly used as extra-territorial foraging sites. Twenty-three pairs (43 percent of all pairs) were observed using non-riparian sites in 1987, and all 23 incorporated these areas into their home ranges. One additional unpaired male was observed occasionally visiting non-riparian sites; this male is excluded from the analyses that follow.

Of the 23 pairs whose home ranges included non-riparian areas, 8 pairs (35 percent) placed at least 1 nest within the non-riparian area, 10 pairs (44 percent) foraged with their fledglings in non-riparian sites, and 4 pairs (17 percent) both nested and fed with fledglings in non-riparian areas (table 1). As in 1986, most of the non-riparian activity occurred in coastal sage scrub habitats; birds also used degraded riparian and chaparral habitats (table 1).

Table 1 — Nature of Use and Type of Non-riparian Habitats Used by Least Bell's Vireos at the Sweetwater River, 1987

		Habitat Type		
Type of Use[1]	# Pairs	Costal Sage Scrub	Degraded Riparian	Chaparral
HR	23	21	8	3
HR + N	8	7	4	0
HR + F	10	10	3	1
HR + N + F	4	4	2	0

[1]HR = home range, N = nesting, F = feeding with fledglings

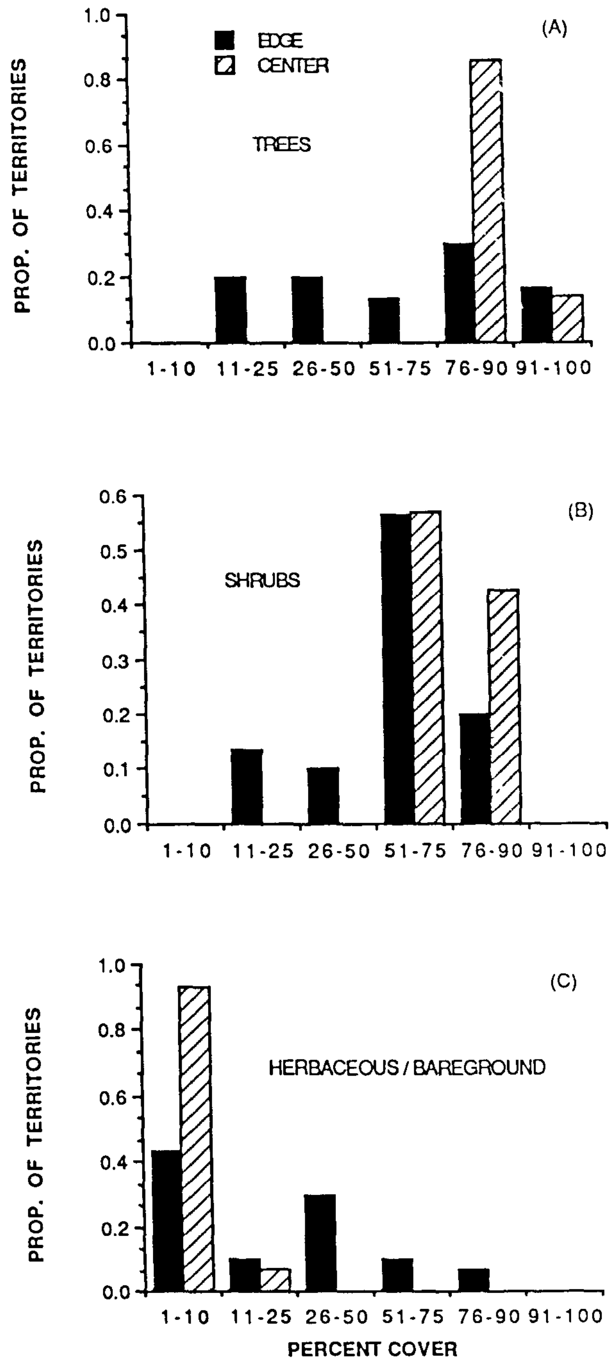

Figure 4— Percent cover of (a) trees, (b) shrubs, and (c) bare ground and herbaceous vegetation in central and edge territories of least Bell's vireos.

Pairs with edge territories were significantly more likely to use adjacent non-riparian sites than those whose territories were centrally located, as observed in 1986. Forty-eight percent (22/46) of pairs with edge territories used non-riparian areas, in contrast with 4 percent (1/23) of pairs with central territories ($x2$ = 18.9, 1 d.f., P<0.005). Of the 23 pairs using non-riparian areas, 22 (96 percent) possessed edge territories.

Pairs using non-riparian areas tended to occur in narrower reaches of the river than did those not using non-riparian areas (Kruskal-Wallace statistic = 12.95, 1 d.f., P<0.003), although pairs using non-riparian areas also occurred in wider reaches. All of the pairs (8/8) occurring in riparian stands less than 50 meters in width used non-riparian sites, while 36 percent (8/22) of those in stands 51-250 meters wide, and only 18 percent (7/38) of those in the widest riparian stands, used adjacent non-riparian areas.

The distance between the riparian edge and the outermost border of the non-riparian component of vireo home ranges averaged 19.9 + 15.3 meters, and ranged from 7.6 meters to 61.0 meters. Ninety-six percent (22/23) of home range boundaries were less than 46 meters from the riparian edge, and 87 percent (20/23) were less than 40 meters from the riparian edge. The distance between non-riparian home range borders and the riparian edge differed as a function of the width of the riparian stand in which pairs were located. In stands less than 50 meters in width, home range boundaries occurred on average 13.1 + 8.7 (range: 7.6 - 33.5) meters from the riparian edge. This distance averaged 29.9 + 19.4 (range: 3.1 - 61.0) meters, and 16.3 + 8.8 (range: 4.6 - 45 .7) meters, for stands 51-250, and greater than 250 meters in width, respectively.

Conclusions

Recent efforts to protect least Bell's vireos and achieve the recovery goals established by the USFWS (USFWS 1988) have focused on an assessment of the species' habitat requirements and use patterns, with considerable attention being devoted to identification of the habitat characteristics of riparian nesting sites (RECON 1988). Observations of vireos using non-riparian areas at the Sweetwater River and other sites suggest that the habitat requirements of some birds may include the availability of areas beyond the riparian woodlands themselves. These findings have prompted more detailed examinations of the relationship between territory composition and reproductive success, and the extent to which vireos occupying marginal habitats are dependent upon non-riparian resources for successful nesting. Ideally, planning decisions affecting the vireo should await the results of these analyses; in reality, this is unlikely to occur. We contend that even in the absence of additional data, the findings reported here provide sufficient justification for the inclusion of access to non-riparian resources as part of the habit at requirements of nesting vireos, and recommend that protective boundaries encompassing essential resources should include upland areas as well as riparian woodlands.

Acknowledgments

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SESSION G: WILDLIFE II: MANAGING WILDLIFE ASSOCIATIONS WITHIN RIPARIAN SYSTEMS

Mature riparian systems in California are routinely characterized as having the greatest biological diversity and the highest productivity among wildlife habitats. Riparian systems are known to provide shade, food, cover, water, and dispersal and migratory corridors for many invertebrate, fish, amphibian, reptile, bird, and mammal species. A significant number of wildlife species are found only in riparian habitats. Twenty-five percent of California mammals, 80 percent of amphibians, and 40 percent of reptiles are limited to or dependent upon riparian zones, and more than 135 species of California birds depend on or prefer riparian habitats. Desert habitats show an even higher percentage of species dependent on riparian habitats.

Riparian habitats are increasingly recognized as being of tremendous value to wildlife, with greater emphasis now being placed on recovering or restoring riparian habitats. As damaged riparian areas are restored, existing habitats enhanced, and new habitats created, wildlife values should increase. The following papers will explore the means and rationale for monitoring changes in wildlife species composition and numbers over time. Wildlife investigators are seeking to relate species changes with successional changes in vegetation, with vegetation types, and with management strategies. The monitoring of these changes is important in any measure of success in achieving riparian ecosystem mitigation and in evaluating management strategies.

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A TEST OF THE CALIFORNIA WILDLIFE-HABITAT RELATIONSHIP SYSTEM FOR BREEDING BIRDS IN VALLEY-FOOTHILL RIPARIAN HABITAT[1]

Stephen A. Laymon[2]

Abstract: The California Wildlife-Habitat Relationship (WHR) system was tested for birds breeding in the Valley-Foothill Riparian habitat along California's Sacramento and South Fork Kern rivers. The model performed poorly with 33 pct and 21 pct correct predictions respectively at the two locations. Changes to the model for 60 species on the Sacramento River and 66 species on the Kern River are recommended. Special problems, such as differences in habitat suitability among study areas and how the model treats threatened and endangered species, are discussed and solutions are suggested.

The California statewide Wildlife-Habitat Relationship (WHR) system was developed to produce lists of wildlife species expected to occur at any location in the state (Airola 1988). This model is intended for use as a preliminary step in the environmental review or inventory process that should be followed by fieldwork if key species are identified as having potential to occur. The statewide model or its regional precursors have been tested in Douglas-fir (Raphael and Marcot 1986), mixed-conifer (Dedon and others 1986), black-oak (Dedon and others 1986) and red-fir habitats (Hejl and Verner 1988) with varying levels of performance. In this paper I present a preliminary test of the WHR model for birds in Valley-Foothill Riparian habitat (Mayer and Laudenslayer 1988) along the Sacramento and Kern rivers.

Study Areas

The study areas consisted of riparian habitat along the Sacramento River from Red Bluff, Tehama County to Colusa, Colusa County (106 km) and the South Fork Kern River, Kern County from Onyx Ranch downstream to Lake Isabella (15 km). The Sacramento River varied in elevation from 15 to 100 m, while the Kern River varied from 750 to 800 m. Riparian habitat along the Sacramento River are dominated by Fremont cottonwood (*Populus fremontii*), willow (*Salix* spp.), California sycamore (*Platanus racemosa*) and valley oak (*Quercus lobata*). Dominant understory trees are box elder (*Acer negundo*), Oregon ash (*Fraxinus latifolia*) and willow. The shrub layer consists of mugwort (*Artemisia douglasiana*), or blackberry (*Rubus* spp.). The Kern River riparian zone is dominated by Fremont cottonwood and willow, with an understory of willow and a shrub layer of mule fat (*Baccharis viminea*) and stinging nettle (*Urtica holosericea*) (pers. observ.)

Methods

WHR Predictions

Species lists were generated from the WHR database for species reproducing in all seral stages of Valley-Foothill Riparian. Because the birds were surveyed in all seral stages of this habitat, the highest suitability prediction for the species on each study site was used to compare to the survey data. The bird species list for the Sacramento River was generated for the Oroville latilong and the list for the Kern River was generated for Kern County. These geographic areas were the smallest areas that entirely contained each study area.

Surveys

I conducted surveys on the Sacramento River by canoe on a total of 48 days in May, June and July from 1976 to 1987. Each survey covered 16 to 24 km and lasted 8 to 12 hours. I conducted surveys on the Kern River on foot on 38 days in June and July from 1985 to 1987. Each survey covered 3 to 6 km and lasted 5 to 7 hours. I recorded the number of individuals of each species seen or heard during each survey.

The surveys were conducted in conjunction with tape recorder play-back surveys for yellow-billed cuckoos. The surveys were used to obtain species lists, frequency of occurrence and relative abundance of birds. The relative abundance values are not directly comparable from one site to the other because the data were collected differently.

Data Analysis

Based on frequency (# surveys with detections/total # surveys) and abundance (mean # per survey), a

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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recommended rating of high, moderate or low habitat suitability was assigned to each species at each site. These ratings were made prior to the generation and study of the WHR predictions. In general, species with frequency >66 pct and abundance >4/day were assigned a high rating, those frequencies 33-66 pct and abundance of 1-4/day were rated moderate and those frequency <33 pct and abundance <1/day were rated low. Species not recorded on the survey were assigned an unsuitable rating. If the frequency and abundance measures were in conflict, more weight was given to the frequency measure. Consideration for low detectability (e.g. owls and nightjars) and large home ranges (e.g. raptors and cuckoos) was given by rating these species one category higher than the data indicated (i.e. 33-100 pct frequency and abundance of >1/day were rated high, and <33 pct frequency and <1/day abundance were rated moderate). The WHR predictions and the recommended ratings were then compared and differences were noted. Errors of omission, i.e. species that were observed but were not predicted, were considered more serious than errors of commission, i.e. species that were predicted but were not observed. Likewise it was judged to be a more serious error if a species was predicted in low numbers and many were observed than when a species was predicted in high numbers and few were observed. The results of the analysis are summarized in table 1.

Results

Sacramento River

A total of 106 bird species were predicted by the WHR model and 86 bird species were found during the survey, for a total of 117 bird species considered in the analyses (see table 1 for species and scientific names of bird species). Of these, 38 (32.5 pct) of the predictions matched the recommendations generated from the data (fig. 1). An additional 19 species (16.2 pct) were similar in that survey results closely approach the criteria used to define categories. The survey data differed greatly (generally more than 2 categories) from the predicted WHR status for 58 species. Of these 58 species 11 species were observed, but not predicted and 30 species were predicted, but not observed. Fifteen species were predicted to be high but were observed in low numbers and 4 species were predicted low but were observed in high numbers.

SACRAMENTO RIVER
N = 117 SPECIES

SAMPLED \ WHR PREDICTION	H	M	L	U	
H	24.8	4.3	3.4	2.5	35.0
M	6.8	3.4	1.7	0.9	12.8
L	12.8	3.4	4.3	6.0	26.5
U	9.4	11.1	5.1	X	25.6
	53.8	22.2	14.5	9.4	

KERN RIVER
N = 112 SPECIES

SAMPLED \ WHR PREDICTION	H	M	L	U	
H	17.9	1.8	0.9	1.8	22.3
M	14.3	2.7	3.6	0.9	21.4
L	11.6	2.7	0.9	8.0	23.2
U	10.7	15.2	7.1	X	33.0
	54.5	22.3	12.5	10.7	

Figure 1– Matrix of percentages of species in 15 cells, representing predicted versus sampled WHR categories on the Kern and Sacramento rivers. Species on the diagonals from the upper left to the lower right are correctly predicted. H = high, M = medium, L = low and U = unsuitable.

Table 1. Common and scientific name, frequency (F), mean abundance (X), 2SE, California Department of Fish and Game WHR model rating (WHR), and recommendations based on data from this study (REC), for bird species found in riparian habitats on the Sacramento and the Kern river, California.

		Sacramento River (n=48)					Kern River (n=38)				
Common Name	Scientific Name	F	X	2SE	WHR	REC	F	X	2SE	WHR	REC
Great Blue Heron	*Ardea herodias*	96	16.8	3.96	H	H	82	3.6	1.84	H	H
Great Egret	*Casmerodius albus*	79	5.6	3.03	L	H*	--	---	----	L	U
Snowy Egret	*Egretta thula*	31	1.5	1.32	M	L	--	---	----	M	U
Cattle Egret	*Bubulcus ibis*	--	---	----	U	U	--	---	----	L	U
Green-backed Heron	*Butorides striatus*	79	3.1	1.02	M	H	--	---	----	M	U
Black-crowned Night Heron	*Nycticorax nycticorax*	19	0.4	0.25	M	L	24	0.8	0.66	M	L*
Wood Duck	*Aix sponsa*	69	3.3	1.22	H	H	32	0.7	0.45	H	M
Mallard	*Anas platyrhynchos*	63	5.3	5.00	L	Ms	58	12.4	8.56	L	Ms
Cinnamon Teal	*Anas cyanoptera*	8	0.1	0.13	U	L*	16	1.1	1.25	U	Ls
Common Merganser	*Mergus merganser*	75	11.5	3.74	M	H	--	---	----	M	Us
Turkey Vulture	*Cathartes aura*	79	26.5	5.61	H	H	55	1.6	0.84	H	M
Osprey	*Pandion haliaetus*	27	0.6	0.3	U	L*	3	0.0	0.05	U	Ls
Black-shouldered Kite	*Elanus caeruleus*	13	0.1	0.12	H	M*	21	0.3	0.21	H	Ms
Bald Eagle	*Haliaeetus leucocephalus*	--	---	----	M	U	--	---	----	U	U
Northern Harrier	*Circus cyaneus*	6	0.1	0.10	L	L	5	0.1	0.07	L	L
Cooper's Hawk	*Accipiter cooperii*	6	0.1	0.07	H	Ls	8	0.1	0.09	H	L*
Red-shouldered Hawk	*Buteo lineatus*	65	1.4	0.41	H	H	74	1.2	0.38	H	H
Swainson's Hawk	*Buteo swainsoni*	38	0.5	0.25	H	M	--	---	----	H	Us
Red-tailed Hawk	*Buteo jamaicensis*	92	5.6	1.35	H	H	79	1.6	0.46	H	H
Golden Eagle	*Aquila chrysaetos*	--	---	----	M	U*	--	---	----	M	Us
American Kestrel	*Falco sparverius*	31	0.4	0.18	H	Ms	55	1.0	0.36	H	M
Peregrine Falcon	*Falco peregrinus*	--	---	----	M	Us	--	---	----	M	Us
Prairie Falcon	*Falco mexicanus*	--	---	----	L	U*	--	---	----	L	Us
Chukar	*Alectoris chukar*	--	---	----	U	U	--	---	----	H	U*
Ring-necked Pheasant	*Phasianus colchicus*	31	0.4	0.19	L	L	--	---	----	L	U
Turkey	*Meleagris gallopavo*	--	---	----	H	U*	--	---	----	U	U
California Quail	*Callipepla californica*	85	8.5	2.90	H	H	58	6.2	3.68	H	M
Mountain Quail	*Oreortyx pictus*	--	---	----	M	U*	--	---	----	M	U*
Virginia Rail	*Rallus limicola*	--	---	----	L	U		---	----	L	U
Killdeer	*Charadrius vociferas*	92	16.3	4.41	U	H*	34	0.5	0.28	U	L*
Spotted Sandpiper	*Actitis macularia*	94	15.8	3.74	U	Hs	16	0.3	0.23	U	Ls
Rock Dove	*Columba livia*	13	0.5	0.48	U	Ls	--	---	----	U	U
Band-tailed Pigeon	*Columba fasciata*	4	0.2	0.27	M	Ls	--	---	----	M	U*
Mourning Dove	*Zenaida macroura*	100	26.6	7.86	H	H	95	14.1	4.18	H	H
Yellow-billed Cuckoo	*Coccyzus americanus*	44	1.3	0.54	L	H*	79	1.9	0.51	L	Hs
Common Barn Owl	*Tyto alba*	6	0.1	0.07	H	L*	16	0.2	0.12	H	L*
Flammulated Owl	*Otus flammeolus*	--	---	----	M	Us	--	---	----	M	Us
Western Screech Owl	*Otus kennicottii*	2	0.0	0.04	H	L*	--	---	----	H	U
Great Horned Owl	*Bubo virginianus*	67	1.1	0.39	H	H	21	0.3	0.22	H	M
Northern Pygmy Owl	*Glaucidium gnoma*	--	---	----	H	U*	--	---	----	H	Us
Long-eared Owl	*Asio otus*	--	---	----	H	U	3	0.0	0.05	H	L*
Northern Saw-whet Owl	*Aegolius acadicus*	--	---	----	H	U*	--	---	----	H	U*
Lesser Nighthawk	*Chordeiles acutipennis*	21	0.8	0.52	U	Ms	3	0.1	0.16	U	L
Common Nighthawk	*Chordeiles minor*	10	0.5	0.79	L	L	--	---	----	U	U
Common Poorwill	*Phalaenoptilus nuttallii*	--	---	----	M	U*	--	---	----	M	Us
Vaux's Swift	*Chaetura vauxi*	--	---	----	L	Us	--	---	----	U	U
Black-chinned Hummingbird	*Archilochus alexandri*	13	0.2	0.14	H	Ls	37	0.6	0.30	H	M
Anna's Hummingbird	*Calypte anna*	15	0.3	0.30	H	Ls	34	0.6	0.31	H	M
Costa's Hummingbird	*Calypte costae*	--	---	----	U	U	3	0.0	0.51	M	Ls
Belted Kingfisher	*Ceryle alcyon*	90	10.3	2.62	M	H*	--	---	----	M	Us
Lewis' Woodpecker	*Melanerpes lewis*	--	---	----	M	Us	--	---	----	U	U
Acorn Woodpecker	*Melanerpes formiciyorms*	71	3.6	1.00	M	M	--	---	----	M	Us
Nuttall's Woodpecker	*Picoides nuttallii*	10	12.6	2.46	H	II	97	5.6	1.32	H	H
Downy Woodpecker	*Picoides pubescens*	96	5.4	0.94	H	H	92	4.4	1.05	H	H
Hairy Woodpecker	*Picoides villosus*	2	0.1	0.07	L	L	58	0.9	0.35	L	Ms
Northern Flicker	*Colaptes auratus*	65	1.7	0.52	H	M	97	4.7	1.04	H	H
Western Wood-pewee	*Contopus sordioulus*	94	15.4	2.82	H	H	76	3.1	1.44	H	M
Willow Flycatcher	*Empidonax traillii*	6	0.2	0.11	U	L	58	2.0	0.83	U	Hs
Western Flycatcher	*Empidonax difficilis*	2	0.0	0.04	H	Ls	11	0.1	0.10	H	Ls
Black Phoebe	*Sayornis nigricans*	92	13.6	3.75	H	H	82	4.5	1.75	H	H
Ash-throated Flycatcher	*Myiarchus cinerascens*	92	9.9	2.08	H	H	97	5.9	1.36	H	H
Brown-crested Flycatcher	*Myiarchus tyrannulus*	--	---	----	U	U	3	0.0	0.05	U	L

Table 1. Continued.

Common Name	Scientific Name	Sacramento River (n=48) F	X	2SE	WHR	REC	Kern River (n=38) F	X	2SE	WHR	REC
Western Kingbird	*Tyrannus verticalis*	98	15.7	4.16	H	H	63	2.5	1.03	H	M
Purple Martin	*Progne subis*	4	0.4	0.59	L	L	--	---	----	U	U
Tree Swallow	*Tachycineta bicolor*	81	62.1	26.60	H	H	79	6.3	2.55	H	H
Violet-green Swallow	*Tachycineta thalassina*	--	---	----	H	U*	--	---	----	H	U*
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	54	7.7	4.39	H	M	24	0.3	0.25	H	L*
Bank Swallow	*Riparia riparia*	73	137.2	50.92	L	H*	--	---	----	U	U
Cliff Swallow	*Hirundo pyrrhonota*	67	121.8	60.30	H	H	24	13.6	17.93	H	M
Barn Swallow	*Hirundo rustica*	29	2.6	2.39	H	M	3	0.0	0.05	H	L*
Steller's Jay	*Cyanocitta stelleri*	--	---	----	L	U*	--	---	----	L	U*
Scrub Jay	*Aphelocoma coerulescens*	96	8.7	1.47	H	H	21	0.3	0.18	H	L*
Yellow-billed Magpie	*Pica nuttalli*	17	1.0	0.92	H	L*	--	---	----	U	U
American Crow	*Corvus brachyrhynchos*	60	2.3	1.11	M	M	--	---	----	M	U*
Common Raven	*Corvus corax*	--	---	----	U	U	87	3.7	2.11	U	Ni
Chestnut-backed Chickadee	*Parus rufescens*	--	---	----	L	U*	--	---	----	U	U
Plain Titmouse	*Parus inornatus*	92	8.0	1.68	H	H	92	4.3	0.92	H	H
Bushtit	*Psaltriparus minimus*	71	6.7	1.90	M	M	66	8.6	2.98	M	M
White-breasted Nuthatch	*Sitta carolinensis*	83	3.0	0.86	H	M	79	2.1	0.63	H	M
Bewick's Wren	*Thryomanes bewickii*	100	11.3	1.67	H	H	79	2.4	0.71	H	H
House Wren	*Troglodytes aedon*	75	3.5	1.40	H	M	95	11.6	2.46	H	H
Winter Wren	*Troglodytes troglodytes*	--	---	----	H	U*	--	---	----	H	U*
American Dipper	*Cinclus mexicanus*	--	---	----	M	U*	--	---	----	M	U*
Blue-gray Gnatcatcher	*Polioptila caerulea*	--	---	----	L	U*	--	---	----	L	U*
Western Bluebird	*Sialia mexicana*	10	0.3	0.27	H	L*	58	2.4	0.92	H	M*
Swainson's Thrush	*Catharus ustulatus*	--	---	----	H	U*	--	---	----	U	U
American Robin	*Turdus migratorius*	88	5.2	1.28	H	H	89	3.0	0.86	H	H
Wrentit	*Chamaea fasciata*	6	0.1	0.19	U	L	--	---	----	U	U
Northern Mockingbird	*Mimus polyglottos*	13	0.3	0.22	H	L*	3	0.0	0.05	M	L*
California Thrasher	*Toxostoma redivivum*	--	---	----	M	U*	--	---	----	M	U*
Phainopepla	*Phainopepla nitens*	--	---	----	M	U*	--	---	----	M	U*
Loggerhead Shrike	*Lanius ludovicianus*	2	0.0	0.04	H	L*	5	3.0	0.86	H	L*
European Starling	*Sturnus vulgaris*	77	8.6	3.72	H	H	61	14.4	10.66	H	H
Solitary Vireo	*Vireo solitarius*	--	---	----	M	U*	--	---	---	U	U
Hutton's Vireo	*Vireo huttoni*	--	---	----	H	U*	--	---	----	H	U*
Warbling Vireo	*Vireo gilvus*	6	0.1	0.13	H	L*	11	0.2	0.18	H	L*
Orange-crowned Warbler	*Vermivora celata*	23	0.3	0.20	H	L*	11	0.2	0.19	H	L*
Yellow Warbler	*Dendroica petechia*	69	4.2	1.19	M	H	74	2.5	1.24	M	H
Macgillivray's Warbler	*Oporornis tolmiei*	--	---	----	H	U*	--	---	----	H	U*
Common Yellow throat	*Geothlypis trichas*	69	4.1	1.21	M	H	79	2.3	0.80	M	H
Wilson's Warbler	*Wilsonia pusilla*	H	---	----	H	U*	--	---	----	H	U*
Yellow-breasted Chat	*Icteria virens*	88	10.4	2.15	L	H*	68	1.3	0.42	L	M*
Summer Tanager	*Piranga rubra*	--	---	----	U	U	74	2.3	0.63	U	H*
Black-headed Grosbeak	*Pheucticus melanocephalus*	100	20.7	2.82	H	H	39	0.6	0.26	H	L*
Blue Grosbeak	*Guiraca caerulea*	58	2.3	1.25	H	M	92	3.7	1.03	H	H
Indigo Bunting	*Passerina cyanea*	4	0.0	0.10	U	U	32	0.5	0.30	U	L*
Lazuli Bunting	*Passerina amoena*	94	6.6	1.56	H	H	63	3.4	1.25	H	M
Rufous-sided Towhee	*Pipilo erythrophthalmus*	100	12.9	1.98	H	H	37	1.0	0.50	H	M*
Brown Towhee	*Pipilo fuscus*	77	3.3	1.10	H	M	39	1.2	0.60	H	M*
Chipping Sparrow	*Spizella passerine*	--	---	----	M	U*	--	---	----	M	U*
Lark Sparrow	*Chondestes grammacus*	46	1.1	0.46	L	M	61	4.6	2.70	L	M*
Song Sparrow	*Melospiza melodia*	31	0.7	0.42	H	L*	100	20.8	4.37	H	H
Dark-eyed Junco	*Junco hyemalis*	--	---	----	H	U*	--	---	----	H	U*
Red-winged Blackbird	*Agelaius phoeniceus*	38	6.5	5.99	M	M	82	17.5	8.48	M	M
Brewer's Blackbird	*Euphagus cyanocephalus*	77	9.0	3.73	H	H	16	1.6	1.61	H	L*
Brown-headed Cowbird	*Molothrus ater*	90	10.0	5.50	U	H*	97	18.1	5.13	H	H
Hooded Oriole	*Icterus cucullatus*	2	0.0	0.04	U	L	--	---	----	L	U
Northern Oriole	*Icterus galbula*	96	11.4	2.00	H	H	100	11.8	3.10	H	H
Purple Finch	*Carpodacus purpureus*	--	---	----	M	U*	--	---	----	U	U
House Finch	*Carpodacus mexicanus*	90	10.5	2.68	H	H	61	2.8	1.24	H	M
Lesser Goldfinch	*Carduelis psaltria*	83	8.6	2.98	H	H	92	7.3	1.77	H	H
Lawrence's Goldfinch	*Carduelis lawrencei*	21	0.4	0.25	M	L*	63	2.5	1.05	M	M
American Goldfinch	*Carduelis tristis*	96	17.0	3.92	H	H	--	---	----	H	U*
House Sparrow	*Passer domesticus*	21	0.9	0.88	U	L*	--	---	----	U	U

H = High Suitability, M = Moderate Suitability, L = Low Suitability, U = Unsuitable.

* = Survey data differs sufficiently from WHR prediction that a change in rating is recommended.

South Fork Kern River

A total of 98 bird species were predicted by the WHR model and 73 bird species were observed during the survey, for a total of 110 bird species considered in the analysis (table 1). Of these, 24 (21.8 pct) of the predictions matched the recommendations generated from the data (fig. 1). An additional 32 species (29.1 pct) were similar in that survey results closely approach the criteria used to define the categories. The survey data differed greatly from the predicted WHR status for 60 species. Ten species were observed, but not predicted, 37 species were predicted, but not observed. Thirteen species were predicted high and were observed in low numbers and 1 species was predicted low and was observed in high numbers.

Discussion

Sacramento River

In general, the WHR system performed poorly for this habitat. Only 32.5 pct of the predictions correctly matched the collected data. Fifty-eight predictions were sufficiently different from the data that a change in the model is recommended.

Four species (killdeer, spotted sandpiper, lesser nighthawk, and brown-headed cowbirds) were not predicted to occur, but were found in high or moderate numbers. The first three nest in the earliest riparian successional stages on sand and gravel bars. The cowbird is a serious omission since its nest parasitism has been linked to the decline of riparian passerines (Laymon 1987). These four species should be added to the WHR model.

Seven species were not predicted but were found in low numbers. Cinnamon teal and osprey are uncommon but regular breeders in the riparian zone. Rock doves and house sparrows breed in the riparian zone near towns and ranches. Wrentits and hooded orioles probably breed at low densities in this habitat. Willow flycatchers may not breed in the Sacramento Valley but one territorial male was found throughout June near Woodson Bridge in 1987. All of these except willow flycatchers should be added to the WHR model.

Thirty species were predicted but were not observed on any of the 48 surveys. Long-eared owls may have been missed. This species breeds sparingly in the Sacramento Valley and should be rated low in the data base. Sixteen species breed only in montane conifer forest types. Several montane species (Steller's jay, chestnut-backed chickadee, winter wren, Swainson's thrush, Wilson's warbler, dark-eyed junco, and purple finch) may breed in coastal Valley-Foothill Riparian habitat. These species should be removed from the database as breeders in inland, lowland areas. A split of the Valley-Foothill Riparian habitat into coastal and inland categories may be appropriate in updates of the model. The other montane species (mountain quail, pygmy owl, saw-whet owl, flamulated owl, Vaux's swift, American dipper, MacGillivray's warbler, solitary vireo and chipping sparrow) probably never breed in this habitat type (Grinnell and Miller 1944, pers. observ.) and should be removed from this habitat in the database.

Nine species that were predicted but not observed are primarily oak woodland and chaparral species. Turkey, Hutton's vireo, California thrasher and blue-gray gnatcatcher may nest in certain Valley-Foothill Riparian habitat but their proper status should be low. Golden eagle, Lewis' woodpecker, common poorwill, violet-green swallow, and phainopepla are not known to breed in these habitats and should be removed from the WHR list.

The Virginia rail, a marsh species, may nest in some moist riparian situations and should remain on the list with a low status. Peregrine and prairie falcons nest on cliffs and are not associated with riparian habitat for nesting. If they nest in the vicinity of riparian vegetation it is incidental to the existence of suitable nest cliffs. They should be removed from the Valley Foothill Riparian habitat. The bald eagle is a localized and irregular breeder in Valley-Foothill Riparian habitat in the Sacramento Valley. However, recent nesting attempts (T. Brumley, P. Detrich, and M. Halterman pers. comm.) suggest that the species should be retained on the list at least at low suitability to ensure its consideration in potential habitat.

Kern River

The WHR model performed poorly at the Kern River. Only 21.4 percent of the WHR predictions correctly matched the collected data. Sixty WHR predictions were sufficiently different from the data that I recommend a change of status in the WHR database.

Three species that were not predicted were found in high or moderate numbers; willow flycatcher, summer tanager and common raven. The South Fork Valley has the largest California populations of both willow flycatchers and summer tanagers, each numbering between 25 and 50 pairs. Seven additional species were not predicted but were found in low numbers. Five of these (cinnamon teal, osprey, killdeer, spotted sandpiper and indigo bunting) regularly nest in riparian habitats in the valley and should be added to the WHR model. The indigo bunting is of particular interest since it is not listed in the data base in any habitat. Approximately 10 pct of the buntings nesting in South Fork Valley are of this species. Lesser nighthawks nests have not been found and they may nest primarily in dryer habitats adjacent to the riparian and therefore need not be added to the WHR model. The brown-crested flycatcher was a single individual which arrived at the site in 1986 and returned in 1987. Three individuals were found in 1988 and apparently bred. In the future the species may have to be added to the model for this location. Thus, 8 of these 10 species should be added to the model at this time.

Thirty-seven species were predicted but not found. Twelve of these were montane species discussed for the Sacramento River (table 1). These should be removed from the WHR database. Nine oak and chaparral species (golden eagle, band-tailed pigeon, common poorwill, acorn woodpecker, violet-green swallow, blue-gray gnatcatcher, California thrasher, phainopepla and Hutton's vireo) should also be removed. Chukar, peregrine falcon and prairie falcon occur at rock and cliff areas and should be removed from the model as breeders in riparian habitat. Four species predicted to occur (snowy egret, cattle egret, green-backed heron, and ring-necked pheasant) do not breed in the South Fork Valley but may breed elsewhere in riparian habitat in Kern County. These species should remain in the WHR model. An additional four species (Swainson's hawk, belted kingfisher, American crow and American goldfinch) do not breed in Kern County and should be removed from the WHR system for that location.

Several species that were predicted, but not observed may occur at times. Great egrets have not bred in the South Fork Valley in the past 80 years, but appear likely to colonize the valley in the near future, as evidenced by many sightings late into the breeding season in the past 2 years. The western screech owl was predicted, but not found on the surveys, but was observed several times while not surveying. Virginia rails are primarily a marsh species which sometimes may nest in wet riparian habitats.

Difference in Suitability

The current WHR model only records a single habitat suitability rating throughout a species' range; it cannot provide different suitability ratings within a habitat type between various geographic areas. Species at the periphery of their range may be much less numerous than at the center of their range. Also, habitat differences not reflected in the WHR model, (e.g. tree and shrub species) might have an effect on the abundance of certain species. Based on the survey data, 7 species (killdeer, spotted sandpiper, willow flycatcher, scrub jay, black-headed grosbeak, song sparrow and Brewer's blackbird) showed a habitat suitability difference from high to low numbers between the study sites. Eight species (American kestrel, black-chinned hummingbird, Anna's hummingbird, hairy woodpecker, rough-winged swallow, barn swallow, western bluebird and Lawrence's goldfinch) differed from moderate to low numbers between the study sites. Fourteen species (wood duck, turkey vulture, California quail, great horned owl, northern flicker, western wood pewee, western kingbird, cliff swallow, house wren, yellow-breasted chat, blue grosbeak, lazuli bunting, rufous-sided towhee and house finch) differed from high to moderate between the study sites. Several of these species (e.g. blue grosbeak and Lawrence's goldfinch) are at the northern limit of their range in the Sacramento Valley, but are nearer the center in the Kern Valley. Other species (e.g. yellow-breasted chat and rufous-sided towhee) may find the blackberry shrub layer of the Sacramento River more suitable than the mule fat and nettle shrub layer on the Kern River. The lack of elderberries and box elders may make the Kern River much less suitable for black-headed grosbeak than is the Sacramento River.

I recommend that the structure of the WHR data base be changed to recognize these differences in site suitability. This should be one of the goals of the next generation of WHR models. At present, the user should adjust for this by reading the species notes and studying the range maps.

Threatened and Endangered Species

Another problem with the WHR database is that threatened or endangered birds (e.g. Swainson's hawk and yellow-billed cuckoo) and bird species of special concern (e.g. willow flycatcher, bank swallow, summer tanager, yellow-breasted chat and yellow warbler) are poorly represented. These species are often the most important ones in an environmental assessment since they have more effect on whether, and in what form, a project can proceed. These species' distribution and habitat relationships are fortunately generally well known. Little of this knowledge, however, is reflected in the WHR model for Valley-Foothill Riparian habitat. Several examples are discussed below.

The Swainson's hawk was predicted to have high suitability in this habitat on both study areas. Surveys have shown that Kern County is outside of its' current breeding range (Bloom 1980). These findings should be incorporated into the data base.

Valley-Foothill Riparian was predicted to have low suitability for yellow-billed cuckoos. This species, while uncommon, is an obligate riparian species and is found in virtually all suitable willow-cottonwood riparian habitats (Gaines and Laymon 1984, Laymon and Halterman 1987 and 1988). Despite its low density and absence from many riparian sites, the suitability of the habitat should be rated high because this is the optimal habitat type and it is found in no other.

Valley-Foothill Riparian habitat was predicted as unsuitable for willow flycatchers and summer tanagers at both sites. While this may be true on the Sacramento River, it certainly is not true on the Kern River where populations of 25 to 45 pairs have been monitored for both species for the past 8 years (Unitt 1987, B. Barnes pers comm., pers. observ.).

Results of research on these species should be incorporated into the WHR. In addition, experts on these species should be consulted to review status and distribution and habitat ratings. It is essential that developers and resource managers be aware of possible occurrence of endangered and threatened species in their project areas.

Conclusions

The results of this test indicate that the model for birds in Valley-Foothill Riparian habitat still needs refinement before the WHR system can yield reliable predictions for this habitat. This test combined all seral stages and should have given the system the best opportunity to perform well, but it performed poorly. The WHR model for Valley-Foothill Riparian is still in the developmental stage. Any use for project planning should recognize that the information may be incomplete or inadequate. The changes to the WHR model recommended here should be made and more detailed studies should be undertaken to further refine the model.

This test is a first step to refining the WHR model for Valley-Foothill Riparian habitat. A more detailed study that would examine riparian bird distribution by seral stages is needed. In addition, study sites throughout the geographical and altitudinal range of this habitat should be chosen. Special attention should be paid to elevational differences in riparian bird distribution. Valley and foothill riparian avifaunas may be too different to include in the same habitat category. The same is true of coastal and inland riparian avifaunas. Designing a study design in this habitat would be difficult since most extant riparian habitats are linear and very fine grained. Finding patches of a single seral stage, large enough to survey without influence from other seral stages, would be difficult, if not impossible, in most riparian settings.

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AVIFAUNA AND RIPARIAN VEGETATION IN CARMEL VALLEY, MONTEREY COUNTY, CALIFORNIA[1]

Molly Williams and John G. Williams[2]

Abstract: Avian abundance and diversity were measured at 5 sites in the riparian zone of the Carmel River, selected to represent different conditions of riparian vegetation, in the spring of 1983. Vegetation varied from lawn (golf course) to mature, undisturbed riparian forest dominated by black cottonwood (Populus trichocarpa). *Birds were counted along 700-meter transects on 10 occasions. The abundance and diversity of birds varied directly with the abundance and diversity of the riparian vegetation. A narrow strip of riparian trees tripled the number of species observed at golf courses. Scattered residential development did not effect the number of birds observed in mature riparian forest.*

In spring 1983, the avifauna of the Carmel River's riparian zone was surveyed for the Monterey Peninsula Water Management District, for use in the development of the Carmel River Watershed Management Plan.

An extensive riparian woodland, covering much of the 100-year floodplain, was supported by the Carmel River floodplain in its unaltered state. With human development, most of the riparian forest has been reduced to narrow strips along the river bank; in some areas it has been completely eliminated (Kondolf and Curry 1986).

Riparian woodland is of high ecological value to wildlife, relative to other vegetation communities. Snider (1975) states that the riparian community supports the most diverse and abundant animal life of the Carmel River system.

This study examined the avifauna of five sites on the floodplain of the Carmel River. The study sites differed in the abundance of riparian vegetation present, in the breadth and age structure of the vegetation, and in the degree of human disturbance. Comparison of the avifauna at these sites gave quantitative estimates of the importance of these factors for avian abundance and diversity.

Study Sites

Sites were chosen along the Carmel River and its floodplain. The sites were representative of larger portions of the streamside and floodplain, and results of the survey should apply to other portions of the river where similar vegetative conditions exist.

Two sites were at golf courses, one with a narrow strip of riparian woodland bordering the streambank, and one with no significant streamside woodland remaining. These sites were compared to determine how the maintenance of such a woodland strip affects the avifauna. A third site was a large wooded area, studied to examine the importance of breadth of riparian vegetation to avifauna. This thickly forested area stretched from the river over the floodplain, and was essentially free from human presence. Another large forested area, also extending from the river across the floodplain, but with scattered houses present, was compared to determine the impact of human presence on the avifauna when a large area of riparian vegetation is basically left intact. The last site was an area of deforested floodplain, chosen to compare relative values for birds of forested floodplain and cleared grassland environment. Once a cattle ranch, it is now within a regional park.

Vegetation descriptions are from personal observations, supplemented by Beattie and Murphy (1981). A 700-meter transect line was established at each site. Each line sampled an area of some 2.3 hectares in a narrow strip running through the site.

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Site #1: Quail Lodge Golf Course

The Quail Lodge Golf Course site (QL) consists of a golf course bordering the Carmel River with an associated strip of riparian forest on the river bank. This strip, averaging 25 meters in width, consists of mature black cottonwood, arroyo willow (*Salix lasiolepis*), red willow (*Salix laevigata*), California box elder (*Acer negundo*), and sycamore (*Platanus racemosa*) trees. The understory is composed of willow (*Salix* spp.), blackberry (*Rubus* spp), and poison oak (*Toxidendron diversiloba).* The cottonwoods are mainly of one age class (mature: over 9 meters tall); there are very few juvenile or old and dying trees present. The golf course itself consists of lawns with scattered cottonwoods and exotic species.

A paved path follows the border between the woodland and the golf course, paralleling the river; this path is used regularly by golf carts and pedestrians. The transect was laid along the path, and birds in both environments, forest and lawn, were studied.

Site #2: Carmel Valley Ranch Golf Course

The Carmel Valley Ranch site (CVR) consists of a golf course directly bordering the river. Other than scattered willow there is little streamside vegetation; the lawns meet the riverbanks. The transect was placed along the riverbank, to duplicate as nearly as possible the position of the QL transect. Birds in both the riparian shrubbery and the golf course were studied.

Site #3: Rancho San Carlos

The Rancho San Carlos site (RSC) is a mature riparian woodland area of some 6 hectares, that covers both river banks and floodplain. While vegetation has been drastically reduced in most places along the river, at this site a wide area of forest remained, and probably represented the original appearance of the floodplain.

The woodland canopy consists mainly of mature cottonwoods, although all age classes are present, including dead and dying trees and saplings (under 3 meters). Other trees present include willows, California buckeye (*Aesculus californicus*), and California box elder. The dense, viny understory is composed of poison oak, with wild cucumber (*March fabacius*), wild hemlock (*Conium maculatum*), rose (*Rosa* spp.), and other shrubs.

The transect line paralleled the river and then angled across the interior region, to provide data on both streamside and floodplain conditions.

Site #4: The Narrows, Residential Woodland

The Narrows Residential Woodland site (NRW) consists of a similar mature riparian woodland but with scattered human residential development. Despite the presence of houses, gardens, and footpaths, the forested area has been left fairly intact. Riparian vegetation extends from the streamside well onto the floodplain. The average width of the forested area is 110 meters.

The canopy consists of black cottonwood, arroyo willow, and red willow. All age classes are present. The understory is of willows, blackberry, poison oak, wild hemlock, and other shrubs. Exotic plant species are also numerous, in hedges and gardens.

Site #5: Garland Park

The Garland Park (GP) site lies within the Garland Regional Park, on the floodplain. The site consists of open grassland, covering about 20 hectares. Once used for cattle-grazing, human disturbance is now limited to foot trails regularly used by riders, bikers, and joggers.

The grassland has remnants of a previously existing forest. There are scattered trees (primarily old, dying, or snags), including cottonwood, willow, and sycamore. Scattered coyote bush (*Baccharis* spp.) and other shrubs also occur. The transect was placed in an L-shaped curve through the site.

Methods

At each study site, a transect line of approximately 700 meters was walked at a pace of approximately 0.7 kilometers per hour. The transects were each walked on 10 separate occasions (visits) regardless of weather conditions, between the hours of 06:00 and 15:00 (PST) on weekends from 17 April to 24 May, 1983, by Molly Williams. Each weekend the sites were visited in random order to correct for changes in avian activity during the study hours. The counts were made by walking along each transect line and counting all birds seen within 20 meters of the path, according to the modified Emlen (1977) method. Binoculars (7 x 26, and 8.5 x 44) were used.

The occurrence of certain species such as Great Blue Heron, Common Merganser, Belted Kingfisher, and Mallard seemed to be influenced more by the condition of the river itself than by the surrounding vegetation. We excluded these "aquatic" species and aerial species (those seen only flying over the transects at high elevation) from the count. The remaining species are more closely associated with the particular ecology of each study site and provide a more accurate comparison.

Results

Figure 1 shows the cumulative number of species seen at each site as a function of the number of visits. The plots level off, indicating the survey is complete for the season studied. The data are summarized in Table 1.

A list of species seen at the different sites is given in Table 2. For each site, the total number of sightings of a species is given, followed by the range of sightings during visits. Species that displayed breeding behavior (singing, mating, nesting, or feeding young) are indicated. (The Mallard is discounted as an aquatic species at all sites except QL, where a flock lived on the golf course.)

Discussion

Avian diversity and abundance varied directly with the diversity and abundance of the riparian vegetation. The golf course site with a narrow strip of riparian woodland bordering the river (QL) supported three times as many species, and four times as many birds, as the golf course site with no woodland border (CVR). While 13 species showed breeding activity at the first site, demonstrating significant utilization of the environment, no breeding behavior was observed in the second site. The importance of riparian vegetation to avian abundance and diversity has been previously demonstrated (e.g. Stauffer and Best, 1980), but it is noteworthy that even a narrow strip of forest supported a dramatic increase in the avifauna. Hurst and others (1980) also found this to be true on the Sacramento River.

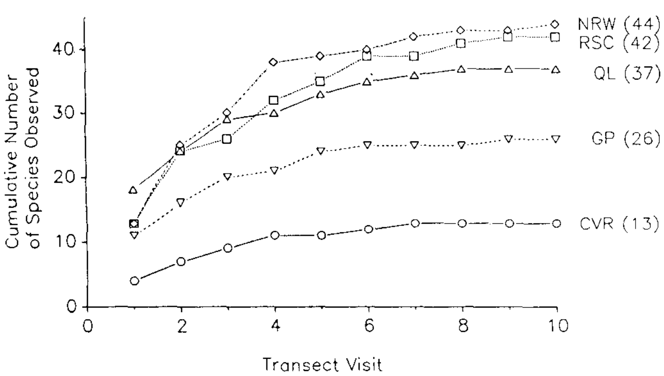

Figure 1– Cumulative species richness.

Table 1 — Summary of Avian Diversity and Abundance.

Site	QL	CVR	RSC	NRW	GP
Total sightings, all species	494	114	565	569	307
Total species	37	13	42	44	26
Breeding species	14	0	17	19	6

With a broader area of woodland there is a further increase in diversity and abundance. At RSC we counted five more species than at QL, and 69 more bird sightings. Three more species were seen breeding. The NRW site also supported more birds than QL, with seven more species, 73 more sightings, and five more breeding species. Similar trends of avian diversity increasing with the width of riparian woodland were observed by Stauffer and Best (1980).

The QL woodland varies from RSC and NRW in age structure as well as forest width. The latter sites have abundant dead limbs and snags, while at QL the trees are younger. This difference mainly affects hole-nesting birds, which may require soft snags for nest sites (Stauffer and Best, 1980). Both the "primary" hole-nesters which excavate holes (the five species of woodpeckers observed) and the "secondary" hole-nesters using previously excavated holes or naturally-occurring cavities (Chestnut-backed Chickadee, Pigmy Nuthatch, House Wren, Bewick's Wren, and Starling, in this study) were more abundant at RSC and NRW than at QL. An exception was the Chestnut-backed Chickadee, which was scarce at NRW for unknown reasons. However, dead limbs and trees do not fully account for these species' presence. At the GP site, where the trees are almost exclusively old and dying, there were four species of primary hole-nesters seen but only one secondary hole-nesting species (the Starling). Perhaps some secondary hole-nesters require denser woodland as well as older and dying trees.

The savannah-like environment of GP supported a poorer avifauna than either the forested areas of RSC and NRW, or the narrow border of QL. At GP, 18 fewer species were seen than at NRW, 16 fewer than at RSC, and 11 fewer than at QL. There were also far fewer bird sightings. This demonstrates the greater value to avian species of riparian vegetation compared to other environments.

Table 2 - Species Occurrence and Relative Abundance at Five Sites

	QL		CVR		RSC		HRH		GP	
Species	T	R	T	R	T	R	T	R	T	R
Acorn Woodpecker	0		0		20*	0-5	5	0-2	52*	0-8
Allen's Hummingbird	1	0-1	0		10	0-3	4	0-1	2	0-1
American Crow	0		0		4	0-2	0		31	0-5
American Goldfinch	0		0		0		0		3	0-3
Anna's Hummingbird	3	0-1	4	0-1	16	0-3	8	0-2	16	0-4
Ash-throated Flycatcher	0		0		0		0		3	0-1
Barn Swallow	21	0-5	5	0-5	0		18	0-5	15	0-3
Bewick's Wren	4*	0-1	0		16*	0-4	12*	0-3	0	
Black Phoebe	5	0-2	0		5	0-2	17*	0-4	0	
Black-headed Grosbeak	21*	1-4	0		14*	0-3	9*	0-2	0	
Black-Shouldered Kite	0		0		0		0		16*	1-2
Brewer's Blackbird	36	1-9	15	0-4	3	0-2	5	0-2	0	
Brown Towhee	13	0-1	0		24	0-4	10	0-3	1	0-1
California Quail	29*	1-5	0		48*	2-9	52*	0-14	13	0-5
Chestnut-backed Chickadee	68*	3-9	0		77*	4-12	28*	0-8	0	
Cliff swallow	37*	0-10	10	0-10	0		46*	0-8	2	0-2
Common Bushtit	41*	1-6	0		31*	0-9	49*	2-9	1	0-1
Common Flicker	0		0		12*	0-2	6*	0-2	10*	0-2
Cooper's Hawk	0		0		1	0-1	1	0-1	0	
Dark-eyed Junco	4	0-2	0		0		0		0	
Downey Woodpecker	4	0-1	0		12	0-3	15	0-3	0	
English Sparrow	2	0-1	3	0-1	0		3	0-2	0	
Hairy Woodpecker	0		0		3	0-1	3	0-1	3	0-1
House Finch	0		0		1	0-1	29*	1-5	0	
House Wren	2	0-1	0		5	0-2	12*	0-2	0	
Hutton's Vireo	11	0-2	1	0-1	5	0-2	5	0-1	0	
Kestral	2	0-1	0		4	0-1	5	0-2	9	0-1
Killdeer	0		20	0-6	0		1	0-1	0	
Lesser Goldfinch	2	0-1	0		4	0-2	14	0-4	1	0-1
Mallard	17*	0-6	Aq		Aq		Aq		Aq	
Mourning Dove	12	0-2	0		16*	0-4	12*	0-3	2	0-1
Nuttal's Woodpecker	1	0-1	0		4	0-2	5	0-2	1	0-1
Olive-sided Flycatcher	0		0		1	0-1	0		1	0-1
Orange-crowned Warbler	0		0		3*	0-1	1	0-1	0	
Pygmy Nuthatch	0		0		4	0-2	5	0-2	0	
Red-shouldered Hawk	0		0		0		11*	0-2	0	
Red-winged Blackbird	0		2	0-1	0		1	0-1	1	0-1
Robin	28	1-5	12	1-2	13	0-3	16	0-3	0	
Ruby-crowned Kinglet	2	0-1	0		2	0-1	0		0	
Rufous Hummingbird	0		0		1	0-1	0		0	
Rufous-sided Towhee	2	0-1	0		12*	0-2	11*	0-2	0	
Scrub Jay	12	0-4	2	0-1	18	0-4	13	0-2	17*	0-4
Song Sparrow	29*	1-5	2	0-1	51*	3-8	31*	1-5	23*	0-5
Starling	12*	0-3	6	0-2	36*	0-8	14*	0-5	51*	2-10
Steller's Jay	4	0-2	0		4	0-2	5	0-1	0	
Swainson's Thrush	5*	0-2	0		5*	0-2	9	0-2	0	
Tree Swallow	0		0		0		0		4	0-4
Turkey Vulture	0		0		0		0		21	0-4
Violet-green Swallow	0		32	0-12	6	0-6	4	0-3	8	0-3
Warbling Vireo	35*	1-5	0		31*	0-6	27*	1-5	0	
Western Flycatcher	6	0-2	0		8	0-2	7'	0-2	0	
Western Tanager	4	0-4	0		0		0		0	
Western Wood Pewee	5*	0-1	0		7*	0-2	9*	0-2	0	
Wilson's Warbler	4*	0-2	0		12*	0-3	21*	0-5	0	
Wrentit	4	0-1	0		9	0-2	6	0-2	0	
Yellow Warbler	6*	0-2	0		7*	0-2	4*	0-2	0	

T = Total sightings
R = Range of sightings from visit to visit
* Species exhibiting nesting behavior

When the undisturbed RSC and the human disturbed NRW sites were compared to determine the effects of human habitation where the woodland is left intact, we found both sites to be rich in bird abundance and species diversity. Two more species were observed at the inhabited NRW than in the undisturbed forest of RSC, and two more species were seen breeding at NRW. However, due to the residential nature of the NRW site, we had to assume the birds there were more accustomed to human presence. They were probably less secretive, and consequently more detectable. They might also have been more willing to exhibit breeding behavior in the presence of an observer than the wilder birds at RSC were. Such variation in detectability may also exist when comparing RSC to the other sites, all of which had more human exposure than RSC. Unfortunately we were unable to measure this "shyness factor." Shyness and detectability also vary between species, making absolute bird densities very difficult to determine. In this study only relative densities were examined, so this issue was ignored. RSC may well have "hidden" more species that are particularly intolerant to human presence.

Nevertheless, the NRW site figures indicate that human presence is generally tolerable to riparian avifauna, so long as the riparian forest (with all age-classes present) is allowed to remain.

This study did not measure the seasonal variations in species richness caused by migrating and overwintering species. Some birds sighted were transients, such as the Western Tanagers sighted at QL, but the relative value to migrants of different vegetative conditions can only be determined by carrying out a year-long survey. Such a study was conducted in the Sacramento Valley (Hurst and others, 1980), and mature riparian forest was found to support 90 species annually, while rip-rap streambank supported only 25 species.

In conclusion, this study supports previous work that has shown riparian vegetation to be a vitally important environment for native birds. Unless river management includes the maintenance of at least narrow strips of riparian woodland, the abundance and diversity of the native avifauna will be severely at risk.

Acknowledgments

We thank the late Dr. Richard Warner, Editor, California Riparian Systems, and a champion for the cause of the riparian environment, who helped design this survey and provided extremely valuable guidance and assistance. This work was supported by the California Department of Fish and Game, through a contract with the Monterey Peninsula Water Management District.

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WILDLIFE MONITORING OF A RIPARIAN MITIGATION SITE[1]

Michael Rigney, L. Richard Mewaldt, Blair O. Wolf, and Ronald R. Duke[2]

Abstract: In December, 1986, nearly 4,000 riparian trees and shrubs were planted on 4 acres of floodplain land adjacent to Coyote Creek in Santa Clara County, California. To document changes in wildlife habitat characteristics of the revegetation area and surrounding habitats, an intensive wildlife monitoring program was established. Techniques employed included variable radius circular plot sampling for birds and mammals, live-trapping of small mammals, reptiles and amphibians, breeding bird censuses and mist netting of birds along established transect lines. This monitoring program is a joint effort involving a non-profit research organization, a private environmental consulting firm and the local project sponsor. This paper presents a description of these monitoring techniques and summarizes some findings to date.

Proposed flood control improvements along the lower reaches of Coyote Creek, Santa Clara County, will require the permanent loss of 5.6 acres of riparian vegetation and one major break in the riparian corridor (U.S. Army Corps of Engineers 1987). To determine the extent of mitigation required for this loss, the U.S. Fish and Wildlife Service conducted a Habitat Evaluation Procedure (HEP) analysis of the project. As a result of this analysis, the local project sponsor (Santa Clara Valley Water District) proposed to create and maintain mid- and upper terrace riparian habitat on 32.5 acres within the project area (Miller 1986).

Since most prior riparian planting projects were conducted in areas with different climatic conditions, plant species compositions and flow regimes, a pilot study was initiated by the local project sponsor to evaluate various plant materials, propagation methods and irrigation techniques. A more detailed description of planting methodology is presented by Stanley and others (1989). The U.S. Fish and Wildlife Service in its Fish and Wildlife Coordination Act Report (1986) also recommended that wildlife use of at least one riparian revegetation site be monitored for a minimum of 10 years after initial planting and then monitored at year 15 and every 10 years thereafter for the life of the project (100 years).

In December, 1986 Harvey and Stanley Associates, Inc. (acting as contractors for the Santa Clara Valley Water District) cleared and planted the 4.4-acre pilot study site with over 4,000 riparian trees and shrubs.

Study Site

Located adjacent to and within the floodplain of Coyote Creek, the area being monitored includes the 4.4 Pilot Revegetation Study Site, the adjacent future overflow channel (approximately 7 acres) and a 2 acres portion of the existing riparian corridor (fig. 1). Operational headquarters for the Coyote Creek Riparian Station are located adjacent to the overflow channel and a future 7.9-acre riparian restoration site.

The Pilot Revegetation Site currently supports 14 species of planted trees and shrubs. Many native and introduced annual and perennial herbs and grasses occur within the study area. The northern half of the site is sprinkler irrigated while the southern portion is flood irrigated. A complete description of the revegetation project and plant monitoring protocol is provided by Stanley and others (1989).

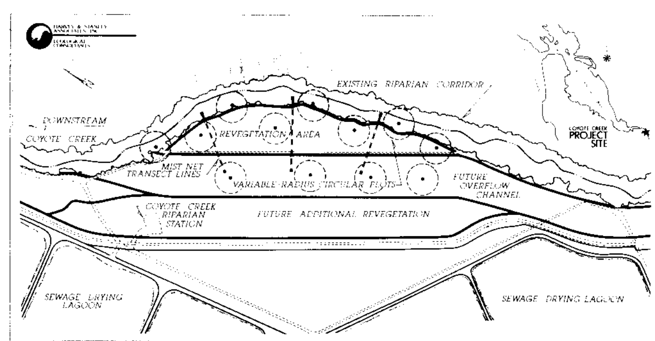

Figure 1— Coyote Creek riparian revegetation study site.

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The future overflow channel is comprised primarily of annual and perennial herbs, grasses and shrubs with remnant cultivated species such as pear (*Pyrus* sp.) and Beefwood (*Casuarina cunninghamiana*). Future flood control plans call for removal of all woody vegetation 3" DBH or greater and maintenance of the ruderal characteristics of the site.

The existing riparian corridor is composed mainly of 30-70 year old Fremont cottonwoods (*Populus Fremonti*), California black walnut (*Juglans hindsii*), red and yellow willow (*Salix laevigata* and *S. lasiandra*), blue elderberry (*Sambucus mexicanus*) box elder (*Acer negundo*), live oak (*Quercus agrifolia*), tree tobacco (*Nicotiana glauca*) and weeping willow (*Salix babylonica*). An understory of giant reed (*Arundo donax*) and blackberry (*Rubus* sp.) *is* dominant in many areas.

Monitoring Methods

In 1982 a modest bird-banding program was begun by the Avian Biology Laboratory of San Jose State University. The banding program was more intensified in 1984 and incorporated into the newly formed San Francisco Bay Bird Observatory. The Coyote Creek Riparian Station (CCRS) was established in 1986 and the banding program was transferred to this non-profit research organization. It now operates on a near daily basis using 40-50 volunteers.

As plans progressed on the flood control project, it became apparent that wildlife monitoring of the Pilot Revegetation Site would be an integral part of the overall assessment of the success of the mitigations.

General Methodology

Riparian revegetation projects are relatively new and untested. As a consequence, a multi-faceted monitoring approach was deemed the most suitable. The monitoring program, instituted in the summer of 1987, became a joint effort between the sponsoring agency (The Santa Clara Valley Water District) the sponsoring agency's prime ecological consulting firm (Harvey and Stanley Associates) and the Coyote Creek Riparian Station.

In order to make use of the baseline information already derived from CCRS's program a banding component was incorporated into the monitoring methodology. In addition to the bird banding program, variable-radius circular plots were established in each of the three habitats (the revegetation plot, the overflow channel and the existing riparian corridor) to assess terrestrial vertebrate (primarily avian) use. During the breeding season breeding bird censuses were conducted monthly. Regular mammal trapping (mark-release) sessions were also instituted on a quarterly basis. Censusing of herptile populations occurred in the spring and summer.

Mist-net Transects

Three transects were established perpendicular to Coyote Creek. Each transect extends from creekside through the revegetation study plot and into the future overflow channel. transects contained 8 or 9, 4-panel, 36 millimeter stretched mesh, black mist nets 12 meters long. When opened these nets extend from 0.15 meters above ground to a height of 2.15 meters. Individual net numbers identify the habitat in which each net is positioned.

Birds captured in each individually numbered net were marked with serially numbered bands issued by the U.S. Bird Banding Laboratory. During the banding process, mensural data were gathered. The age, sex, weight and reproductive or migratory status of each bird was also recorded. In addition, the numbered net in which the bird was captured was noted. On this project, nets were operated from dawn to about 11 a.m. on Wednesday of each week.

Variable-Radius Circular Plot Census

Thirteen permanent variable radius circular plots were established (four each in the revegetation study plot, the future overflow channel, and 5 in the existing riparian corridor) in Fall, 1987. Sampling protocol follows that suggested by Reynolds (1980) and DeSante (1986). During a 10-minute period, the observer records each bird or other vertebrate observed, its distance from the center point of the plot, its position in vegetation and its activity. Care is taken to avoid making repeated observations of a single individual. Birds flying over the plot are recorded if the overflight bears a relationship to the plot (e.g. aerial foraging).

Breeding Bird Census

In each of the months from March through July, breeding bird counts were conducted within hectare grids in each of the three study habitats. Censuses were conducted from dawn to approximately 11 a.m. During each census the number of territorial males (or breeding females if males were not observed) of each species were recorded. For species with three or more territories within a grid, the number of breeding pairs was calculated.

Mammal, Reptile and Amphibian Sampling

Beginning in the fall 1987, quarterly mammal trapping was instituted. Using Sherman live traps set in ten meter grids established along existing vegetation monitoring transects, each of the three study habitats was sampled. Approximately 100 traps were run on 4 to 5 consecutive nights within each grid. All animals were ear-tagged, weighed, sexed, examined for reproductive condition, general health, and released.

Drift fences and funnel traps were used to sample amphibian and reptile presence and abundance within each of the three areas. Drift fences were 100 feet long and set in a crossed configuration (Campbell and Christman 1982) with pitfall traps located at the center and at each end. Six sets of funnel traps were used, two each in the three areas.

Vegetation Sampling

In order to correlate changes in species composition, density and other wildlife population trends with changes in vegetation, the structure of the plant communities in the three study areas is being characterized. Data are being gathered on relative cover and species composition of herbaceous growth, canopy height, foliage height and diversity (MacArthur and MacArthur 1961) and horizontal patchiness (Anderson and others 1978) for each of the 13 variable-radius circular plots. At present, only one vegetation survey has been conducted and thus no comparative data are available.

Results

Because this is the first year of the wildlife monitoring program our findings can only be represented by general comparisons of data among the habitat types.

Net Transects

Numbers of birds captured per 100 net-hours (1 net-hour = 1-12 meter long net operated for 1 hour) remained relatively constant month to month in the existing riparian corridor (fig. 2). This contrasts sharply with the highly variable numbers of birds captured per 100 net-hours in the proposed overflow channel and in the revegetation area. House Finches (*Carpodacus mexicanus*) accounted for most of the captures in the revegetation area and the overflow channel, usually about 75 percent, when numbers were high. House Finches as well as Lesser Goldfinches (*Carduelis psaltria*) and American Goldfinches (*Carduelis tristis*) were apparently attracted by the abundant weed seeds available along the border between revegetation plot and the overflow channel.

Species variability among the different areas (expressed as cumulative numbers of bird species captured each month of transect operation) remained relatively constant through the winter months (fig. 3). The higher values recorded in September and October likely reflect movement of migratory populations.

In terms of feeding guild representation, encounters with granivorous species (seed eating) were about twice as frequent as encounters with insectivorous species. A measure of this variability may be seen in fig. 4. Although we are only beginning to measure habitat variables such as foliage diversity and canopy stratification, it is apparent that the granivorous species were attracted by the prolific growth of herbaceous plants in the overflow channel and the revegetation plot. As the revegetation area matures and the existing riparian corridor achieves greater understory growth the ratio of insectivorous to granivorous species may well change.

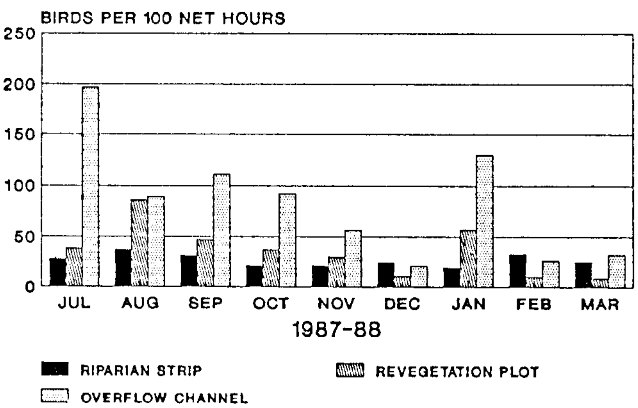

Figure 2– Birds captured per 100 net hours in three mist net transects.

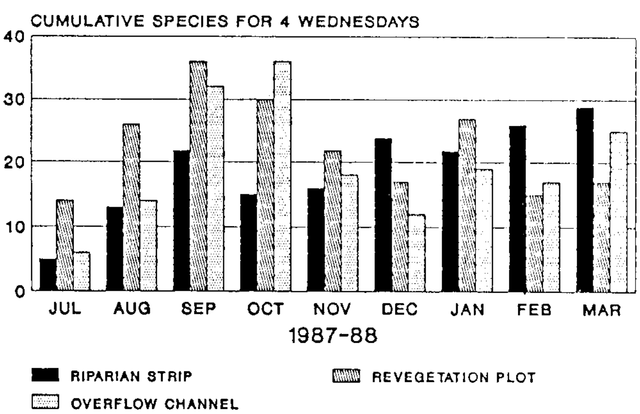

Figure 3– Cumulative numbers of bird species captured in mist net transects within each study area.

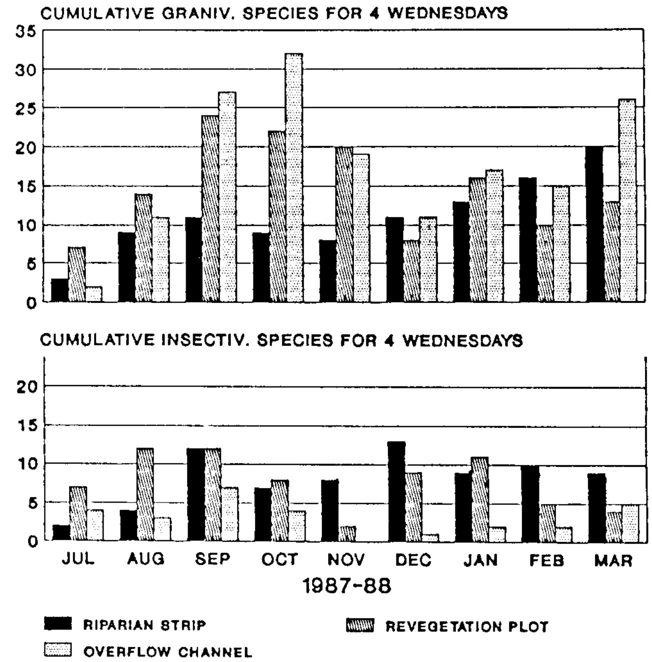

Figure 4– Cumulative numbers of granivorous and insectivorous bird species captured during mist net transect operation.

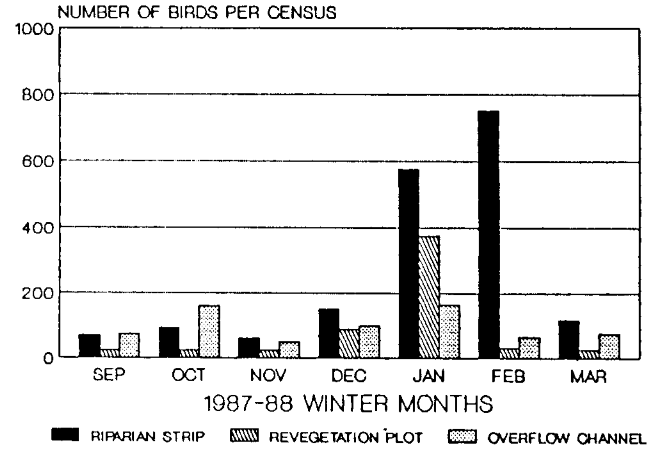

Figure 5– Numbers of birds encountered during variable-radius circular plot censuses.

Variable-Radius Circular Plots

Numbers of birds observed per census increased sharply in the riparian corridor in January and February and in the revegetation area in January (fig. 5). These increases were due to large flocks of House Finches using the large cottonwoods for roosting cover between feeding forays into the revegetation and overflow channel areas. For 6 of the 7 months censuses were conducted, numbers of birds were smallest in the revegetation area.

Census plots within the riparian corridor contained the highest species diversity in all months (fig. 6). In part, the higher species variability in this area is due to the presence of water birds (*e.g.* Belted Kingfisher (*Ceryle alcyon*), American Coot (*Fulica americana*), Pied-billed Grebe (*Podilymbus podiceps*), etc.). These species are not usually expected in the other two habitats.

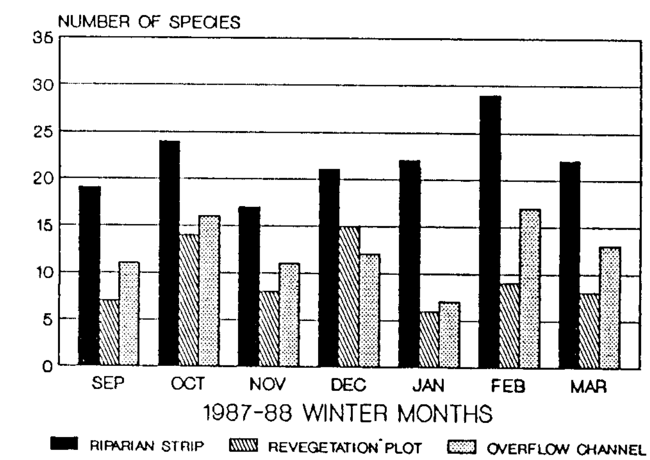

Figure 6– Numbers of bird species encountered on variable-radius circular plot censuses.

Mammal Surveys

One hundred Sherman "live traps" were run 5 nights in each of the three areas in November-December, 1987 and late February-early March, 1988. Numbers of mammals captured and species composition, considered by area, differed substantially between the two trapping sessions (table 1). Most notable were the differences between the two sessions in captures within the revegetation area of house mice (*Mus musculus).* A similar decline (90%) in capture rates was evident for the Western Harvest Mouse (*Reithrodontomys megalotis*). These dramatic differences may be the result natural seasonal succession augmented by irrigation procedures and weed control in the revegetation area.

Breeding Bird Census

The first breeding bird census was conducted in the latter part of March. Census procedures follow those suggested by Van Velzen (1972). In this first year, species found nesting in the three test plots included: Song Sparrow (*Melospiza melodia*) and Common Bushtit (*Psaltriparus minimus),* Tree Swallow (*Tachycineta bicolor*), Red-winged Blackbird (*Agelaius phoeniceus*), Common Yellowthroat (*Geothlypis trichasi* and Brown-headed Cowbird *(Molothrus ater).* Although there were singing or displaying males of other species (*e.g.*, Ring-necked Pheasant and House Finch), there was no confirmation of nesting in the study areas.

Table 1 — Mammals captured and recaptured in Sherman traps Nov-Dec 1987 and Feb-Mar 1988.

Group	Riparian strip		Revegetation plot		Overflow channel	
	No-De	Fe-Ma	No-De	Fe-Ma	No-De	Fe-Ma
Nights of trapping	5	5	5	5	5	5
Trap nights	500	500	500	500	500	500
House Mouse						
Number tagged	3	0	30	4	28	43
Recaptures	0	0	25	3	28	49
Harvest Mouse						
Number tagged	9	3	18	2	11	12
Recaptures	11	1	15	2	8	6
California Vole						
Number tagged	0	1	5	3	0	10
Recaptures	0	0	0	0	0	10
Deer Mouse						
Number tagged	2	0	1	0	0	0
Recaptures	8	0	1	0	0	0
Norway Rat						
Number tagged	2	0	0	0	0	0
Recaptures	0	0	0	0	0	0

Information available for March on paired, singing or displaying males and the number hectares (out of 16 for the three habitat study areas) occupied is summarized below:

Species	Singing males (pairs)	Hectares occupied
Song Sparrow	39	14 of 16
Red-winged Blackbird	31	8 of 16
Common Yellowthroat	6	6 of 16
Ring-necked Pheasant	6	5 of 16
Common Bushtit	3	3 of 16
House Finch	5	3 of 16
Black-shouldered Kite	2	2 of 16
Northern Harrier	1	1 of 16

Reptile and Amphibian Surveys

To date, one reptile and amphibian trapping session has been conducted which was largely unsuccessful. Another trapping attempt is scheduled to be conducted in September, 1988 with a modified trapping array and additional pitfall traps. Anecdotal and incidental observations have provided us with sightings of 2 species of lizards and 3 species of snakes, 3 species of amphibians and 2 species of turtles (including the first Santa Clara County record for the spiny softshell (*Apalone spiniferus*).

Discussion

A first year of wildlife monitoring activities has provided us with baseline information on relative species abundance and diversity. Future work, in the years to come will provide comparative data on wildlife population trends as habitats change.

We have also found that an important role in long-term monitoring programs can be played by volunteer organizations such as the Coyote Creek Riparian Station. The large amount of time which is necessary to provide a comprehensive monitoring program may be prohibitive on many revegetation projects if all field work is conducted by paid staff. Coordination and quality control is essential and best handled by paid professional biologists.

In choosing to include a bird-banding component in our monitoring program, we understood the labor intensity of such techniques. We felt, however, that the information gained on an individual organism's use of the different study areas would be important enough to warrant such expenditures of time. The inclusion of the volunteer organization made it economically feasible.

Future analyses will focus on quantitative relationships between vegetational characteristics in the three study areas and species abundance and diversity. We hope thorough examination of bird capture and recapture data will yield a detailed picture of the use pattern of mature and developing riparian habitats.

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STATUS CHANGES OF BIRD SPECIES USING REVEGETATED RIPARIAN HABITATS ON THE LOWER COLORADO RIVER FROM 1977 TO 1984[1]

Bertin W. Anderson, William C. Hunter, and Robert D. Ohmart[2]

Abstract: Two dredge-spoil sites were revegetated on the lower Colorado River with native riparian trees. Another site was cleared of exotic saltcedar (Tamarix chinensis) *and revegetated with native shrubs. Sites were censused for birds through all phases of revegetation. Bird species were grouped by natural-history characteristics to determine changes in the types of species occurring during the development of revegetation sites. Most species responded positively within 2 years after planting, including some sensitive species. This study is the first of its kind to document changes in bird use of artificially established native riparian habitats.*

Revegetation with native riparian species is often suggested in mitigation proposals to offset expected losses to riparian habitats in the southwestern U.S. Despite the continuing need for large-scale revegetation efforts, there are few success stories and even fewer detailed assessments of wildlife responses to these measures. In an effort to address this deficiency, we summarize the response among birds species in developing riparian habitats on three revegetation sites along the lower Colorado River from 1977-1984.

Documentation for overall increases in birds on these three revegetation sites has been provided elsewhere (Anderson and Ohmart 1982). In this paper, we examine natural-history characteristics of responding species, how they respond (positively, negative, or not at all), and when they respond (before, during, or after development of the habitat) to revegetation. This data provides an opportunity to predict how particular species, or groups of species, are attracted to revegetation sites, given that the intensity and duration of the effort is adequate to attract the bird species of interest.

Methods

Revegetation techniques are detailed elsewhere (Anderson and others 1978, Anderson and Ohmart 1982, Anderson and others 1984, Disano and others 1984, Anderson and Ohmart 1985). Three sites were selected for revegetation with native riparian trees and shrubs in 1977. Two sites were on dredge spoil devoid of vegetation since the 1950's. These sites were planted with native Fremont cottonwoods (*Populus fremontii*), Goodding willows (*Salix gooddingii*), honey mesquite (*Prosopis glandulosa*), and palo verde (*Cercidium floridum*) in January 1979. The third site was a mixed-species stand dominated by saltcedar (*Tamarix chinensis*) and a few decadent Goodding willow; saltcedar was completely cleared, root-ripped, and the site leveled between July 1978 and April 1979. Shrubs were established on this third site by March 1980 and native trees were planted July 1980.

Development of vegetation on each site was evaluated by comparing each of nine variables describing vegetation structure and numbers of trees and shrubs, with the average and standard deviation for all native and non-native riparian vegetation types along the lower Colorado River during the years 1975-1979. Techniques for collecting and analyzing vegetation data on the lower Colorado River are treated elsewhere (Anderson and others 1983, Anderson and Ohmart 1986). Values obtained for the revegetation sites were standardized as:

$$Value_{reveg} — Mean_{rip}/SD_{rip} = \text{standardized value}$$

where $Value_{reveg}$ is a quantified variable on a revegetation site, $Mean_{rip}$ is the same variable from all riparian vegetation, and SD_{rip} is one standard deviation of the mean from all riparian vegetation. In this way it was possible to tell where the value for any variable on any site fell with respect to the lower Colorado River average.

Determining when vegetation on each site began to exceed the lower Colorado River average was defined by taking an average of the standardized values for all variables at each measuring period (two per year). Then we determined when the average changed from negative to positive. In this way, we could determine how long it took a bird species' status to change relative to the change in vegetation.

Status changes among bird species, within each site, were determined by pinpointing the first season that there was a noticeable and consistent change in densities from prior seasons or years. Each of the three sites was surveyed six to nine times each season of each year using a modified Emlen variable-distance transect (Emlen 1971, Anderson and others 1977).

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Five seasons were defined as winter (December-February), spring (March-April), summer (May-July), late summer (August-September), and fall (October-November). In addition to pinpointing the first season of change, the number of seasons before and after vegetation change was determined (adjusted for species that were summer or winter visitors), as well as the direction of change.

Species were then grouped by generalized foraging guilds (insectivores, omnivores, granivores, frugivores/nectivores, gamebirds, and raptors), residency (permanent resident, summer visitor, winter visitor), breeding phonology (early [March to mid-April], medium [mid-April to mid-May], late [mid-May to late July]), typical foraging height (ground, understory, midstory, canopy), and typical foraging technique (scratch, glean, aerial). Change in status, direction of change, and first season of change were assessed by the number of species within guilds among sites. Magnitude of changes within groups were assessed by total individuals recorded before and after change in vegetation at each site.

Results

Vegetation

The two dredge-spoil sites were transformed in 1.5 to 2 years from being barren of vegetation to supporting higher than average number of cottonwoods, willows, and shrubs, as well as higher than average horizontal patchiness and foliage height diversity (table 1; Anderson and Ohmart 1982). The cleared Cibola Refuge site was transformed in 0.5 year from a saltcedar-dominated habitat to a habitat supporting high numbers of native shrubs (principally, quail bush *Airiplex lentiformis* and inkweed *Suaeda torreyana*). The Cibola Refuge site also changed to having higher than average foliage density in the shrub layer and patchiness in the shrub and midstory layers.

Birds

A total of 96 species were found on at least one of the three sites during the study. Of these 96, 57 species occurred regularly on at least two sites to be considered in this paper. Data for these 57 species are assessed in their responses to revegetation in the figures below by grouping them by natural-history characteristics. Data for individual species are omitted here due to length constraints, but are available upon request.

Most permanent resident species responded quickly to changes in vegetation; many within three seasons (< 1 year) before or after vegetation change on each site (fig. 1). Although many visiting species responded within three seasons, density changes were often not evident within the same year as change in vegetation. This disparity was because of the fewer seasons visiting species occurred each year along the lower Colorado River relative to permanent residents (table 1).

Revegetation primarily benefited insectivorous species (fig. 2A). Granivorous species, the other major trophic group, were about evenly split in status change. Reorganizing species by residency status indicated that most permanent residents and summer visitors increased among revegetation sites, except for permanent residents on the Cibola National Wildlife Refuge site, where they were nearly evenly split among status change categories (fig. 2B). Winter visitors were split among status change categories, but with a simple majority of species increasing on each site. Combining trophic and residency groups indicated that declining species were mostly wintering granivores on dredge-spoil sites.

Table 1 – Revegetation site development from planting to change in vegetation structure with respect to the lower Colorado River average (Anderson and Ohmart 1982). Also noted are the number of seasons from initiation of study through season of vegetational change which serve as base points for comparing changes in bird densities within each residency group.

			Number of seasons between change in vegetation and initiation of study			
Site/study Initiation	Season/year trees planted	Vegetation change	Permanent resident	Summer visitor	Winter visitor	Season/year of
East dredge spoil	Winter 1978-79	Summer 1980	15	9	12	Summer 1977
West dredge spoil	Winter 1978-79	Fall 1980	15	9	12	Fall 1977
Cibola Refuge	Summer 1980	Fall 1980	11	7	9	Late summer 1978

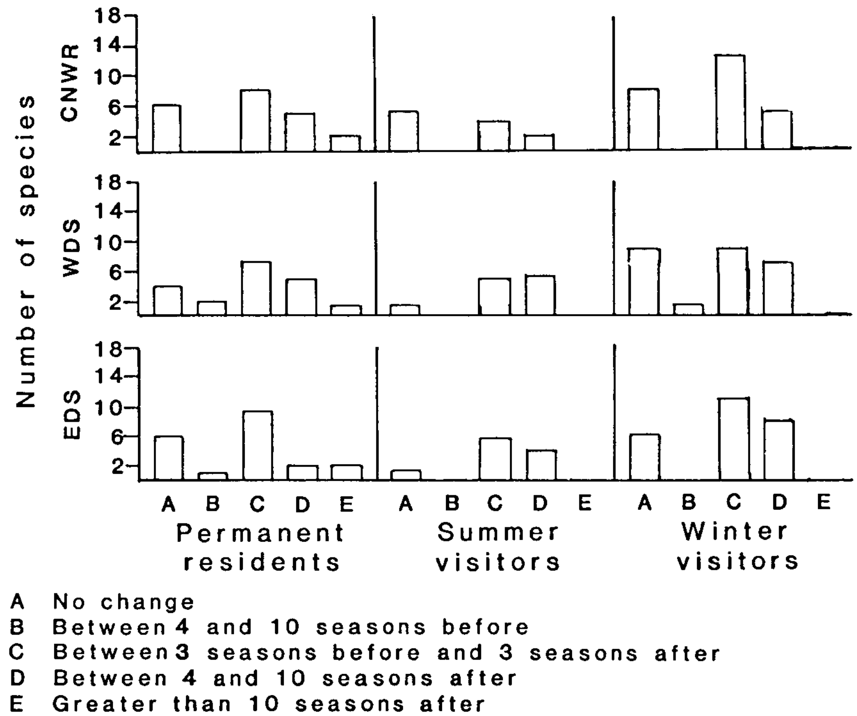


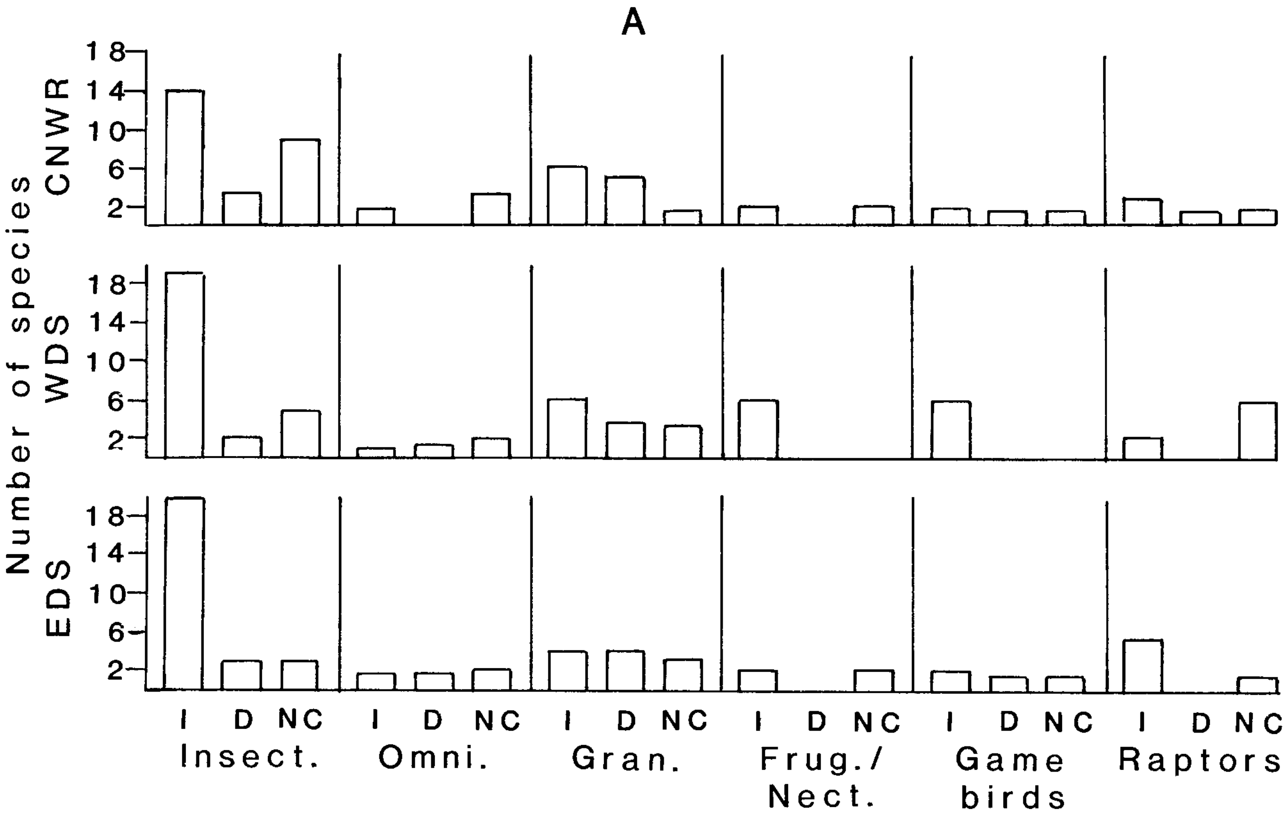
Figure 1 – Number of seasons before or after vegetation change that each bird species (grouped by seasonal residency) changed. See table 1 for base points of season of vegetation change relative to initiation of the study for each residency group at each site. CNWR = Cibola National Wildlife Refuge, WDS = west dredge spoil, EDS = east dredge spoil.

Noticeable and lasting changes for permanent residents typically occurred during their postbreeding seasons (summer, late summer, and fall) (fig. 3). Usually, after an additional year had passed, noticeable changes for permanent residents occurred during every season. Season of first noticeable change for visiting species showed no clear pattern except that many of these species usually responded 1 year or more after permanent residents for both summering and wintering species (figs. 2, 3).

Quantified comparisons of insectivorous, omnivorous, and granivorous individuals during summer indicated, within natural-history groupings, that early breeders, scratchers and gleaners, insectivores, and omnivores benefited the most from revegetation (fig. 4A). Late breeders, aerial foragers, and granivores benefited the least. During winter, species that benefited most from revegetation were midstory and canopy foragers, gleaners, permanent residents, and insectivores (fig. 4B). Individuals that were ground and understory foragers, scratchers, winter visitors, and granivores benefited greatly on the Cibola National Refuge site where shrub cover was extensive, but these types of birds declined on dredge-spoil sites.

Discussion

The very rapid development of revegetation sites, in comparison with natural riparian vegetation, was very encouraging but should be kept in perspective. Native riparian plant species are fast growing when planted under optimal conditions, however, relatively few areas remain on the lower Colorado River where revegetation would be successful (Anderson, unpubl. data). Thus, interpreting growth rates and overall site development requires assuming optimal conditions. Also, revegetation sites quickly surpassed the average for nine vegetation variables (Anderson, unpubl. data), largely because of the overall decadent condition of lower Colorado River habitats, most of which are dominated by exotic saltcedar.



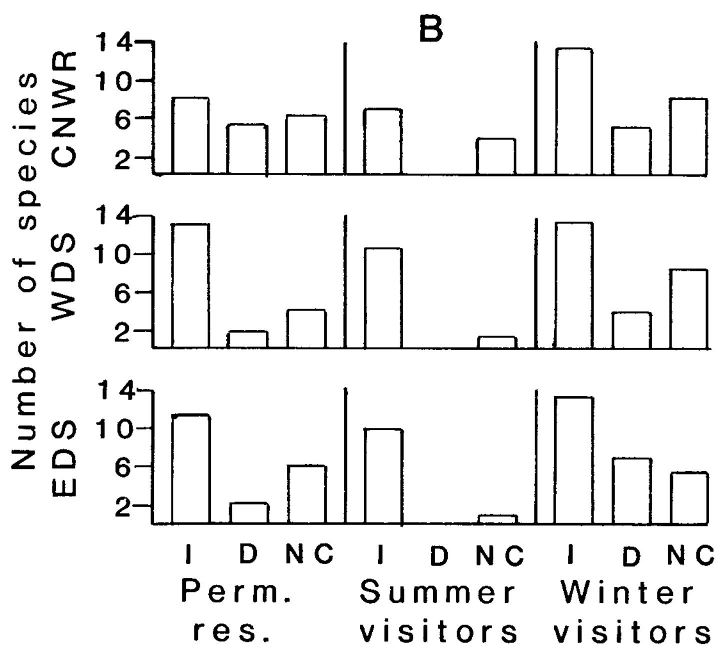


Figure 2 - Direction of status change among birds, if any, after vegetation change. Species grouped by foraging guild (A) and by residency status (B). I = increase, D = decrease, NC = no change, Insect. = insectivore, Omni. = omnivore, Gran. = granivore, Frug./Nect. = frugivore/nectivore. Site abbreviations as in figure 1.

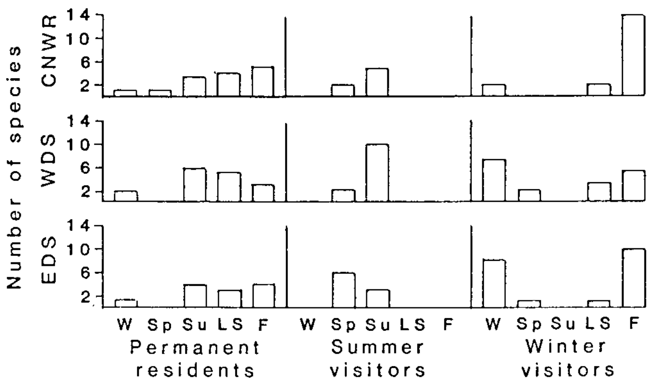


Figure 3 – Season of first noticeable and permanent change in abundance among birds grouped by residency status. W = winter, Sp = spring, Su = summer, LS = late summer, F = fall, site abbreviations as in figure 1.

Before assessing the relative overall success of these revegetation efforts it is important to address species that would be potentially targeted in future efforts. On the lower Colorado River, these species fall into three main groups: (1) late-breeding insectivores, (2) cavity nesters, and (3) large raptors (Hunter 1984, Hunter and others 1987b). Only a few representative species from these groups were found to use any of the three revegetation sites extensively during our study.

The rarest species to breed successfully was the yellow-billed cuckoo (*Coccyzus americanus*), with up to three pairs present on the two dredge-spoil sites in 1981 (2 years after planting) and 1982. Although cuckoos raised young during both years they have since disappeared from these sites, as well as from most of the lower Colorado River (Laymon and Halterman 1986); perhaps, these efforts were "too little, too late" in maintaining population levels of this species for the entire river. Other late-breeding insectivorous species such as Bell's vireo (*Vireo bellii*), yellow warbler (*Dendroica petechia*), and summer tanager (*Piranga rubra*) have been found only sporadically on these sites; this may have more to do with their very low population levels than with the attractiveness of the revegetated habitat.

Cavity-nesting species, especially larger ones, were not expected to rapidly move onto the dredge-spoil sites, as there were few snags. Censusing through to 1984 confirmed this prediction, although we did find increasing numbers of smaller cavity-nesting species, such as ladder-backed woodpeckers (*Picoides scalaris*), ash-throated flycatcher (*Myiarchus cinerascens*), and Lucy's warbler (*Vermivora luciae*). Limbs of some trees were girdled in November 1981 to attract species such as elf owl (*Micrathene whitneyi*), Gila woodpecker (*Melanerpes uropygialis*), gilded flicker (*Colaptes auratus mearnsi),* and brown-crested flycatcher (*Myiarchus tyrannulus*), all of which are considered sensitive or State-listed cavity-nesting species in California. We found breeding Gila woodpeckers and brown-crested flycatchers on the dredge-spoil sites on surveys after 1984.

Large raptors, many of which are obligated to broadleaf riparian habitats, are now very rare on the lower Colorado River. Raptors occurring within the riparian zone require large trees for nest platforms; cottonwood is one of the most important tree species for this purpose. Although we found an increasing frequency of raptors using the sites during winter, we found no nesting activity throughout the study. There are ongoing attempts to reintroduce Harris' hawks (*Parabuteo unicinctus*) to the lower Colorado River, and we suspect the dredge-spoil sites may eventually support a nesting pair.

Assessing natural-history characteristics and response to revegetation by these species provides some qualitative predictions as to which species are likely to respond and to what extent. Permanent residents were not initially attracted to developing revegetation sites for breeding. Eventually, however, many of these species were found to increase during winter and spring, the latter season represents the peak breeding season for most permanent residents. A similar sequence of events may occur for visiting species with the first individuals occurring only after all other natural and preferred habitats become saturated, thus possibly explaining the delay of a year or more for some species in responding to revegetation sites when compared to permanent residents. For all species, breeding and/or overwintering success should increase as vegetation continues to develop, resulting in greater use of these sites through time. Revegetation sites may be treated initially by most species as secondary "sink" habitats for dispersing young or nonbreeding adults. Only later will species respond to these habitats as primary "source" habitats that are important for increasing overall population stability. The time span for the transition from "sink" to "source" is dependent, at least partially, on how rapidly the habitat attains a high-quality level and how well the bird populations can produce "excess" individuals.

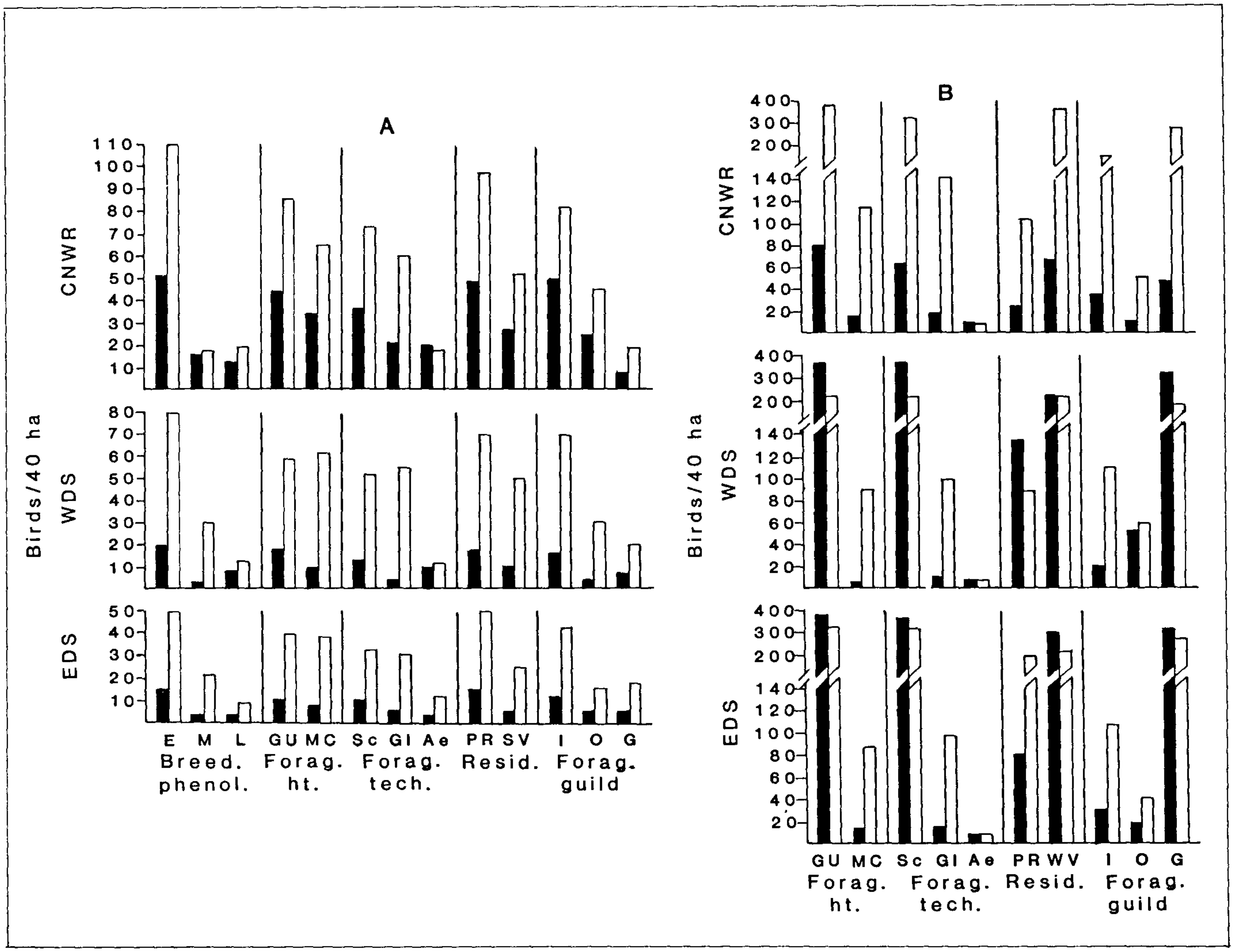


Figure 4 – (A) Spring-summer-late summer summary of numbers of individuals in response to revegetation (before = solid; after = open) within natural-history groups among study sites. Breeding phenology: E = early, M = middle, L = late; Foraging height: G = ground forager, U = understory, M = midstory, C = canopy; Foraging technique: Sc = scratch, Gl = glean, A = aerial; Residency: PR = permanent resident, SV = summer visitor; Foraging guild: I = insectivore, 0 = omnivore, G = granivore, site abbreviations as in figure 1. (B) Fall-winter-spring of numbers of individuals in response to revegetation within groups among study sites. WV = winter visitor, other abbreviations as in figure 4A.

There are many different approaches being used in revegetation, but to our knowledge few, if any, other efforts have documented success in attracting and increasing any bird populations. The total area (54 ha) revegetated in our efforts is still insignificant relative to loss of native riparian habitat on the lower Colorado River (Younker and Andersen 1986); although, we did document increasing bird populations for many species. The lack of response, however, by many sensitive species targeted in these efforts supports the need for even greater commitment to revegetation as a mitigation procedure. Sadly, the dredge-spoil sites (30 ha) now support the largest remaining stands of mature cottonwood-dominated habitat along the entire 450 km of the lower Colorado River (Hunter and others 1987a).

There are a few organizations that have demonstrated a strong commitment to revegetation. The Nature Conservancy of California and the California Department of Fish and Game have adopted both an experimental approach to revegetation and one of annually revegetating adjacent to original sites or healthy natural stands when possible. Both of these approaches are positive and these organizations should be commended. Such approaches allow for additional knowledge in developing the most cost-effective revegetation techniques that will benefit a diversity of wildlife species.

Acknowledgments

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BIRD USE OF NATURAL AND RECENTLY REVEGETATED COTTONWOOD-WILLOW HABITATS ON THE KERN RIVER[1]

William C. Hunter, Bertin W. Anderson, and Reed E. Tollefson[2]

Abstract: Birds were censused concomitant with revegetation efforts on the Kern River Nature Conservancy Preserve during spring and summer 1987. Three types of sites were surveyed: naturally occurring cottonwood (Populus fremontii)-*willow* (Salix *spp.*) *habitats, one 10-ha revegetation site implemented in 1986, and two 10-ha revegetation sites implemented in 1987. Six natural-history criteria were used to compare bird species found in naturally occurring habitat with species found in recently revegetated habitat. These data are extremely useful in discerning species responses to revegetation across sera] stages of vegetation development.*

Avian response to revegetated riparian habitats is poorly documented, with the exception of the long-term study conducted on the lower Colorado River (Anderson and others, 1989). The lower Colorado River represents an extremely degraded system with little native riparian habitat remaining (Ohmart and others 1977). Therefore, it is unclear whether legitimate comparisons can be made between these data and data collected on a system with relatively healthy riparian habitat such as that found along the South Fork of the Kern River.

Revegetation of cottonwoods (*Populus fremontii*) and willows (*Salix laevigala, S. lasiolepis, S. gooddingii,* and *S. exigua*) on the South Fork of the Kern River was undertaken to increase the habitat necessary for successful breeding of the California-endangered yellow-billed cuckoo (*Coccyzus americanus;* Anderson and Laymon, 1989). In addition, we were extremely interested in assessing response to revegetation by all riparian species on the Kern River. Many state threatened and endangered bird species and species of special concern, occurring in California's remaining riparian habitats, are all but extirpated outside of the Kern River Valley. These species include willow flycatcher (*Empidonax traillii extimus;* see Unitt 1987), yellow warbler (*Dendroica petechia brewsieri*), yellow-breasted chat (*Icteria virens*), and summer tanager (*Piranga rubra cooperi*). These species have healthier populations on the Kern River, which may result in a more rapid and permanent response to revegetation than has been found on the lower Colorado River (Anderson and others, 1989).

Fleshman and Kaufman (1984) presented background information and management recommendations for maintaining and improving the South Fork of the Kern River's riparian forest. We refer the reader to this paper for an in-depth description of the study area. They also included density estimates for riparian birds, however, an evaluation of their bird densities suggested that estimates for common species were unrealistically high, while uncommon species went unrecorded. Several frequent problems in sampling design contributing to these results include too few sample points, too few repetitions, and extrapolating densities from small (2 ha) to large (40 ha) scales of analysis (Anderson and others 1977; Engel-Wilson and others 1981; Wiens 1981).

In this paper, therefore, we present our data on initial responses by birds to Kern River revegetated habitats compared with their concurrent use of naturally occurring riparian habitats. Further we compare the initial response data on the Kern River to data collected on the lower Colorado River. Data collection on the Kern River is an ongoing project that will add significantly to the baseline established here.

Methods

All data were collected on the Kern River Preserve administered by the Nature Conservancy. Two seasons were recognized: spring from 15 March to 15 May and summer from 16 May to 30 July. Three habitats were defined and surveyed: five stands as naturally occurring riparian vegetation consisting of cottonwood-willow, one 10-ha stand revegetated in 1986, and two 10-ha stands revegetated in 1987 were surveyed.

Tree and shrub counts constitute the major measurements of vegetation pertinent to this study. Vegetation structure was not assessed in depth during this study as there was a clear distinction between the highly structured naturally occurring vegetation and the revegetation sites; as revegetation sites develop differentially through time, structure will become more important in assessing differences among habitats. Individual trees and shrubs were counted within a distance of 15 m from the transect line. Tree species were identified

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and divided into two broad size classes that were <3 m in height (this class included all revegetated and recently regenerated trees) and >3 m in height (Anderson and others 1977, Anderson and Ohmart 1986). Counts of mature riparian trees parasitized by mistletoe (*Phoradendron tomentosum*) were also taken as well as the number of snags present. Almost all shrubs were <3 m so no height distinction is made among these plant species. Number of sunflowers (*Helianthus* spp.), which were important to granivorous bird species, were also noted. Densities were expressed as plants per hectare.

During the spring season, daily anecdotal observations were made on bird use of the sites before and during preparation for revegetation. Preparation of revegetation sites involved clearing surface vegetation and creating earthen berms by bulldozer; changes in bird use during spring were interpreted with respect to these activities. Summer bird use of revegetation sites before preparation was ascertained from notes taken on other potential revegetation sites with similar vegetation on the Preserve. Following revegetation, transects were established to census birds using the variable-distance line technique (Emlen 1971; Anderson and others 1977).

Five transects were established along edges of riparian habitat and encompassed all noticeable variation of vegetation among stands within the Preserve (table 1). Although there may be problems in overestimating birds concentrating along edges (i.e., western bluebird [*Sialia mexicana*], house wren [*Troglodytes aedon*], song sparrow [*Melospiza melodia*], and both species of goldfinches [*Carduelis* spp.]), we were concerned primarily with interior-forest birds. One transect was established at each of the three revegetation sites and these were designed to cover as much of the sites as possible. Transects were censused 18 times during the entire study, with half in spring and half in summer.

Table 1 — Length and area covered by transects used in determining bird densities on the Kern River Preserve.

Habitats[1]	Transect	Sites censused	Transect length(m)	Area covered (ha)
NATRIP	DS-2	1	762	20
HQ-1		1	457	10
HQ-2		1	762	20
SH-2		1	457	10
KM-1		1	1,067	28
Total		1	3,505	88
REVEG86	DS-1		1,524	10
REVEG87	SH1	2	1,676	10
MF-1		2	1,524	10
Total		2	3,200	20

[1]NATRIP = riparian vegetation; REVEG86 = revegetation site implemented in 1986; REVEG87 = revegetation site implemented in 1987.

Eighty-eight ha of the approximately 200 ha of riparian habitat on the Preserve (Hewett and Laymon, pers. comm.) were surveyed. Based on this, we estimated the total number of birds present in riparian habitat. In this paper, we compare our population estimates with known population sizes (Laymon and Harris, pers. comm.) during 1987 for yellow-billed cuckoo, willow flycatcher, and summer tanager, three interior-forest species of special interest.

Bird Group Classification

Bird species were grouped by six natural-history criteria. These were use of cavity nests, residency, breeding phenology, foraging guild, typical foraging height, and typical foraging technique. This general classification allowed us to directly compare changes in habitat use among seasons, among habitats, and among birds with different natural histories. Within each criterion, total numbers of individuals were determined for each habitat and compared among habitats. Categories are as defined by Anderson and others (these proceedings).

Results and Discussion

Habitats

All natural riparian transects were dominated by red willows (*Salix laevigata*) >3 m in height. Mature Fremont cottonwoods were much less common than red willows except on one transect (table 2). The total number of riparian trees, >3 m in height, varied substantially among transects. Riparian trees <3 m in height were absent except where there were stands of recently regenerated riparian trees and these were scarce on all transects. Mulefat (*Baccharis viminea*) was the dominant shrub on all but one transect; emergent vegetation replaced shrubs on that transect (HQ-1; table 2).

The site revegetated in 1986 was dominated by revegetated and regenerated Fremont cottonwoods. Other features in this habitat included a clumped distribution of four-winged salt bush (*Atriplex canescens*), widely distributed rabbit brush (*Chrysothmanus* sp.), and many patches of annual chenopods and grasses representing several species. All these plants contributed to a well-developed understory, especially during summer. Sunflowers, which were abundant in 1986, were almost nonexistent when this habitat was surveyed in 1987.

Table 2 - Trees and shrubs counted along each transect. Trees were grouped into those above and those below 3 m in height. RW=red willow, CW=Fremont cottonwood, GW=Goodding willow, SBW=sandbar willow (*Salix exigua*), /M=with mistletoe, sn=snag, MF=mulefat, RB=rabbit brush (*Chrysothamnus* spp.), FW salt= four-winged salt bush (*Atriplex canescens*), SF=sunflower.

		Plants per hectare														
Habitat	Transect	RW >3	CW >3	CW <3	RW <3	GW >3	GW <3	SBW >3	CW/M	RW/M	CW sn	RW sn	MF	RB	FW salt	SF
NATRIP	DS-2	90	8	43	3	0	0	0	0	3	0	0	123	110	0	35
	HQ-1	218	13	10	10	0	0	0	0	3	0	0	0	0	0	0
	HQ-2	50	38	5	5	5	5	0	10	0	3	0	113	0	0	0
	SH-2	250	23	0	5	0	0	0	0	10	0	5	160	0	0	0
	KB-1	73	30	0	5	0	0	0	5	3	8	0	48	0	0	0
REVEG86	DS-1	0	3	240	50	0	0	0	0	0	0	0	25	80	8	0
REVEG87	SH-1	5	0	153	48	0	0	5	0	0	0	0	8	20	25	55
	MF-1	0	0	150	48	0	0	0	0	0	0	0	0	0	3	0

The two sites revegetated in 1987 were also dominated by revegetated Fremont cottonwoods, but contained few regenerated trees reaching measurable heights. Both sites were at least 90% cleared of grasses and shrubs before revegetation. During summer, many annual chenopods germinated and formed a patchy understory. Other features associated with revegetation activities were the occurrence of sunflowers on one site and earthen berms on both sites.

Seral Changes Among Bird Species Within Revegetation Sites

Number of bird species using sites revegetated in 1987 increased progressively through the summer period. Eleven species were recorded on revegetation sites before clearing in spring 1987. All but one species (prairie falcon, *Falco mexicanus*) were found on the sites after clearing. During clearing, the number of species increased to 23. These included a number of species foraging on seeds and animals exposed by clearing the sites of grass and other plants. During spring, after clearing was completed but before planting, the number of species increased to 26.

Six species were found regularly during summer in fields similar to those revegetated in 1987, four of which were found to breed. All of these species were also found on revegetation sites after planting, although only horned lark (*Eremophila alpestris*) and savannah sparrow (*Passerculus sandwichensis*) were found to breed (one pair each). Thirty-three species were recorded during summer after planting and after annuals and sunflowers germinated on the sites. Thus, there was an increase of 27 species during summer that may be attributed to just clearing and planting the sites.

At initial stages of clearing there were almost immediate responses from blackbirds, sparrows, bluebirds, American robins (*Turdus migratorius*), and European starlings (*Sturnus vulgaris*). Higher trophic level species, such as gulls (*Larus* spp.) and common raven (*Corvus corax*), were observed foraging along the recently formed berms. The large flocks of blackbirds and European starlings were replaced with arriving spring migrants, such as western kingbirds (*Tyrannus verticalis*) and savannah sparrows. Trees were planted in late April about the time the first Lazuli buntings (*Passerina amoena*) and blue grosbeaks (*Guiraca caerulea*) were found. Annuals and sunflowers were setting seed by late June and these attracted large numbers of mourning doves (*Zenaida macroura*), red-winged blackbirds (*Agelius phoeniceus*), both species of goldfinches, house finches (*Carpodacus *menicanus*), and lark sparrows. In addition, northern flickers (*Colaptes auratus*), western kingbirds, western bluebirds, western meadowlarks (*Sturnella neglecta*), and savannah sparrows continued to be found in small numbers on the revegetated sites through the end of July.

A slightly different set of species was found on the 1986 site one year after revegetation. White-crowned (*Zonotrichia leucophrys*), Lincoln's (*Melospiza lincolnii*), and song sparrows were abundant in this habitat in dried up patches of sunflower and annual chenopods. Large numbers of California quail (*Callipepla californica*) were also found, mostly where four-winged salt bush and rabbit brush were most dense. As spring turned into summer, song sparrows remained while all other sparrows departed. California quail increased with the coming of summer. Lazuli bunting and blue grosbeak were the first spring migrants to be consistently observed perched in revegetated trees. House wrens and song sparrows were the most common understory and ground foragers present. By mid-July large flocks of tricolored (*Ageliaus tricolor*) and Brewer's blackbirds (*Euphagus cyanocephalus*) were found in the more open areas of the site. Unlike sites revegetated in 1987, very few mourning Doves, savannah and lark sparrows, lesser (*Carduelis psaltria*) and Lawrence's (*C. lawrencei*) goldfinches, and house finches were found. Among insectivores, northern flickers, western kingbirds, western bluebirds, European starlings, and western meadowlarks were no longer found foraging on the revegetated parts of the habitat; however, most of these species still were occasionally seen perched in adjacent naturally occurring riparian trees.

Estimated Populations for Riparian Birds

Estimated population sizes for birds on the Kern River Preserve can be determined by multiplying bird densities by the number of hectares (200) of riparian habitats found on the Kern River Preserve. Three species of particular interest were yellow-billed cuckoo, willow flycatcher, and summer tanager. Observers in the field found 9, 38, and 36 individuals for these bird species, respectively (Laymon and Harris, pers. comm.). Our census estimates were 11, 36, and 35 individuals, respectively. Since population estimates were very close to known population size for these three rare interior-forest species, we were confident that our density estimates for most nonedge species are also nearly accurate.

Comparison of Natural-History Characteristics Between Natural Riparian and Revegetated Habitats

Birds in every natural-history category were clearly more abundant in natural riparian habitat than on all revegetation sites (fig. 1). The avifauna of natural riparian habitats was dominated by insectivores, noncavity nesters, ground and understory species, and early breeders with individual numbers evenly split between permanent residents and summer visitors and scratchers and gleaners. On the revegetation sites, granivores were proportionally well represented in contrast to natural riparian habitat. Absolute numbers of late breeders, cavity nesters, midstory and canopy users, and gleaners were very low on revegetation sites during one or both seasons, when compared to natural riparian habitats. Within revegetation sites, the proportion of noncavity users on all revegetated sites and the proportion of late breeding species (due almost solely to nonbreeding goldfinches (*Carduelis* sp.) and lark sparrows [*Chondestes grammacus*]) in 1987 sites during summer were substantially higher than found in natural riparian habitats.

Differences between sites revegetated in 1986 and 1987 were more in magnitude than in trend with most bird categories having higher individual numbers on the 1986 site than on 1987 sites. An exception, was the presence of proportionately, as well as numerically, more winter visitors in the site revegetated in 1986 than on 1987 revegetated sites. The very high proportion of winter visitors and granivores during spring on the 1986 site was reflective of the high number of seed-eating sparrows present in this habitat (Appendix I).

Birds using revegetation sites during early stages of habitat development tend to be quite different in a number of natural-history characteristics from birds using riparian forests. In fact, many of the species found during the early stages of revegetation are better described as open-country birds (Appendix I). Many of these species can be considered opportunists and are not expected to remain on the sites as the habitat develops. Many species during spring, after clearing but before planting, were found using berms. Berms remained important as perches, hiding places, and forage substrate to some species after trees were planted and annuals germinated.

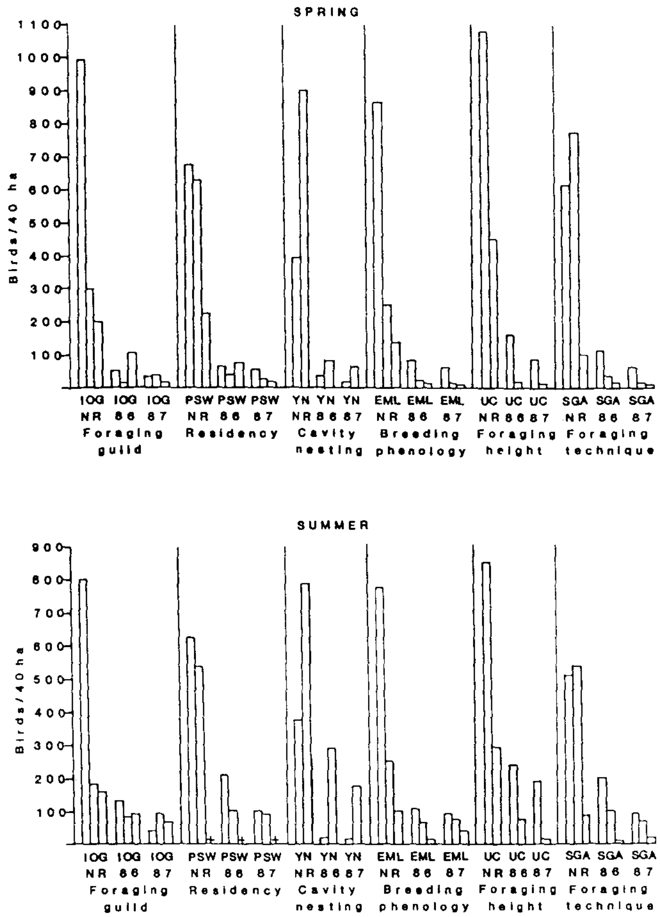

Figure 1– Bird use of natural riparian and revegetation sites as gauged by natural-history characteristics during spring and summer 1987. Foraging guild: I = insectivore, O = omnivore, G = granivore; Residency: P = permanent resident, S = summer visitor, W = winter visitor; Cavity nester: Y = yes, N = no; Breeding phenology: E = early, M = middle, L = late; Foraging height: GU = ground/understory, MC = midstory/canopy; Foraging technique: G = glean, S = scratch, A = aerial; NR = natural riparian; 86 = revegetation site 1986; 87 = revegetation site 1987.

Comparisons with the Lower Colorado River

An attempt to compare bird use of revegetated sites between the Kern River and the lower Colorado River is precarious as there is only one year of data on the former system. However, the occurrence of opportunistic granivores and other open-country species is consistent on both river systems. The occurrence of some species that require either large trees for cavity nesting or are otherwise most common in forest interiors (northern flicker, house wren, western bluebird, and song sparrow) may parallel the pattern observed on the lower Colorado River. Common permanent resident species became established on the lower Colorado River revegetated sites first for increased foraging opportunities and later for nesting (Anderson and others, 1989). Individual numbers increased for many common riparian species on the lower Colorado River revegetation sites 2-3 years after planting; if habitats develop at the same rate on the Kern River we may expect a similar response to revegetation, even with the more sensitive species.

Cavity-nesting, late-breeding, and canopy-foraging species are most closely associated with riparian forest but were poorly represented during the early stages of revegetation. It is these species, however, that we eventually hope to attract to revegetation sites. The work presented here is a first step in determining at what point in vegetative development we should expect these species to occur where relatively healthy populations exist in naturally occurring riparian habitats. We must stress that monitoring for bird occurrence, especially sensitive species, may require more than 3 years of intensive surveys to fully document the success of any revegetation effort. Therefore, we encourage the development of a strict and long-term survey whenever revegetation is proposed as mitigation for habitat losses (see also Anderson and others, 1989).

Acknowledgments

The California Nature Conservancy and the California Department of Fish and Game are gratefully acknowledged for their foresightful support of revegetation through research. Margaret L. Gallagher critically read and improved the manuscript. We thank Rick Hewett, Manager of the Kern River Preserve, for helping us throughout the course of the bird study. Cindy D. Zisner prepared the figure and completed the word processing and we are always indebted to her for her professionalism.

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Appendix I. — Densities and natural-history characteristics of birds found on the Kern River Preserve among habitats for spring (15 March-15 May) and summer (16 May-31 July) 1987.

		Densities (birds/40 ha)						
		Spring			Summe			Natural-history**
Group*	*Species*	Reveg 1986	Reveg 1987	NatRip	Reveg 1986	Reveg 1987	NatRip	characteristics
PROC								
California quail	*(Callipepla californica)*	33	0	10	79	1	61	N,P,E,GV,Gr,Sc
Killdeer	*(Charadrius vociferas)*	0	2	0	0	2	0	N,P,E,I,Gr,Gl
Horned lark	*(Eremophila alpestris)*	0	+	0	0	3	0	N,P,E,O,Gr,Gl
Red-winged blackbird	*(Agelaius phoeniceus)*	1	27	183	26	25	59	N,P,E,O,Gr,Gc
Western meadowlark	*(Sturnella neglecta)*	0	3	0	0	11	+	N,P,E,O,Gr,Sc
Brewer's blackbird	*(Euphagus cyanocephalus)*	0	1	0	6	4	4	N,P,E,O,Gr,Gc
Lesser goldfinch	*(Carduelis psaltria)*	0	0	68	9	29	31	N,P,M,GV,U,Gl
House finch	*(Carpodacus mexicanus)*	0	0	1	0	0	0	N,P,E,GV,U,G1
SVOC								
Mourning dove	*(Zenaida macroura)*	3	3	46	2	28	64	N,SV,M,GV,Gr,Sc
Western kingbird	*(Tyrannus verticalis)*	2	6	6	0	3	2	N,SV,M,I,Gr,Ae
Savannah sparrow	*(Passerculus sandwichensis)*	1	7	+	1	10	1	N,SV,E,O,U,Sc
Lark sparrow	*(Chondestes grammacus)*	0	0	0	1	28	40	N,Sv,L,O,Gr,Sc
Yellow-headed blackbird	*(Xanthocephalus*	0	15	0	0	0	0	N,SV,M,O,Gr,Sc
Tricolored blackbird	*(Agelaius tricolor)*	0	+	21	51	10	11	N,SV,M,O,Gr,Sc
Brown-headed cowbird	*(Molothrus ater)*	0	1	102	0	0	65	N,SV,M,O,Gr,Sc
Lawrence's goldfinch	*(Carduelus lawrencei)*	2	+	46	0	10	11	N,SV,L,GV,U,G1
WVOC								
Dark-eyed junco	*(Junco hyemalis)*	0	2	7	—	—	—	-,WV,-,GV,Gr,Sc
White-crowned sparrow	*(Zonotrichia leucophrys)*	55	6	12	—	—	—	-,WV,-,GV,Gr,Sc
Golden-crowned sparrow	*(Zonotrichia atricapilla)*	2	0	+	—	—	—	-,WV,-,GV,Gr,Sc
Lincoln's sparrow	*(Melospiza lincolnii)*	16	1	12	—	—	—	-,WV,-,GV,Gr,Sc

Appendix I. – Continued.

Group*	Species	Densities (birds/40 ha) Spring Reveg 1986	Spring Reveg 1987	Spring NatRip	Summer Reveg 1986	Summer Reveg 1987	Summer NatRip	Natural-history** characteristics
PRFI								
Northern flicker	*(Colaptes auratus)*	1	2	10	1	4	16	Y,P,E,I,Gr,Gl
Downy woodpecker	*(Picoides pubescens)*	0	0	5	0	0	12	Y,P,E,I,C,Gl
Hairy woodpecker	*(Picoides villosus)*	3	0	5	0	0	6	Y,P,E,I,C,G1
Nuttall's woodpecker	*(Picoides nuttallii)*	1	0	12	0	0	14	Y,P,E,I,C,G1
Black phoebe	*(Sayornis nigricans)*	3	1	14	2	2	20	N,P,E,I,U,Ae
Scrub Jay	*(Aphelocoma coerulescens)*	*0*	*0*	3	1	0	3	N,P,E,I,M,GI
Plain titmouse	*(Parus inornatus)*	5	0	18	0	0	32	Y,P,E,I,C,Gl
Bushtit	*(Psaltriparus minimus)*	2	0	55	51	0	86	N,P,E,I,M,Gl
White-breasted nuthatch	*(Sitta carolinensis)*	0	0	2	0	0	10	Y,P,E,I.C,G1
Bewick's wren	*(Thyromanes bewickii)*	1	0	9	1	0	15	Y,P,E,I,U,Gl
Western bluebird	(Sialia *mexicana)*	3	4	15	0	8	13	Y,P,E,I,Gr,Ae
American robin	*(Turdus migratorius)*	0	5	10	0	1	8	N,P,E,I,Gr,Sc
California thrasher	*(Torostoma redivivum)*	0	0	0	0	0	1	N,P,E,I,Gr,Sc
European starling	*(Sturnus vulgaris)*	5	9	39	0	8	30	Y,P,E,I,Gr,Gl
Rufous-sided towhee	*(Pipilo erythopthalamus)*	0	0	4	0	0	4	N,P,E,I,Gr,Sc
Brown towhee	*(Pipilo fuscus)*	8	0	4	4	+	7	N,P,E,I,Gr,Sc
Song sparrow	*(Melospiza melodia)*	4	3	199	28	5	187	W,P,E,I,Gr,Sc
SVFI								
Yellow-billed cuckoo	*(Coccyzus americanus)*	–	–	–	0	0	2	N,SV,L,I,C,A1
Ash-throated flycatcher	*(Myiarchus cinerascens)*	0	+	18	+	1	21	Y,SV,MR,I,Ms,Ae
Western wood-pewee	*(Contopus sordidulus)*	0	1	15	0	0	13	N,SV,L,I,C,Ae
Willow flycatcher	*(Empidonax traillii)*	0	0	4	0	0	7	N,SV,L,I,C,Ae
Tree swallow	*(Tachycineata bicolor)*	0	1	26	+	1	4	Y,SV,E,I,C,Ae
House wren	*(Troglodytes aedon)*	9	1	237	22	0	206	Y,SV,E,I,U,Gl
Yellow warbler	*(Dendroica petechia)*	0	0	18***	0	0	2	N,SV,MR,I,U,Gl
Common yellowthroat	*(Geothlypis triches)*	0	0	13	1	0	10	N,SV,MB,I,U,Gl
Yellow-breasted chat	*(Icteria virens)*	0	0	2	0	0	3	N,SV,L,I,U,Gl
Blue grosbeak	*(Guiraca caerulea)*	2	1	15	8	4	18	N,SV,MB,I,Ms,Gl
Lazuli bunting	*(Passerine amoena)*	2	+	4	13	+	15	N,SV,MB,I,Ms,Gl
Northern oriole	*(Icterus galbula)*	0	1	42	1	1	29	N,SV,MB,I,Ms,Gl
Summer tanager	*(Piranga rubra)*	1	0	3	0	1	7	N,SV,L,I,C,A1
WVFI								
Hermit thrush	*(Catharus guttatus)*	0	0	7	–	–	–	-,WV,-,I,Gr,Sc
Ruby-crowned kinglet	*(Regulus calendula)*	0	0	8	–	–	–	-,WV,-,I,C,Gl
Orange-crowned warbler	*(Vermivora celata)*	1	0	6	–	–	–	-,WV,-,I,C,Gl
Yellow-rumped warbler	*(Dendroica coronata)*	1	1	156	–	–	–	-,WV,-,I,C,GI
NECTIVORE								
Black-chinned hummingbird	*(Archilochus alexandri)*	0	+	8	1	1	7	NA
Anna's hummingbird	*(Calypte* anna)	0	0	7	0	0	3	NA
WVF								
Cedar waxwing	*(Bombycilla cedrorum)*	0	0	11	–	–	–	NA
Phainopepla	*(Phainopepla nitens)*	0	0	1	–	–	–	NA
RAPTORS								
Turkey vulture	*(Cathartes aura)*	0	0	1	0	0	0	NA
Black-shouldered kite	*(Elanus caerulus)*	0	0	+	+	0	0	NA
Cooper's hawk	*(Accipiter cooperii)*	0	0	+	0	0	0	NA
Red-shouldered hawk	*(Buteo lineatus)*	0	0	+	0	0	+	NA
Red-tailed hawk	*(Buteo jamaicensis)*	0	0	+	0	0	1	NA
American kestrel	*(Falco sparverius)*	0	0	+	0	+	1	NA
Great horned owl	*(Bubo virginianus)*	0	0	1	0	0	1	NA
Common raven	*(Corvus coral.)*	0	0	+	0	+	1	NA

*PROC = permanent resident, open-country; SVOC = summer visiting, open-country; WVOC = winter visiting, open-country; PRFI = permanent resident, forest insectivore; SVFI = summer visiting, forest insectivore; WVFI = winter visiting, forest insectivore; WVF = winter visiting frugivore.

**Y = cavity nester; N = noncavity nester; P = permanent resident; SV = summer visitor; WV = winter visitor; E = early (April) breeding; MB = middle (May) breeding; L = late (June) breeding); I = insectivore; O = omnivore; GV = granivore; Gr = ground foraging; U = understory foraging; Ms = midstory foraging; C = canopy foraging; Gl = gleaning; Sc = scratching; Ae = aerial pursuit; NA = not applicable; and + species not included in fig. 1.

***Density includes northbound migrants.

THE UPPER SANTA YNEZ RIVER AS HABITAT FOR A DIVERSE RIPARIAN FLORA AND FAUNA[1]

M. Violet Gray, James M. Greaves, and Thomas E. Olson [2]

Abstract: The upper Santa Ynez River, Santa Barbara County, provides habitats for a relatively large population of least Bell's vireos (Vireo bellii pusillus), *as well as diverse riparian flora and fauna. Of particular interest is the richness of the species within particular guilds. Four species of vireos: least Bell's, warbling* (Vireo gilvus), *solitary* (Vireo solitarius) *and Hutton's* (Vireo huttoni), *coexist together often on overlapping territories taking advantage of both vertical and horizontal diversity. Floristically these habitats are equally rich, hosting five species of willows* (Salix *spp.*), *two cottonwoods* (Populus *spp.*), *two oaks* (Quercus *spp.*), *alder (*Alnus rhombifolia*), and sycamore* (Platanus racemosa), *often in close or overlapping proximity. The most complex layer of vegetation is found precisely within the selected nesting range of the least Bell's vireo, suggesting that this degree of complexity may be of utmost importance in terms of future survival of the endangered vireo, and also many other riparian species.*

We subdivided the habitats into six basic community types (Fig. 1). Although these types of habitats are highly generalized they illustrate the diversity of niches available for use by wildlife.

These riparian habitats function as an ecological island in an otherwise inhospitable arid region (Fig. 2). The surrounding Chapparal Woodlands and meadows provide miles of buffer between the fragile riparian habitats and urban or agricultural development. Most of this area is within the Los Padres National Forest.

During the spring and summer breeding season, the riparian habitats experience a marked increase in use as animals migrate to and from breeding and nursery grounds (Fig. 3). Mammals which routinely inhabit the surrounding arid regions move into the riparian zone to raise their young near the more reliable sources of food and water. Also as the summer drought extends into the later months of summer many animals move out of their habitual montane shelters as food and water sources become depleted, and seek temporary shelter in the more hospitable riparian habitats. The Phainopepla (*Phainopepla nitens*), for example usually breeds in the deserts of Southern California in the early spring, and then moves to riparian habitats for a late summer breeding season.

The combination of a high water table, and a deep alluvium provide a comparatively high degree of humidity. Because much of this area is characterized by closed canopy forests, the air moisture provides a cooling effect within the riparian zone. The temperature gradient between the riparian and surrounding slopes is often as much as fifteen degrees. Because coastal fog flows from the Pacific Ocean up the lower Santa Ynez River near Lompoc, California, and inland to the upper Santa Ynez River, these habitats are often shrouded in morning fog, providing an additional cooling effect.

Because this section of habitat is surrounded by the National Forest, it is provided with protection that few other riparian habitats in California enjoy. A nearby mercury mine (Fig. 4),is no longer in operation, and grazing allotments in the area have been closed. Few areas remain in California, that can provide a nearly pristine setting in which to study the population dynamics of riparian related wildlife.

These habitat areas are proposed for listing as critical habitat for the least Bell's vireo, and as such may receive protection from the Federal Endangered Species Act.

This research has received the continuing support of the U.S. Forest Service, and the advice of Los Padres National Forest Biologist, Maeton Freel. Also we wish to thank the City of Santa Barbara, and Dames and Moore for their interest and support during 1987 and 1988. Dr. John T. Gray of Dames and Moore provided invaluable advice, and logistical assistance.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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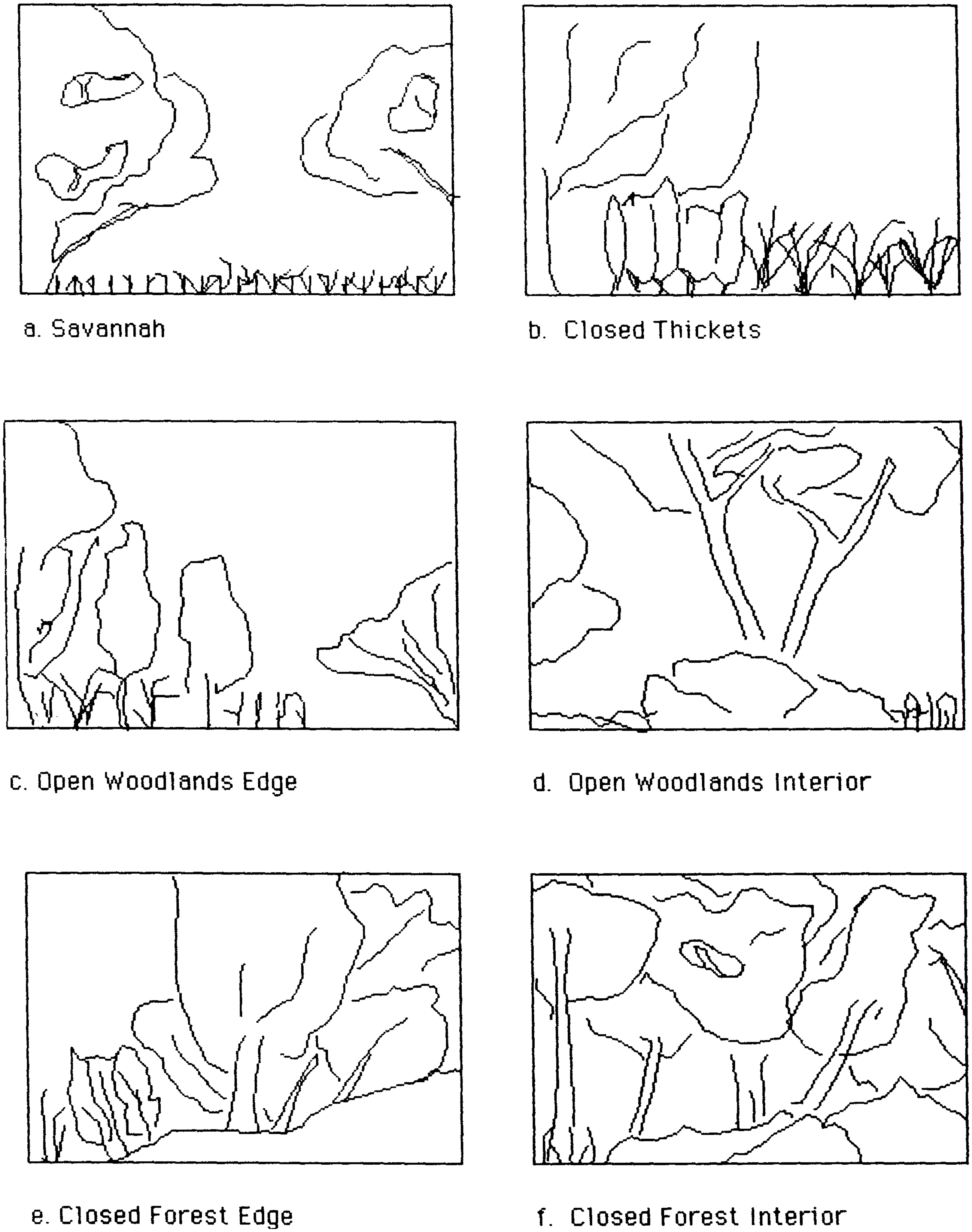

Figure 1– These drawings (a-f) represent composites taken from drawings of the habitat at all least Bell's vireo nest sites studied at Gibraltar Reservoir in 1987.

Figure 2- Steep arid slopes stretch for miles, and abut the Dick Smith Wilderness Area.

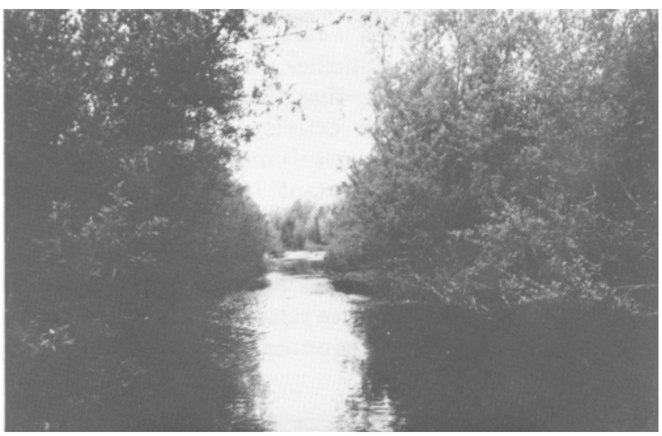

Figure 3- Cool stream channels serve as corridors for some migrating birds and mammals and nursery grounds for others.

Figure 4- A mercury mine on the slopes above Gibraltar Reservoir may continue to pose an environmental threat to this river basin.

ACTIVITIES AND ECOLOGICAL ROLE OF ADULT AQUATIC INSECTS IN THE RIPARIAN ZONE OF STREAMS[1]

John K. Jackson and Vincent H. Resh[2]

Abstract: Most adult aquatic insects that emerge from streams live briefly in the nearby riparian zone. Adult activities, such as mating, dispersal, and feeding, influence their distribution in the terrestrial habitat. A study at Big Sulphur Creek, California, has shown that both numbers and biomass of adult aquatic insects are greatest in the near-stream vegetation; however, adults can be relatively common 150 meters or more from the stream. Because adult aquatic insects are abundant, they represent a primary food resource for many riparian insectivores. The role of adult aquatic insects in the riparian zone must be better understood for riparian management plans to be complete.

The adult stages of most stream insects inhabit the riparian zone (e.g., Anderson and Wallace 1984; Erman 1984). Although adults are generally short-lived (from one day to a week), they often exhibit physical characteristics and life history traits that facilitate their survival in the terrestrial environment and their reproductive success (e.g., Butler 1984; Jackson 1988). Such adaptations suggest that the brief interaction between adult aquatic insects and the riparian zone has been, and presumably continues to be, important to their survival. At the same time, aquatic insects can influence the distribution and abundance of riparian insectivores because the adults of aquatic insects often represent an important food resource (Jackson and Fisher 1986). The purpose of this paper is to summarize some activities and roles of adult aquatic insects in riparian zones in California and other regions.

Activities of Adult Aquatic Insects

Adult aquatic insects engage in several activities, the most common of which are reproduction, dispersal, and feeding. Reproduction [i.e., mate location, followed by oviposition in the stream or on overhanging vegetation by females, see Anderson and Wallace (1984) for descriptions of the latter] is essential for the initiation of the next generation in the aquatic environment.

Reproductive activities are often well defined with respect to time of the day and location in the riparian zone. Some species form mating swarms [e.g., mayflies (Ephemeroptera), caddisflies (Trichoptera), and chironomid midges (Diptera)] at specific times of the day, distances from the stream, and heights above the ground (e.g., Edmunds and others 1976; LeSage and Harrison 1980).

Recent studies in the Coast Range of northern California demonstrated that males of some species of caddisflies locate conspecific females by following sex pheromones (i.e., chemicals that mediate reproductive activities between males and females) that are released by females (Wood and Resh 1984; Resh and Wood 1985). Similar to swarming, pheromone-induced mating occurs at a specific time of the day. For example, the pheromone-induced mating period for *Gumaga nigricula* (McL.) (Trichoptera: Sericostomatidae) is in the morning and lasts only 3 to 6 h (Jackson and Resh, unpublished data).

Dispersal is also a key activity for most adult aquatic insects. The short-lived adult stage in many species (e.g., most mayflies, stoneflies, caddisflies) would appear to limit the distance that they can potentially disperse, either passively or actively. However, long distance (greater than 1 kilometer) movements both within stream corridors (e.g., Coutant 1982) and across land (e.g., Svensson 1974; Edmunds and others 1976) have been recorded for some species in these groups. Not surprising, long distance movements have been commonly observed in species that have relatively long-lived adults [e.g., some blackflies, mosquitoes, dragonflies (Johnson 1969)].

Long-lived adults often feed (e.g., they are predators or require a blood meal for egg development) and prey or host availability may contribute to the distance traveled. The effect that limited feeding activities [e.g., stoneflies feeding on young leaves and buds or on algae on tree trunks (Frison 1935; Harper and Stewart 1984), midges and caddisflies feeding on nectar or honeydew (Burtt and others 1986)] may have on dispersal distance has not been examined.

The above activities contribute to the distribution and abundance of adults in the riparian zone. In a recent study of the distribution of adult aquatic insects in the mixed evergreen forest adjacent to a third-order

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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California stream (Big Sulphur Creek, Sonoma Co.), we found that the abundance of adult aquatic insects was greatest near the stream and decreased as distance from the stream increased (fig. 1). The rate of decrease in abundance varied among species. For example, two species of caddisflies, *G. nigricula* and *Helicopsyche borealis* (Hagen) (Trichoptera: Helicopsychidae), were very abundant in the trees next to the stream. However, *H. borealis* was almost absent 40 meters from the stream whereas *G. nigricula* was still common 150 meters from the stream (Jackson and Resh, in press). By flying more than 50 meters from the stream, adult aquatic insects would be outside of most riparian buffer zones that are recommended to protect water quality and aquatic life in streams (Brinson and others 1981).

Within the forest canopy, most of the species examined in the Big Sulphur Creek study exhibited one of two distribution patterns: adults were either equally abundant at all heights examined (2, 5, 8 meters above the ground) or they were more abundant near the tree tops (8 meters) than at the tree bases (2 meters). Only one species, an undescribed species of the caddisfly *Ochrotrichia* (Trichoptera: Hydroptilidae), was more abundant near the tree bases than the tree tops (Jackson and Resh, in press).

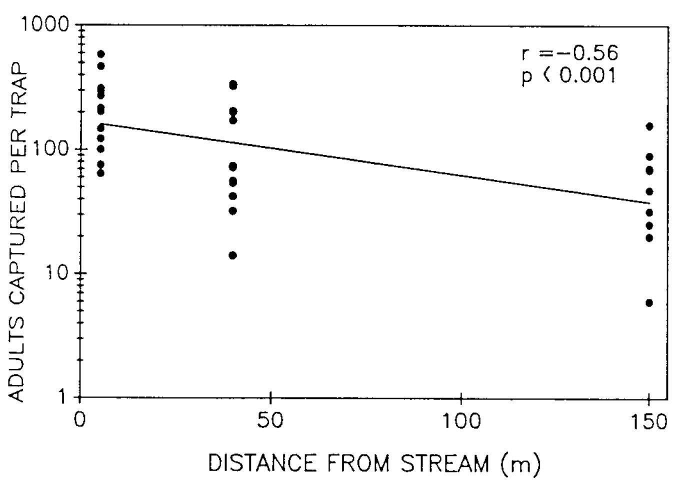

Figure 1— Simple linear regression between distance from the stream and total number of adult aquatic insects captured (logarithmic scale) in sticky traps set in the mixed evergreen forest adjacent to Big Sulphur Creek.

Ecological Role of Adult Aquatic Insects

Various studies have shown that between 1 percent and 57 percent of the biomass produced by immature aquatic insects (i.e., secondary production of aquatic insects) emerges from the aquatic system in the form of adult insects (see Jackson and Fisher 1986 for review). Because many of these adults die in the riparian zone, much of this biomass does not return to the aquatic habitat (Jackson and Fisher 1986). This export of biomass reduces the organic matter and nutrients that are available to aquatic insectivores (e.g., fish, amphibians, other macroinvertebrates) and increases organic matter and nutrients that are available to riparian insectivores (e.g., birds, bats). For riparian insectivores, the importance of this export of aquatic biomass depends on the abundance of adult aquatic insects as prey relative to the abundance of terrestrial insects as prey.

Adult aquatic insects represented 37 percent of total arthropod numbers and 25 percent of total arthropod biomass captured by sticky traps placed in trees 5 meters from Big Sulphur Creek; 150 meters from the stream, adult aquatic insects still represented 15 percent of numbers and 11 percent of biomass (Jackson and Resh, in press). Adult aquatic insects are often major components in the diets of riparian birds (e.g., Clark 1984; Blancher and others 1987) and bats (e.g., Herd and Fenton 1983; Swift and others 1985), which suggests that this aquatic-terrestrial interaction may have contributed to the abundant insectivore faunas that characterize riparian systems. The potential importance of adult aquatic insects to riparian insectivores is greatest in arid regions such as California and Arizona (e.g., Gaines 1977; Brinson and others 1981; Clark 1984) because terrestrial insects may be less abundant in upland areas.

Implications for Management of Riparian Zones

The above examples illustrate the importance of the interaction between adult aquatic insects and the riparian zone. However, adults have not been considered in the management of riparian systems. Modifications of the riparian zone can directly affect adult aquatic insects by interfering with the reproductive activities of adults [e.g., swarm or oviposition markers are lost (Statzner 1977)] or by changing abiotic (e.g., air temperature) or biotic (e.g., insectivore density) conditions that adults are exposed to in the riparian zone. Indirect effects can include changes in the survival and growth of the immature stages of aquatic insects (i.e., those that occur in the stream), which in turn affects the abundance of adult aquatic insects in the riparian zone.

This array of direct and indirect effects increases the complexity of management decisions. For example, opening the stream canopy can increase the production of the immature stages of aquatic insects in the stream. As a result, immatures would be more available as prey for stream insectivores, such as trout (Hawkins and others 1983), and adults would be more available as prey for riparian insectivores, such as birds and bats. However, such a modification of the riparian zone may actually have a negative effect on stream biota because other essential stream parameters (e.g., water temperature) would also change (Hawkins and others 1983). Birds and bats may be adversely affected as well if the survival and reproductive success of adult aquatic insects decrease (and consequently numbers in subsequent generations decrease) because of modification of the riparian zone.

Factors that affect the distribution, abundance, and function of the immature stages of aquatic insects in aquatic systems have been examined extensively (Resh and Rosenberg 1984).

In contrast, comparable information is not available for the adult stages. If management plans for riparian zones are to be complete, further studies that elucidate the role of adult aquatic insects in riparian systems are needed.

Acknowledgements

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SESSION H: EFFECTS OF STREAM DIVERSIONS ON CALIFORNIA RIPARIAN SYSTEMS

Man has historically diverted California streams to provide better access to water resources, for agriculture and to assist in mining. In more recent times, water in montane areas has been diverted for hydroelectric power production. As a result of population expansion and the subsequent increase in demand for a limited resource, competition for access to water has intensified. Resource and regulatory agencies have the responsibility to provide adequate water resources for the maintenance of fisheries, recreation, hydroelectric power production, riparian vegetation, and consumptive uses. As the demand for water increases, better information on the water requirements of these resources is needed to allow resource managers to allocate water equitably. Although verifiable quantitative data for all of these resources is limited, very little research has been conducted on the water relations of riparian vegetation, especially for montane streams.

The papers in this session provide the latest quantitative information on both eastern and western Sierra Nevada and coastal streams, ways to interpret riparian response to changing hydrological conditions, and evaluation of riparian communities with respect to hydrology and geomorphology.

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HYDROLOGY OF BISHOP CREEK, CALIFORNIA: AN ISOTOPIC ANALYSIS [1]

Michael L. Space, John W. Hess, and Stanley D. Smith. [2]

Abstract: Five power generation plants along an eleven kilometer stretch divert Bishop Creek water for hydroelectric power. Stream diversion may be adversely affecting the riparian vegetation. Stable isotopic analysis is employed to determine surface water/ground-water interactions along the creek. surface water originates primarily from three headwater lakes. Discharge into Bishop Creek below the headwaters is primarily derived from ground water. The average δD and $\delta^{18}O$ values are significantly different for surface water and ground water that an isotopic analysis can delineate between these two components of flow. Therefore isotopic shifts along the creek can determine gaining reaches. In addition, by knowing the isotopic signatures of various waters in the watershed, it may be possible to examine tree waters to determine their water source(s).

Bishop Creek is located in east-central California on the east flank of the Sierra Nevada Range (fig. 1). The headwaters of the creek originate from three man-made lakes, situated at 2800 to 3000 meters above sea level. The streams flowing from these lakes converge and the creek eventually flows into Owens Valley, at an altitude of 1300 meters. Southern California Edison has been diverting Bishop creek water for hydroelectric power for many years. Recently there has been concern as to the effects stream diversion has on the riparian community. Although there is a required minimum flow that must be released from the hydroelectric power plants to the channel, during certain times of the year it may be lower than natural flow would be. Decreased stream flow could lower the water table near the stream below the root zone of some plant species. Furthermore, reservoirs temper high flow periods that would otherwise recharge stream banks.

The objective of this study is to determine those areas that gain ground water along diverted reaches. The results of this study will be integrated with other projects funded by Southern California Edison to better understand plant-water relationships and the possible plant stress that can occur due to man-made diversions.

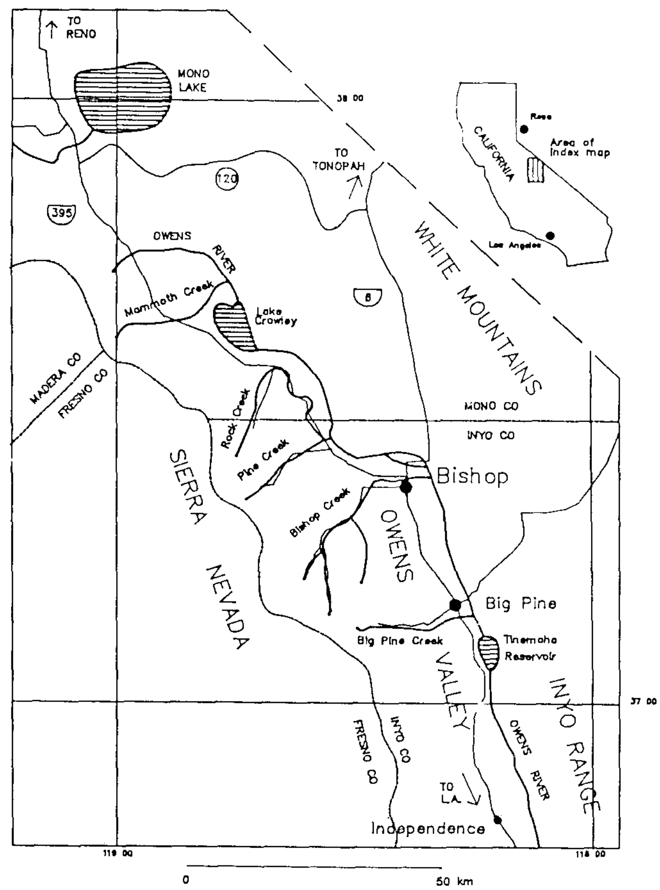

Figure 1– Location map of Bishop Creek, CA.

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[1] Presented at the California Riparian Systems Conference, September 22-24, 1988; Davis, California.

[2] Graduate Research Assistant and Research Professor, respectively, Desert Research Institute, Las Vegas, NV, and Dept. of Geosciences, University of Nevada, Las Vegas, NV; Assistant Professor, Dept. of Biology, University of Nevada, Las Vegas, NV.

Methods

The stable isotopic ratios of hydrogen (D/H) and oxygen ($^{18}O/^{16}O$) are primarily used as conservative water tracers. They are used to determine residence times, mixing, and sources of waters. Deuterium and oxygen-18 are conservative because they are a part of the water molecule. Their concentration in a particular water is dependent on isotope fractionation that occurs during phase changes (i.e. condensation and evaporation). This is due to differences in mass and energy between isotopes. As a result, the isotopic composition of various types of waters are unique. Variation of the isotopic composition in natural waters has been reviewed by Dansgaard (1964).

The values for D/H and $^{18}O/^{16}O$ ratios are produced using a mass spectrometer that compares the sample to a known standard:

$$\delta(\text{per mil}) = (R_{sample}/R_{standard} - 1) \times 1000$$

where for $\delta^{18}O$, $R = {}^{18}O/{}^{16}O$ and for δD, $R = D/H$. The standard is V-SMOW (Vienna Standard Mean Ocean Water), which is nearly identical to SMOW as defined by Craig (1961). The standard deviation for δD and $\delta^{18}O$ values are ±1 per mil and ±0.3 per mil respectively.

Figure 2 shows the locations for surface and ground-water samples collected in 1986. Some sampling points were added and some dropped as deemed appropriate. Surface and ground-water samples were collected on May 28-30, July 21-23, and September 27-28, 1986. Virtually all surface flow into Bishop Creek originates from the three alpine reservoirs. Therefore, analysis of lake outflow provides an isotopic signature for surface water input to the creek. Ground-water sampling from available springs and wells provides an average δD and $\delta^{18}O$ value for subsurface flow to the stream.

Another condition that must be met to determine gaining reaches is that ground-water influx must be significant relative to stream flow, otherwise isotopic shifts cannot be detected. Outflow from the headwater lakes is much greater than ground-water influx. However, penstocks divert most of this water to be used for hydroelectric power. Thus, water that flows out of the Power Plants to the natural channel is much less, though it still reflects the isotopic signature of surface water.

Results and Conclusions

Average δD lake values are -122 per mil, -121 per mil, and -120 per mil for May, July, and September, 1986, respectively. Average $\delta^{18}O$ lake values are -16.3 per mil, -16.3 per mil, -16.0 per mil, for May, July, and September, 1986, respectively. Ground-water samples from wells and spring have average δD values of -133 per mil, -133 per mil, and -131 per mil, for May, July, and September, 1986, respectively. Average $\delta^{18}O$ values are -17.2 per mil, -17.5 per mil, and -17.3 per mil for May, July, and September, 1986, respectively. Because ground water is not exposed to the fractionation effects from evaporation like lake waters, it has a significantly different δD and $\delta^{18}O$ value. Therefore, stable isotope analysis can be used to delineate surface water from ground water.

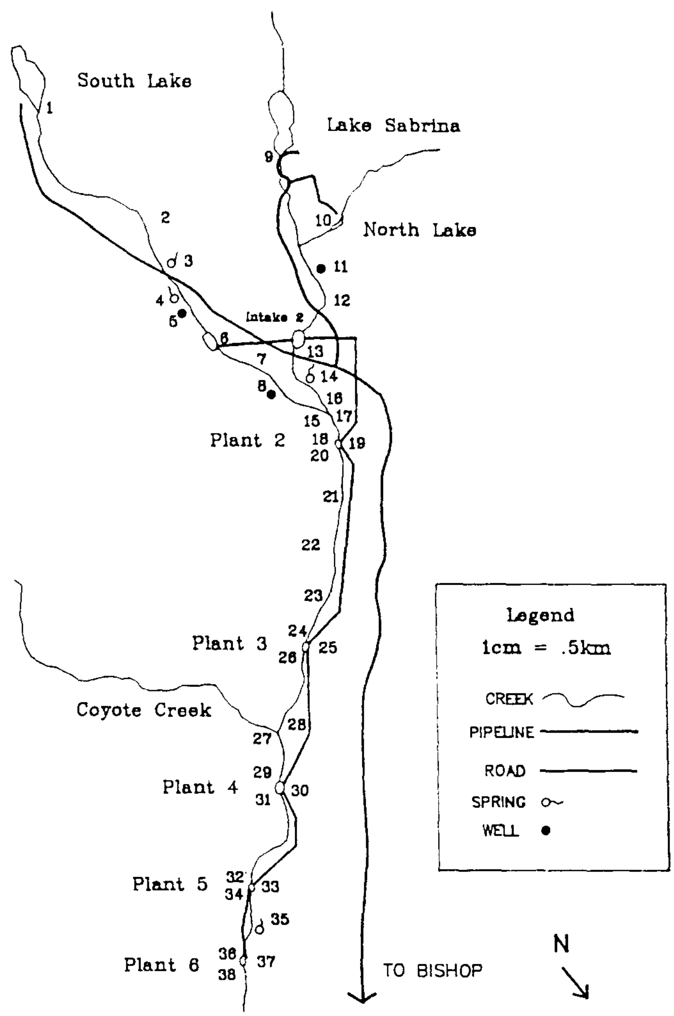

Figure 2- Location of sample sites at Bishop Creek.

Figure 3 shows the δD values of sample points for September 1986. Results for May and July did not show isotopic shifts due to high stream flow conditions from spring snow melt. This masked ground-water input for these sampling periods. However, by September stream flow decreased, and gaining reaches could be determined. Of primary concern are the reaches between each of the Power Plants.

Figure 3 shows a δD shift from -120 per mil to -127 per mil between Power Plants 2 and 3. This shift is from an isotopic signature characteristic of surface water to that of ground water. Therefore, this is a gaining reach. The reach between Power Plants 3 and 4 has a significant influx from Coyote Creek that masks ground-water discharge. A sample just above the confluence with Coyote Creek was not taken in 1986 (as suggested by Figure 2). Samples were collected in 1987 and at this time tentatively suggest that the reach between Power Plant 3 and the confluence with Coyote Creek is gaining.

Isotopic analysis on the two lower reaches does not clearly show an isotopic shift between the Power Plants. The δD values do not shift enough to be significant, since all the values are within measurement error. Field trips taken in 1987 revealed that the reach between Power Plants 4 and 5 was losing due to a playing out of stream flow into the alluvium along this stretch. The stream flowed all the way between Plants 5 and 6 but showed no significant isotopic shift. Whether this stretch is stable or losing is unknown because this method will not detect such reaches. Data from $\delta^{18}O$ values showed similar results as those from the deuterium analyses.

In conclusion, an isotopic analysis of Bishop Creek shows that the upper diverted reaches are gaining while at least one of the lower two reaches are losing. In the future, it may be possible to quantify the amount of ground water discharging into Bishop Creek using an isotopic-mass balance equation. It may also be possible to determine the water source(s) of vegetation using isotopes. At this time laboratory methods are being tested to determine how to extract tree water from wood samples without fractionation. The isotopic signature of the tree water should reflect one or more of the isotopic values of the various waters found in the watershed. These are surface water, ground water, and soil water. Knowledge of the water sources to vegetation will give a better understanding to the possible stresses that can occur to the riparian vegetation due to man-made diversions.

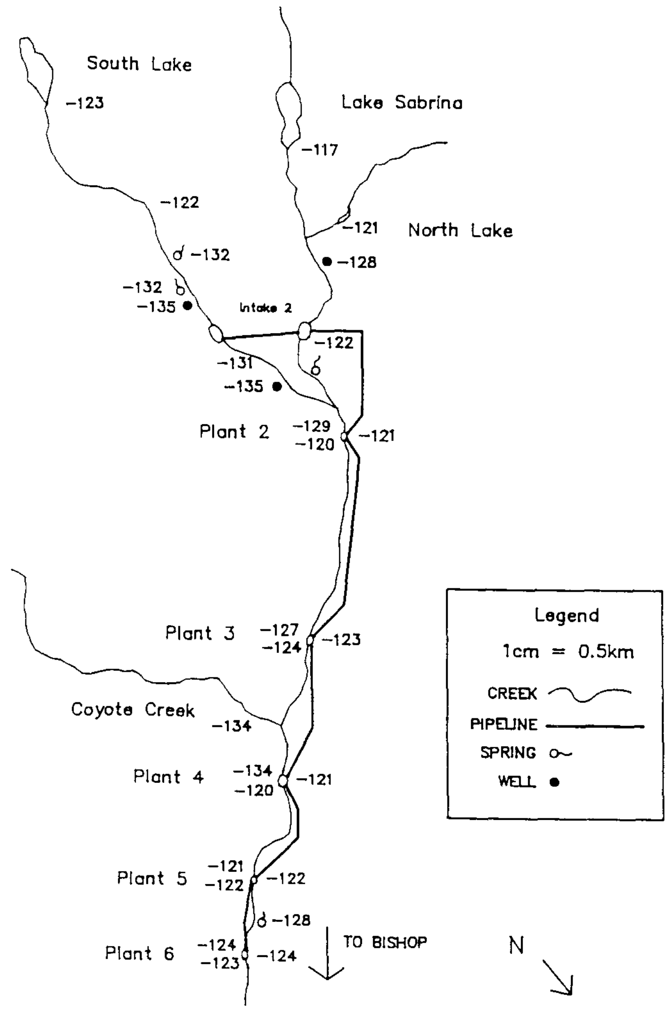

Figure 3– Del δD values (per mil) for September 1986.

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STREAM-GROUNDWATER INTERACTIONS ALONG STREAMS OF THE EASTERN SIERRA NEVADA, CALIFORNIA: IMPLICATIONS FOR ASSESSING POTENTIAL IMPACTS OF FLOW DIVERSIONS[1]

G. Mathias Kondolf[2]

Abstract: One of the most fundamental hydrologic determinations to be made in assessing the probable impacts of flow diversions on riparian vegetation is whether flows are gaining or losing water to groundwater in the reach of interest. Flow measurements on eight streams in the Owens River and Mono Lake basins show that stream- groundwater interactions can produce substantial changes in flow; these changes can vary among streams, along one stream, and in different seasons. Over one stream reach, autumn baseflow increased nearly three-fold from groundwater contributions; in another, summer flow decreased 50 percent.

Increasing recognition of the ecological importance of riparian zones (Johnson and others 1985) coupled with a recent proliferation of proposals to divert water from streams for hydroelectric development has led to growing interest in developing techniques to assess the probable impacts of flow diversions on riparian vegetation. The potential impact of a diversion on riparian vegetation will depend on a variety of factors, including the magnitude of the diversion and/or storage relative to the natural flow, and the geomorphic, hydrologic, climatic, and ecological characteristics of the site.

One of the most fundamental hydrologic determinations to be made is whether a stream is *gaining water* from groundwater (a gaining reach), *losing water* to groundwater and evapotranspiration (a losing reach), or *in equilibrium* with respect to groundwater. There is general agreement that riparian vegetation along losing reaches may be more sensitive to flow reductions than that along gaining reaches: The shallow water table in a losing reach is probably dependent on flow, whereas, in a gaining reach, riparian vegetation may be supported by inflowing groundwater (Risser and others 1984).

Flow gains and losses were measured on eight reaches of streams draining the eastern slope of the Sierra Nevada in California. Seven of these reaches (tributaries to the Owens River) have been proposed for diversion for hydroelectric development and were studied expressly to develop data for assessing the probable impacts of the developments (FERC 1986); the eighth stream (Rush Creek, a tributary to Mono Lake) was studied for a fish habitat study conducted for the California Department of Fish and Game (Kondolf 1988). The purpose of this paper is to present data on gains and losses in flow for all eight study reaches and their implications in assessing probable impacts of flow reductions on riparian vegetation.

Study Area

The study reaches are located along the steep, eastern front of the Sierra Nevada Mountains, California (figures 1 and 2). Topographic relief is remarkably high, with peaks exceeding 4000 m in elevation less than 30 km west of the floor of the Owens Valley, where elevations are generally less than 2000 m. Precipitation occurs primarily as snow at higher elevations. The area east of the mountain range lies in a rain shadow; the town of Bishop receives only 145 mm of precipitation annually (California Department of Water Resources 1980). As a result of this climatic pattern, most runoff in the study streams is derived from snowmelt high in the watershed. The lower reaches of these snowmelt-fed streams (including the study reaches) flow through a semiarid environment.

Riparian vegetation in the study area is found primarily along perennial stream courses and major springs, and is extremely limited. In the Inyo National Forest, where most of the study reaches are located, riparian areas account for only 0.4 percent of all land (Kondolf and others 1987). Riparian vegetation has already been affected in this century by numerous diversions for extra-basin water transfers, hydroelectric generation, and irrigation in the Owens and Mono basins (Vorster and Kondolf, these proceedings). The California Department of Fish and Game has estimated that 88 percent of the stream miles in the Owens-Mono region have been affected by diversion, including 20 percent totally diverted (Wong and Shumway 1985).

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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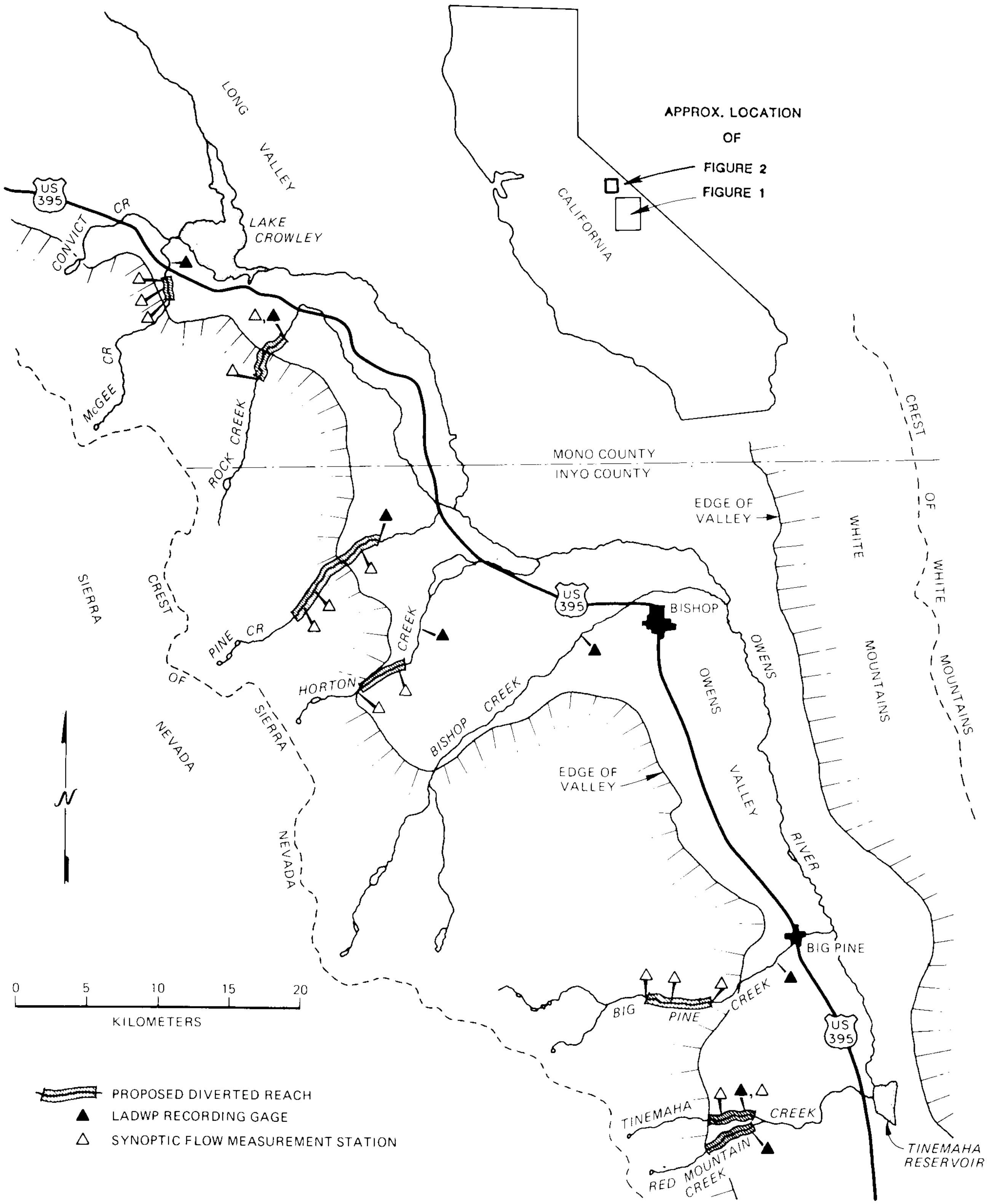

Figure 1— Location map for streams tributary to the Owens River. Reaches proposed for hydroelectric diversion are *highlighted*; stream gages are designated by *solid triangles*; synoptic flow measuring sites are designated by *open triangles*; (Adapted from Kondolf and others 1987)

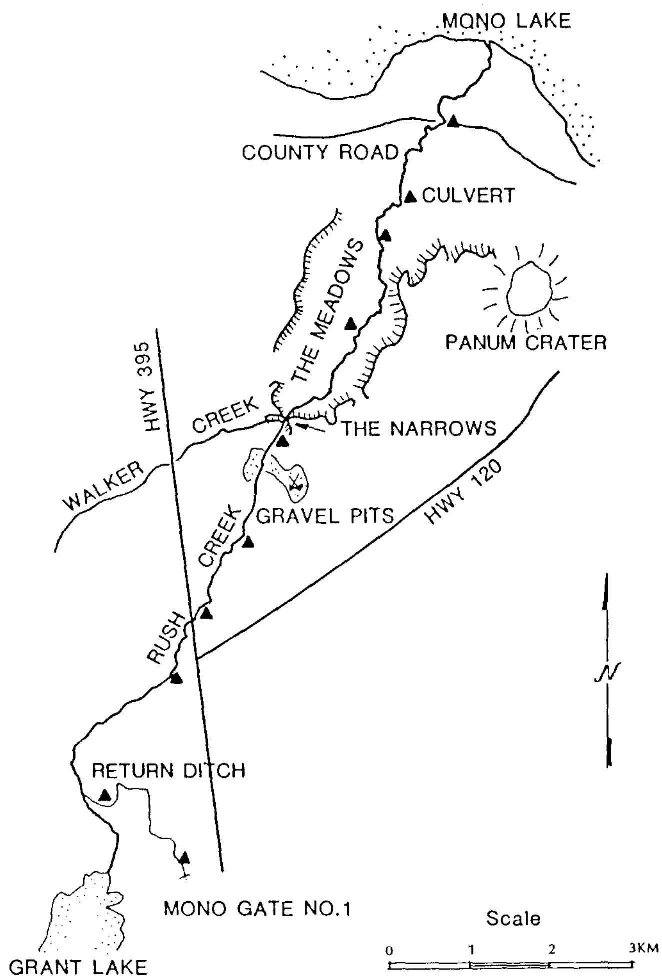

Figure 2 – Location map for Rush Creek below Grant Lake, showing the Hwy 395 crossing and the culvert, sites of principal flow losses. Synoptic flow measuring stations are designated by *solid triangles*.

Methods

To quantify gains and losses in streamflow, *synoptic flow measurements* were made along seven of the study reaches. The procedure was to select days of steady or very slowly changing stage, measure the flow at two or more sites along the length of the stream, and, allowing for tributary contributions and surface diversions, compute the gains and losses in flow between the measuring stations. The measurements are treated as simultaneous, and with the assumption of steady flow, changes in flow can be attributed to groundwater interactions or evapotranspirative losses along the intervening reach. Water velocity was measured with Price AA or pygmy current meters, and standard procedures of the US Geological Survey (Rantz and other 1982) were employed in computation of flow. On Red Mountain Creek, downstream changes in flow were computed from historical flow records for the existing gage and a discontinued gage upstream (Kondolf and others 1987).

On the Owens River tributaries, flow was measured at only two or three sites, and measurements were repeated three times or less, all at flows reflecting natural runoff from the basins. However, on Rush Creek, flow was measured at eight-to-ten sites, and the measurements were repeated six times in different seasons and at different flow releases from an upstream reservoir. As a result, more detailed information is available on downstream flow changes in Rush Creek than in the other streams.

Locating cross sections with flow characteristics favorable for flow measurement was challenging. The Owens tributary study reaches were very steep (table 1) and consisted largely of boulder cascades with extremely turbulent hydraulics. Measurements in such sites would be subject to large errors because of the nonlogarithmic form of the vertical velocity profile (Jarrett 1985). To measure potentially subtle changes in flow, it was necessary to locate (after extensive searching) sites with more uniform flow characteristics (usually in lower gradient pools), even if this required going several hundred meters upstream of the study reach boundary. The Rush Creek study reach was nearly an order of magnitude less steep than the other sites, and good sites were not as difficult to locate. Nonetheless, extreme care was taken to locate the best possible sections there as well. At most measuring sites, rocks were rearranged on the channel bed to achieve more uniform flow and thereby improve measurement accuracy.

Results and Discussion

General Observations

Net unit changes in flow for the study reaches are presented, with other hydrologic data for the study reaches, in table 1. All the study reaches lying entirely east of the base of the mountain front were characterized by net losses, while the only study reach entirely west of the front (Big Pine Creek) was gaining, as was one of the two reaches crossing the mountain front (Pine Creek)(figure 1).

The study reaches on Tinemaha and Red Mountain Creeks are typical of stream reaches crossing alluvial fans along the eastern Sierra Nevada front. The fans are composed of relatively permeable sediments with water tables typically at depths of tens of meters, although perched water tables may exist immediately under the riparian corridors of the streams. (Unpublished groundwater data on file at the Los Angeles Department of Water and Power office, Bishop, CA.)

Table 1– Hydrologic data for study reaches, eastern slope Sierra Nevada

Stream	Drainage Area [a] (km^2)	Avg. Flow [a] (m^3/s)	Reach Distance [b] (km)	Avg. Slope [b] (m/m)	Date of Msmt.	Upstream Flow (m^3/s)	Unit Change ($m^3/s/km$)
PERCHES ON BEDROCK-FLOORED VALLEYS WEST OF ESCARPMENT							
Big Pine Creek	82	1.18	4.3	0.099	8/19/85	1.44	0.032
					10/31/85	0.39	0.014
PERCHES ON ALLUVIAL AND GLACIAL SEDIMENTS EAST OF ESCARPMENT							
McGee Creek	54	0.84	1.8	0.082	7/31/85	0.97	-
					10/29/85	0.46	-0.032
Horton Creek	35	0.24	3.1	0.165	10/31/85	0.12	-0.001
Tinemaha Creek	21	0.24	2.4	0.115	8/13/85	0.39	-0.033
Red Mountain Creek [c]	24	0.12	4.2	0.099	Aug-mean	0.20	-0.008
					Oct. mean	0.10	-0.005
Rush Creek	131	2.39	13.0	0.015	8/21/87	0.57	-0.024
					9/05/87	1.74	-0.026
					9/07/87	1.29	-0.029
					9/09/87	2.71	-0.028
					10/22/87	0.38	-0.012
					11/28/87	0.58	-0.015
PERCHES CROSSING THE EASTERN ESCARPMENT							
Rock Creek	93	0.86	4.3	0.072	8/20/85	0.72	-0.030
					10/30/85	0.41	-0.004
Pine Creek	98	1.34	7.0	0.07	7/30/85	0.88	0.097
					8/20/85	0.42	0.109
					10/07/85	0.25	0.099

a Average flows from Los Angeles Department of Water and Power (LADWP) gaging records through 1985. Drainage areas for LADWP gages from USGS topographic maps.

b. Owens River tributary study reaches were reaches proposed for diversion. Lengths and gradients were measured from USGS topographic maps.

C. Flow losses in Red Mountain Creek were determined from analysis of historical gaging records for an upstream-and-downstream gage pair; values presented here correspond to long-term mean monthly flows for August and October.

Given this geomorphic setting and the fact that virtually all the runoff is derived from high-elevation snowmelt, it is not surprising that such stream reaches typically lose water to groundwater. Historical gaging records for the upstream-downstream gage pair on Red Mountain Creek indicate that losses are greater for higher summer flows (Kondolf and others 1987).

The McGee and Horton Creek study reaches flow between lateral moraines, and thus can be assumed to be flowing largely over till. Till would likely be less permeable than alluvial fan deposits, but these reaches consistently showed losses as well. Conditions on Rush Creek are more complex, but under the present hydrologic regime, it too, loses water to groundwater over the study reach.

The Big Pine Creek study reach lay west of the mountain front and was characterized by gains in flow. The Rock Creek study reach, which traversed the mountain front, evinced losses in flow. The largest changes in flow were observed over the Pine Creek study reach, which gained a relatively constant 0.1 $m^3/s/km$ from groundwater as it crossed the mountain front.

In summary, reaches flowing over the alluvial and glacial deposits east of the mountain front were generally losing, while two out of three reaches west of or crossing the mountain front were gaining (figure 3).

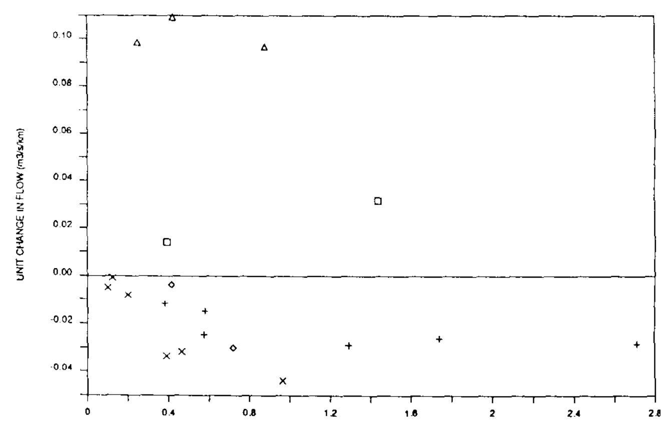

Figure 3- Rates of downstream change in flow plotted against flow at the upstream end of each study reach. Data from table 1. Symbols: Rush Creek (+'s), other streams east of the escarpment (*x*'s), Big Pine Creek (*squares*), Pine Creek (*triangles*), and Rock Creek (*diamonds*).

Pine Creek

Flow in Pine Creek showed remarkable downstream increases from groundwater inflow near the fault-bounded mountain front. The increases included contributions from two short, spring-fed tributaries as well as from direct groundwater inflow. The net downstream increase remained quite constant over the course of three measurements in July, August, and October. Because this seasonally consistent increase was added to a progressively declining contribution from upstream, the percentage increase over the study reach rose from 77 percent in July to 275 percent in October.

These measurements contradicted earlier estimates of the amount of water available for diversion at the upstream end of the reach proposed for diversion. The only gage in the Pine Creek study reach is operated by the Los Angeles Department of Water and Power (LADWP) and is located near the downstream end of the reach. To estimate flow upstream at the proposed point of diversion, the applicant for the hydroelectric project adjusted the gage flows for the smaller drainage area at the upstream site and for differences in precipitation. Based on these considerations, the applicant assumed flows at the proposed point of diversion to be 76 percent of the flows at the LADWP gage (Keating 1982). During weeks of high snowmelt flows, this is probably a reasonable approximation. However, during other times of the year, actual flows are probably quite different.

The applicant's estimate of flow at the upstream site can be compared with the results of synoptic flow measurements in July, August, and October, all expressed as percentages of total flow at the downstream gage, in figure 4. These measurements indicate that there is considerably less water available at the proposed diversion site than assumed by the applicant, a fact with potentially profound implications not only for riparian vegetation in the reach, but also for the economic viability of the project itself.

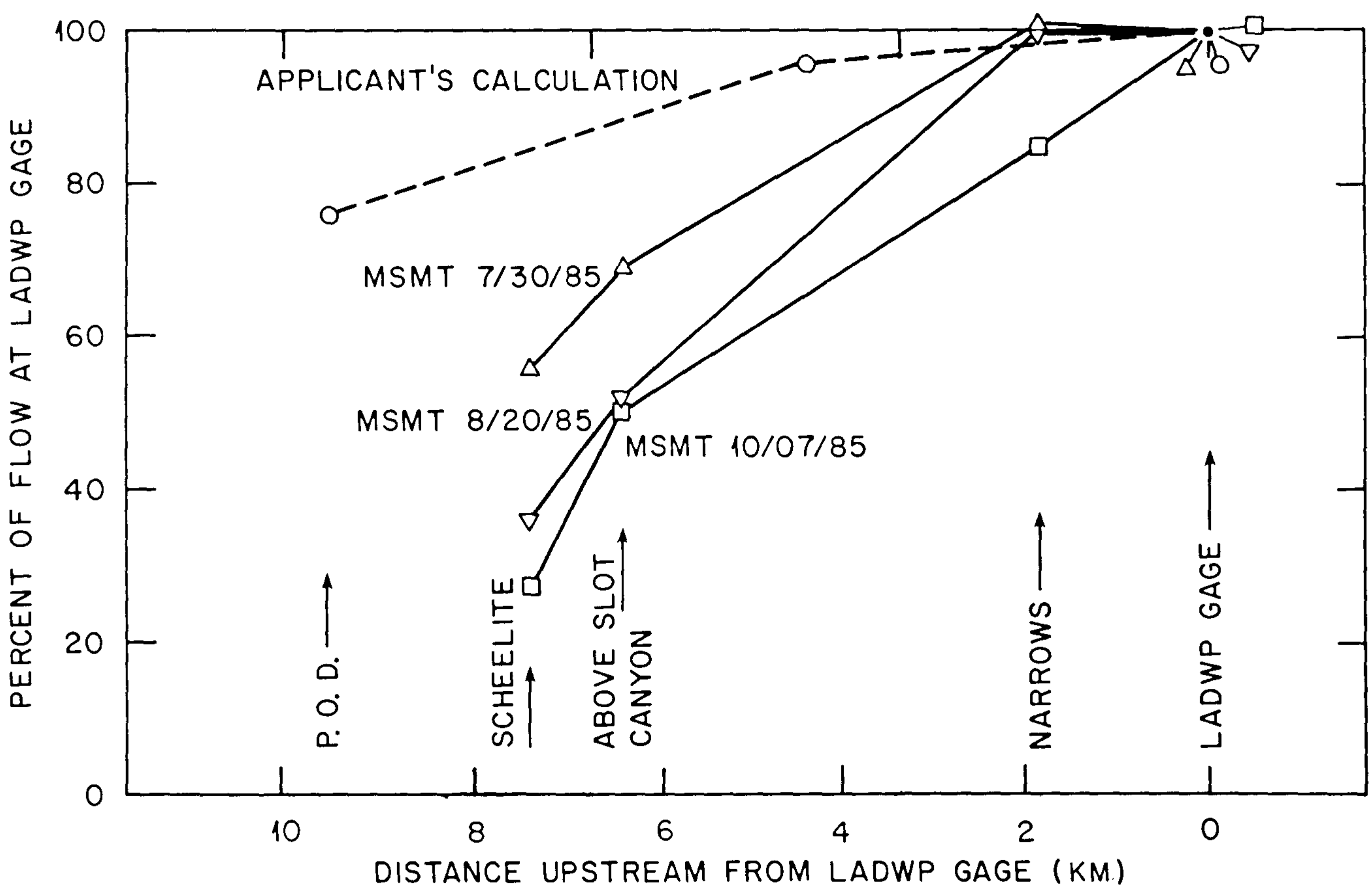

Figure 4— Flows in Pine Creek upstream of stream gage as calculated by applicant (*dashed line*) and as measured in this study (*solid lines*), expressed as percentage of flow at gage. Downstream is from left to right. (Adapted from FERC 1986)

Rush Creek

Rush Creek, the largest tributary to Mono Lake, flows from the eastern Sierra front across alluvium and deposits of a large Pleistocene lake, into the modern lake (figure 2). Results of flow measurements along Rush Creek show some interesting patterns (figures 5 and 6). First, flow losses are concentrated at two points in the channel, both at transitions (contacts) in the underlying geological units. The greatest flow loss, averaging 0.2 m^3/s occurred over a 2 km reach near the US Highway 395 bridge. It is at about this point that the creek, which had been flowing on silty lacustrine deposits, cuts through those deposits and flows over gravels (deposited by the ancestral Rush Creek) with a deep water table (Lajoie 1968). The high permeability of the gravels and the deep water table result in high rates of infiltration. Downstream, the stream continues to flow mostly over gravels through the meadow reach, but here the water table is relatively shallow and the streamflow is relatively constant as groundwater and tributary inflow are balanced by evapotranspirative demand and losses to groundwater. However, about 11.5 km downstream of Grant Lake, the stream begins to flow over volcanic blast deposits from a nearby crater. (Unpublished map prepared by R. Bailey, USGS, Menlo Park, CA.) These deposits are very permeable and, evidently, well-drained so that an average 0.1 m^3/s is lost into them over a 2 km reach.

Second, losses can be quite high. Of the minimum flow release presently required from Grant Lake (0.54 m^3/s), 50 percent is lost along the study reach during summer months.

Third, for a given flow, losses are very different from summer to winter, but are quite similar at very different releases in one season. In the summer, net flow losses over the entire reach varied only from 0.32 to 0.38 m^3/s for releases ranging from 0.54 to nearly 2.83 m^3/s. At a flow release of about 0.54 m^3/s, flow loss in the winter measurement was only 0.20 m^3/s, compared to a loss of 0.32 m^3/s in the summer measurement.

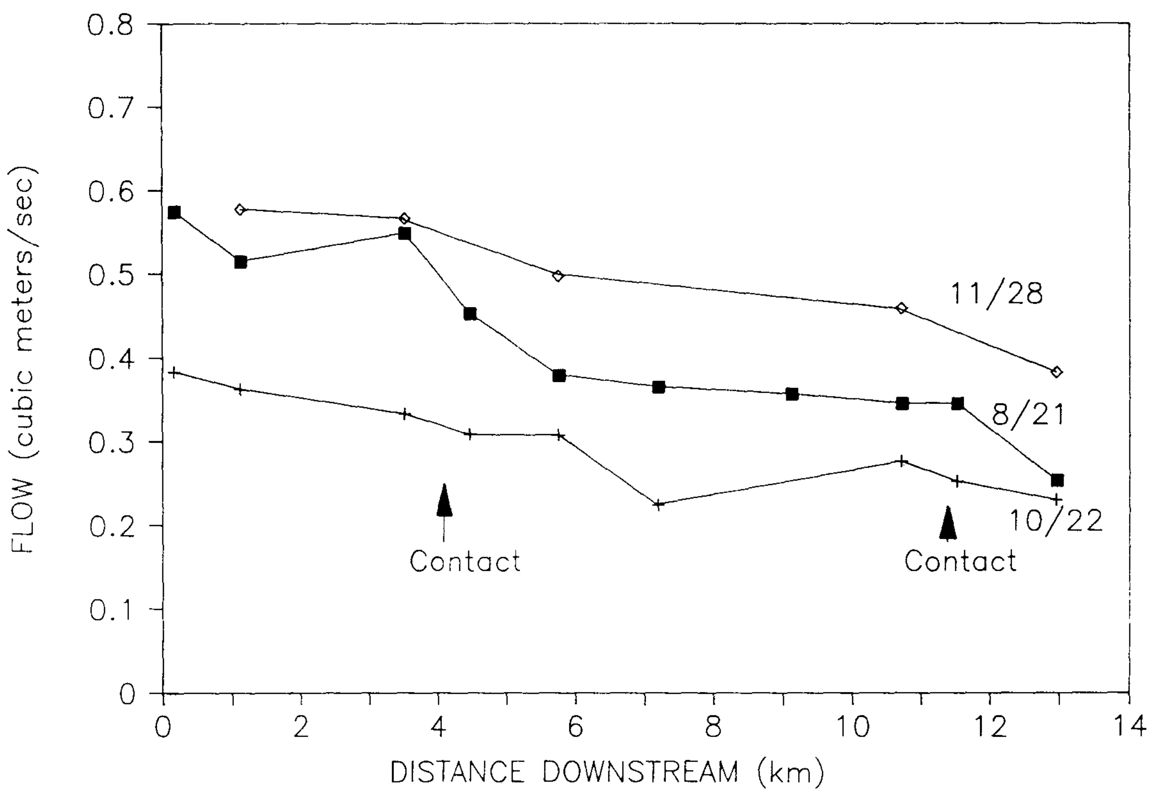

Figure 5– Flow measurements along Rush Creek at releases of 0.54 m^3/s and plotted against distance downstream of Grant Lake Reservoir. Each point represents a nearly simultaneous measurement of flow on the date indicated at the right. Losses were concentrated at two geological contacts: between lake silts and gravels (at about 2.5-3.0 km), and between granitic gravels and volcanic blast deposits (at about 7 kn). For the same 0.54 m^3/s release, net flow loss was much greater in August than in November.

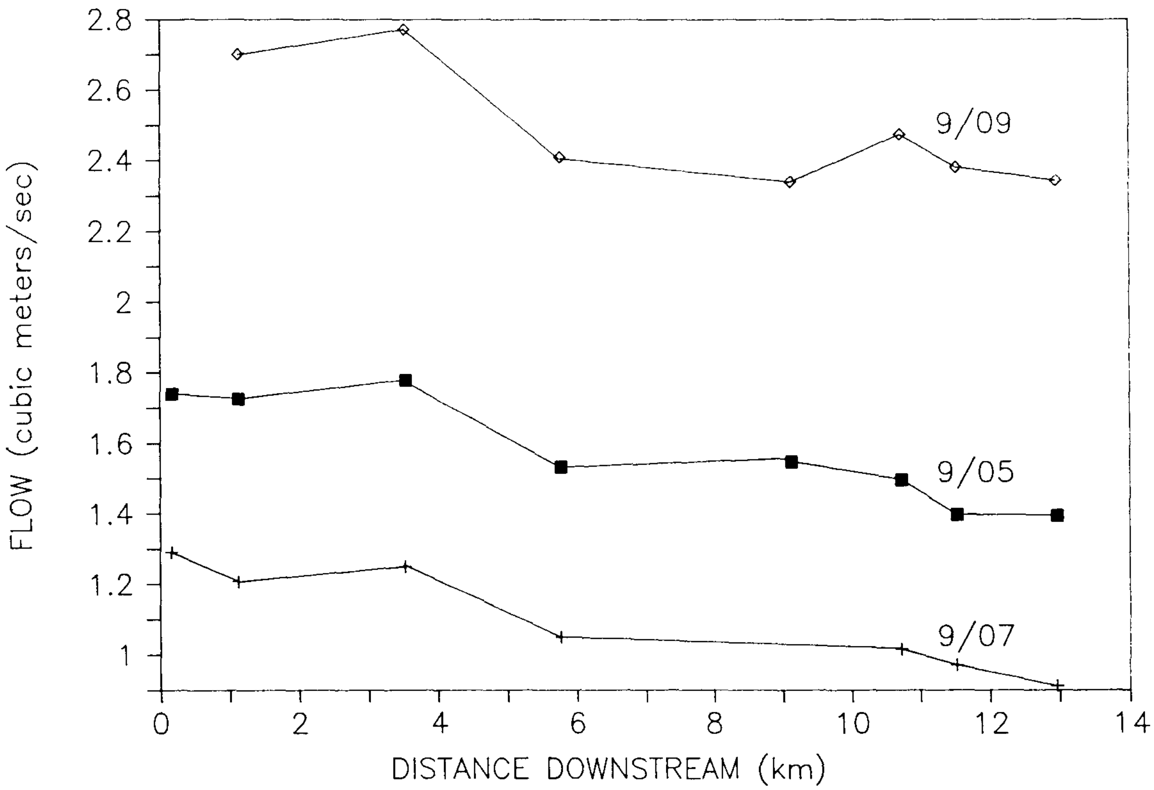

Figure 6– Flow measurements along Rush Creek at releases of 1.3, 1.7, and 2.8 m^3/s in early September. Despite the wide range in releases, net flow losses were similar.

One is inclined to attribute these seasonal differences in loss rates to evapotranspirative demand (ET). In this case, however, the differences may be greater than can reasonably be explained by ET. Estimates of woody riparian acreage along Rush Creek and probable rates of ET indicate that only about 0.023 m^3/s can be attributed to ET from woody vegetation in the summer months. (Unpublished data, Duncan Patten, Arizona State Univ., Tempe, AZ.) This estimate does not include ET from meadows, and much of the vegetation is newly emergent, so its ET demand may be higher than expected. Earlier estimates of ET losses were comparable in magnitude to the seasonal difference (NAS 1987). Thus, the seasonal pattern is not entirely explained, but the empirical observations can still be profitably applied to specifying flow releases required from the reservoir to satisfy minimum flows for aquatic and riparian resources along the entire stream.

Historical gaging records show that Rush Creek was a gaining stream in the lowest 3 km of the study reach earlier this century. Some of this inflowing groundwater was probably derived from irrigation water extensively applied to lands adjoining the stream; some was probably simply natural drainage effected by the deep incision of the channel below the surrounding countryside.

Conclusions

Synoptic flow measurements demonstrate that streams of the eastern front of the Sierra Nevada can undergone substantial changes in flow along their lengths because of stream-groundwater interactions. For example, October baseflow on Pine Creek increased nearly threefold over the study reach from groundwater contributions, while on Rush Creek, the court-prescribed minimum flow release of 0.54 m^3/s decreased by over 50 percent over the study reach in the summer. Clearly, flow changes of this magnitude must be accounted for in any analysis of potential impacts of future flow diversions.

If losing streams are regarded as more sensitive to diversion than gaining streams (Risser and others 1984), it follows that, once losing reaches are identified, resources there should be monitored especially closely. The patterns of gain/loss have implications for the design of instream flow monitoring programs. For example, on a losing stream, flow should be gaged near the downstream end of the diverted reach, where flows are likely to be lowest. Thus, if instream flow requirements are met at the gaged site, they are probably met along the entire reach. Similarly, on gaining streams, instream flows should be monitored at the upstream end of the diverted reach, where flows can be expected to be lowest.

It is worth noting that reaches experiencing a net gain may include losing reaches (and vice versa). For example, Pine Creek is a losing stream in the upper 3 km of study reach, as evidenced by measurements of riparian water table levels (Kondolf and others 1987) and observations of a dry streambed along part of the stream in February of 1987. (Tom Felando, Inyo National Forest, pers. comm., 1987.) Thus, observations along different portions of a reach may be needed to pinpoint gaining and losing reaches.

Because stream-groundwater interactions vary among different streams, along a given stream, and over time, assessment of site-specific conditions requires site-specific measurements, repeated in different seasons. Nonetheless, the data presented here suggest a few generalizations. Reaches east of the mountain front flow across alluvial and glacial deposits, and generally lose water to groundwater. On Red Mountain Creek the rate of loss is higher at higher flows, while on Rush Creek, the loss rate is conservative with flow but varies by season. Reaches that lie west of the mountain front for at least part of their length may gain water from groundwater.

Acknowledgments

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WATER RELATIONS OF OBLIGATE RIPARIAN PLANTS AS A FUNCTION OF STREAMFLOW DIVERSION ON THE BISHOP CREEK WATERSHED[1]

Stanley D. Smith, Janet L. Nachlinger, A. Bruce Wellington, and Carl A. Fox[2]

Abstract: We investigated the water relations of obligate riparian plants on paired diverted and undiverted reaches on Bishop Creek, Eastern Sierra Nevada. Riparian plants on diverted reaches had reduced stomatal conductance and water potential compared to plants on undiverted reaches in a dry year, but not in a high runoff year. Juvenile plants on diverted reaches had reduced stomatal conductance and lower midday water potentials relative to surrounding mature trees, a trend that was not observed on undiverted reaches. Plants on diverted reaches possessed significantly smaller, thicker leaves and a reduced total leaf area relative to trees on streamside reaches. Reduced community leaf area and effective stomatal control of water loss may allow riparian corridors on diverted reaches to retain their canopies in low runoff years. However, a long term consequence of partial streamflow diversion may be selective mortality of juvenile plants because of the elimination of floods and high flows.

Riparian plant communities in the semi-arid western U.S. occur in transition zones between aquatic andupland ecosystems, and are characterized by vegetation types that are adapted to, and tolerant of, relatively high soil moisture content (Swift 1984). Riparian plants have been thought to depend largely on flowing water rather than on groundwater, which separates them functionally from phreatophytes.

Riparian woodlands represent one of the most heavily modified vegetation types in the western U.S., having been reduced in area by more than 80% since presettlement times (Swift 1984). In California, riparian ecosystems are under considerable pressure as a result of increased needs for water and power. These ecosystems may also be highly dependent on streamflow because of the semiarid climate and predictable summer dry season which is characteristic of the region.

The primary objective of the present study was to analyze the water relations of riparian vegetation along Bishop Creek on the eastern slope of the Sierra Nevada Mountains, where a series of streamflow diversions have been in existence since the early 1900's. We wished to determine if streamflow diversions influence plant water relations, patterns of water use, and differential mortality of individuals at key life stages. We have examined daily and seasonal patterns of plant water potential, stomatal conductance and transpirational water loss of adults and juveniles of the dominant riparian species to determine how these patterns may be affected by streamflow diversion.

Materials and Methods

Study Sites and Species

Physiological observations of riparian vegetation on the east slope of the Sierra Nevada were conducted on Bishop Creek, Inyo County, California. Bishop Creek has a well defined series of streamflow diversions, including three catchment lakes, two primary intakes, and five power stations (Fig. 1). Two primary sites of differing elevation were selected for study (Fig. 1). One site, called the Four Jeffrey Site, was located below the Intake 2 South Fork diversion near the U.S. Forest Service Four Jeffrey campground (37° 15' N, 118° 36' W, 2465m). A second site, called the Plant Six Site, was located along the lowermost stretches of Bishop Creek at Southern California Edison Plant Six (37° 21' N, 118° 28' W, 1400 m). Zonal (upland) vegetation adjacent to the two sites was dominated by sagebrush (*Artemisia tridentata*) at Four Jeffrey and a mixed community of Mojave Desert shrubs at Plant Six. Each site was selected so as to include riparian vegetation growing in a streamside environment and in a reduced or diverted streamflow environment. At Four Jeffrey, this entailed comparing a streamside reach with a dry channel located about 100m from the creek that had a riparian corridor. At Plant Six, paired sites we re-selected above (diverted) and below (undiverted) the power station.

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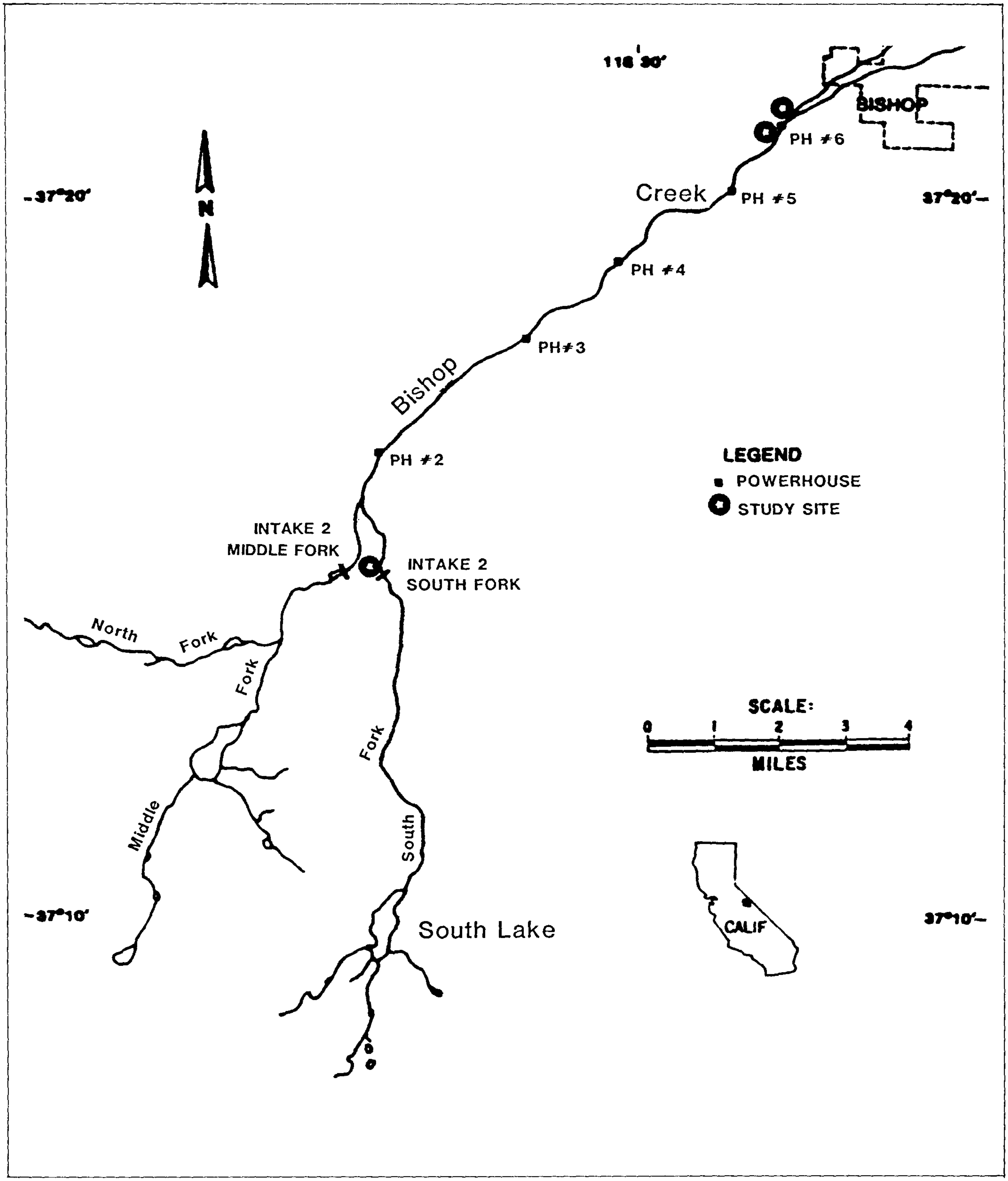

Figure 1— The Bishop Creek Watershed, showing the South, Middle and North Forks (left to right, top) merging into a single channel. A primary pair of intakes (Intake 2) divert water to a series of hydroelectric generating station (Plant 2 - Plant 6). The primary study sites were Four Jeffrey, located below Intake 2 (top), and Plant Six (bottom).

Three dominant riparian plant species were selected for measurement on Bishop Creek: water birch (*Betula occidentalis* Hook.); black cottonwood (*Populus trichocarpa* T. & G.); and Fremont cottonwood (*Populus fremontii S.* Wats. ssp. *fremontii*). All three taxa are obligate riparian plants in the region. *Populus trichocarpa* only occurred at higher elevations on Bishop Creek, including the Four Jeffrey site, whereas *P. fremontii* only occurred at lower elevations, including the Plant Six site. Observations were also made on willows (*Salix* spp.).

For each species at the two paired study sites on Bishop Creek (Fig. 1), three adult individuals and three juveniles were chosen for measurement. Adults were at least 3m in height, whereas juveniles were either saplings or vegetative suckers less than lm tall. When present, first year seedlings were also monitored.

Measurements were made approximately monthly at Bishop Creek, from July to September 1985 and from May to September 1986.

Plant Water Relations and Morphology

Diurnal patterns of stomatal conductance, transpiration, and the microclimate of selected leaves were determined for the sample plants at a paired site on a given day. Measurements were made at 60 to 90 minute intervals with a Lambda Instruments LI-1600 steady state porometer (LI-COR, Lincoln, Neb.) Abaxial leaf surfaces were measured on two leaves of each plant and comparative readings of adaxial and abaxial leaf surfaces were made periodically. Incident photon flux density was measured for individual leaves with a Lambda Instruments LI-190S quantum sensor. Plant water potentials (xylem potentials) were obtained for two to three leaves or shoots from each tagged individual both before dawn and at midday (1200 to 1300 h) with a portable pressure chamber apparatus (Soil Moisture Equip. Corp., Santa Barbara, Calif.).

In September 1986, twenty shoots (ca. 25 cm in length) were randomly harvested from each adult at the two sites on Bishop Creek. Shoots were stored in sealed bags on ice. Leaves on each shoot were counted, shoot lengths were measured, and total leaf area per shoot was measured with a Lambda Instruments LI-3000 leaf area meter. Dry weight of leaves and stems was determined after oven drying plant material at 80°C for 48h.

Results and Discussion

Mean monthly streamflows during the growing seasons of 1985 and 1986 for key reaches of Bishop Creek are given in Table 1. On the upper Bishop Creek watershed, streamflows above the diversion intakes were 0.6 to 1.3 m^3/sec (20-40 cubic feet per second) in 1985 and 1.1 to 3.0 m^3/sec (30-100 cfs) in 1986.

Table 1 - Mean monthly streamflow (in m^3 sec) for the Bishop Creek watershed during the 1985 and 1986 growing seasons. Sites are shown in Fig. 1. All flows above Intakes and below Plant Six are undiverted.

		Streamflow					
Date	Site	Apr	May	Jun	Jul	Aug	Sep
1985	Above Intakes*	1.12	1.33	0.63	0.77	0.97	0.87
	Four Jeffrey	0.08	0.30	0.10	0.10	0.07	0.11
	Above Plant Six	0.12	0.30	0.03	0.03	0.003	0.006
	Below Plant Six	4.16	4.68	4.29	3.81	3.32	2.92
1986	Above Intakes*	1.30	1.60	2.61	3.01	2.03	1.13
	Four Jeffrey8	0.11	1.06	1.69	2.20	1.28	0.08
	Above Plant Six	0.03	2.40	6.26	5.18	2.23	0.08
	Below Plant Six	9.06	9.23	9.13	9.06	9.06	8.13

*Mean value for Middle and South Forks of Bishop Creek.

The Four Jeffrey Site, located below the South Fork diversion, exhibited a streamflow of less than 0.1 m^3/sec throughout most of 1985 but about 1-2 m^3/sec in 1986. The dry creek at Four Jeffrey had no observable flows during any of our measurement periods, but based on the presence of a well-developed riparian corridor we can assume it had maintained perennial flow in the past.

Water that is diverted from Bishop Creek and pumped through power plants 2-6 (see Fig. 1) re-enters Bishop Creek below Plant Six. At the Plant Six undiverted reach (below the power station), streamflows averaged 3.9 m^3/sec (120 cfs) in 1985 and 9 m^3/sec (280 cfs) in 1986. In contrast, streamflows in the diverted reach above Plant Six averaged 0.08 m^3/sec (2.5 cfs) in 1985 and 2.7 m^3/sec (100 cfs) in 1986. High flows at the diverted site did not cease until early September in 1986. A comparison of these flows with past records for the whole watershed indicates that 1985 was a low flow year and 1986 was a high flow year.

Seasonal trends in maximum (predawn) and minimum (midday) water potentials are shown for *Betula occidentalis* at Four Jeffrey (Fig. 2), and *Populus fremontii* at Plant Six (Fig. 3).

Minimum water potentials were obtained around midday (1200-1300 h), based on representative diurnal curves of plant water potential (data not shown). A comparison of these data sets suggest the following trends: (1) both predawn and midday water potentials tended to be lower in the low flow year than in the high flow year; (2) minimum water potentials tended to be lower on diverted than on undiverted reaches, a pattern which was not observed for predawn water potentials; and (3) there were no consistent differences in water potentials between adult and juvenile plants of the same species.

Although no predawn water potentials that could be interpreted as stressful were observed in either year, minimum water potentials reached -1.2 MPa or lower in several species.

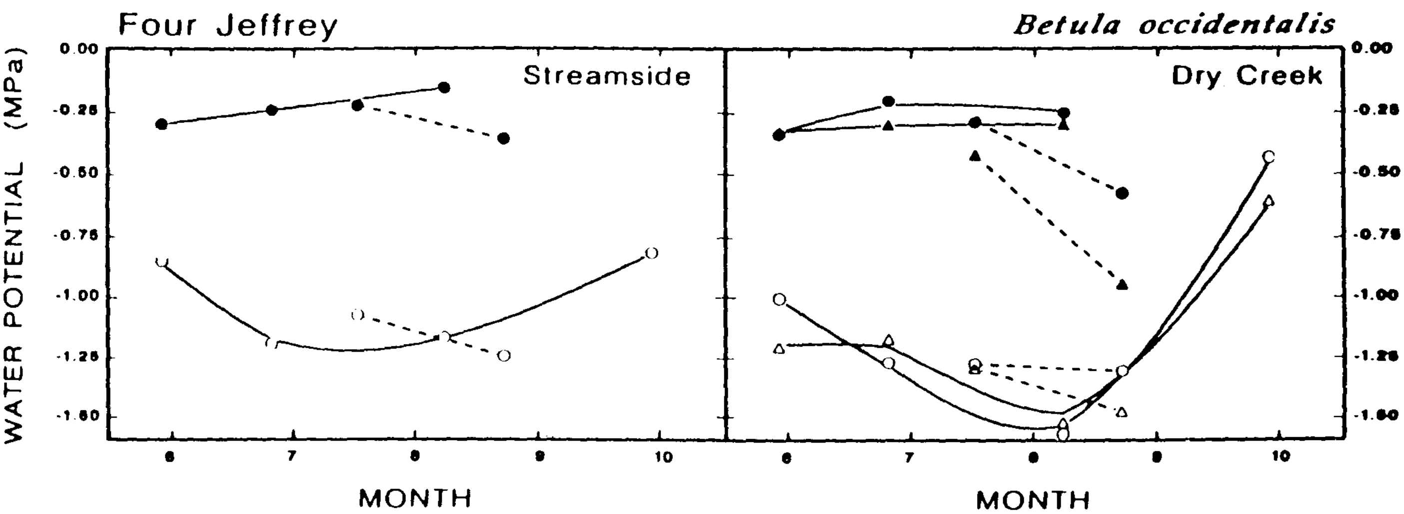

Figure 2— Seasonal patterns in plant water potential (xylem potential) for *Betula occidentalis* at the Four Jeffrey site. Data are for the growth seasons of a high flow year (solid lines) and a low flow year (dashed lines) for both adult (circles) and juveniles (triangles) plants. Water potentials were obtained at predawn (solid symbols) and at midday (open symbols).

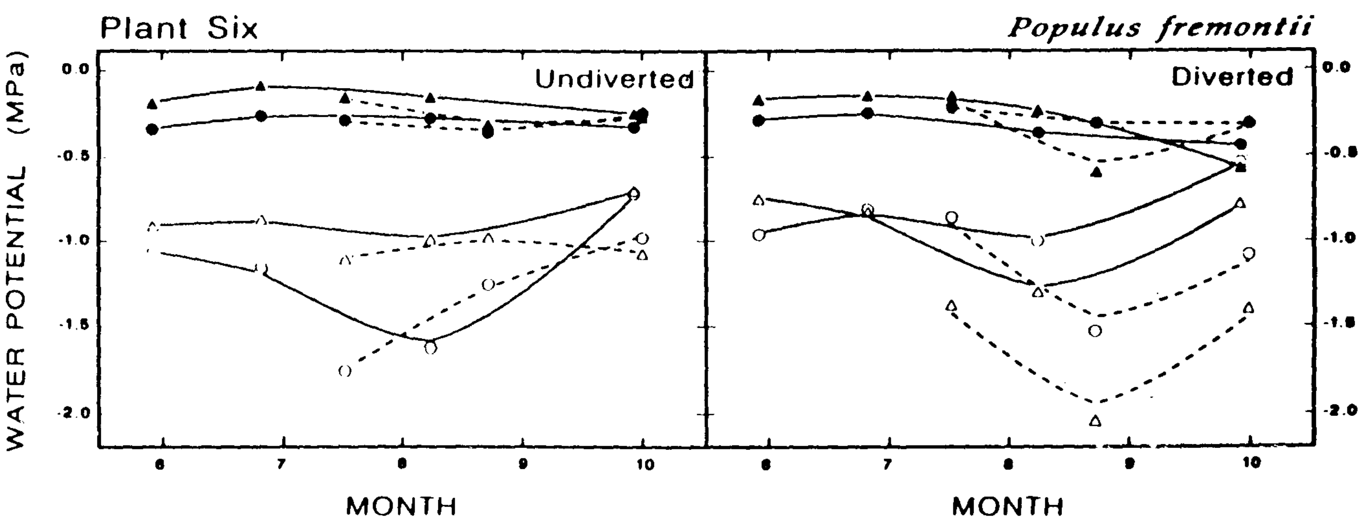

Figure 3— Seasonal patterns in plant water potential (xylem potential) for *Populus fremontii* at the Plant Six site. Legends are as in Fig. 2.

This was particularly the case on diverted reaches in the low flow year. Woodhouse (1983) observed *P. trichocarpa* and *Salix laevigata* to reach photosynthetic compensation at about -1.2 MPa, while Schulte and coworkers (1987) found *P. trichocarpa* to exhibit bulk leaf turgor loss at about -1.4 MPa. *Betula occidentalis* and *P. fremontii* both reached minimum water potentials below -1.5 MPa in late summer, but only on diverted reaches (Figs. 2 and 3). Several juveniles of *P. fremontii* reached water potentials below -2.0 MPa on the diverted reach at Plant Six in August of the low flow year. Such levels of water stress would certainly be anticipated to adversely affect carbon balance of these young plants, and may result in selective mortality in the regenerating population.

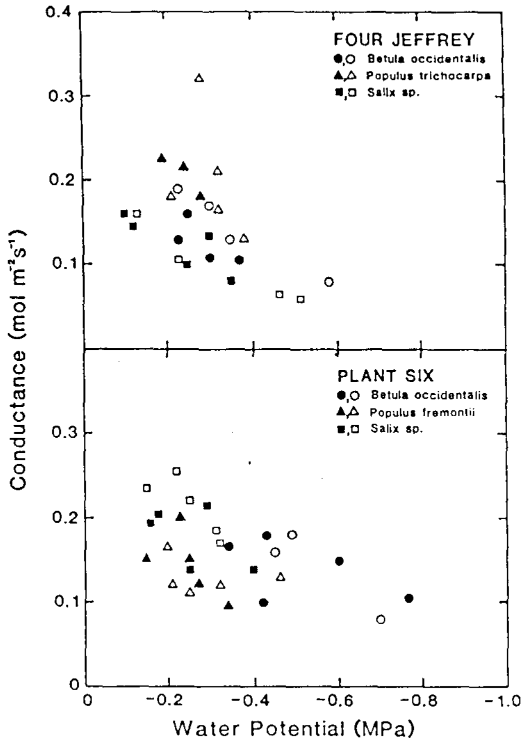

Figure 4– Diurnal patterns in stomatal conductance of *Betula occidentalis* (top) and *Populus trichocarpa* (bottom) at the Four Jeffrey site in August of the low flow year. Closed and open symbols designate undiverted and diverted reaches, respectively, for adult (circles) and juvenile (triangles) plants.

Similar seasonal and diurnal courses in stomatal conductance within a given species were found on diverted and undiverted reaches during much of the growth season. Variations occurred only during times of dry weather and low flow, as shown for *B. occidenialis* and *P. trichocarpa* in August of the low flow year (Fig. 4).

Mature plants on the diverted reach showed much lower conductance than did plants from the undiverted reach through a majority of the day, but particularly after about 1000 h. Furthermore, juvenile plants showed even greater reductions in conductance on the diverted reach. Similar reductions were not observed at the Plant Six site, possibly because small flows were maintained on the diverted reach even during the driest months of the year (Table 1). However, we monitored several first-year seedlings of *P. fremontii* on the diverted reach and found stomatal conductances in these plants during the midday period to be only 10-20% of that observed in older juveniles and mature plants.

Comparative plant morphologies of *B. occidentalis, P. fremontii,* and *P. trichocarpa* on paired diverted vs undiverted reaches are given in Table 2 for plant samples harvested at the end of the growth season in the high flow year. Plants on diverted reaches produced significantly smaller leaves at reduced leaf area, and had higher specific leaf weights relative to plants on undiverted reaches. Similar trends were observed in adult and juvenile plants of each species. In some cases the morphological differences between paired sites were substantial.

Table 2—Comparative morphology of riparian plants on paired undiverted and diverted reaches at two sites on Bishop Creek. Harvests were taken late in the growth cycle of a high flow year. (*) Indicates a significant difference (t-test; p=0.05) between paired undiverted-diverted sites for each parameter. Total leaf area was not recorded for juveniles.

			Individual leaf area (cm²)		Leaf area/branch length (cm² · cm⁻¹)		Specific leaf weight (mg · cm⁻²)	
			Undiverted	Diverted	Undiverted	Diverted	Undiverted	Diverted
Betula occidentalis	Four Jeffrey	Adults	9.93	4.68*	5.17	3.22*	4.61	6.44*
		Juveniles	9.66	4.70*			4.61	6.08*
	Plant Six	Adults	8.50	6.78*	4.35	3.51*	6.56	9.35*
Populus trichocarpa	Four Jeffrey	Adults	25.28	20.97*	15.20	11.84*	6.08	9.60*
		Juveniles	16.63	14.69			6.24	11.77*
Populus fremontii	Plant Six	Adults	19.58	6.39*	8.67	2.85*	10.86	8.64*
		Juveniles	15.24	9.94*			11.65	10.51

In summary, we conclude that streamflow diversions may remove water normally available to shallow-rooted juvenile plants, while deep-rooted mature trees remain largely unaffected. Thus, it is doubtful that partial diversion of streamflows will result in substantial mortality of the riparian corridor over the short term. However, its more long term consequence could be the elimination of floods and high flows which stimulate regeneration and full canopy development of the riparian corridor.

For example, *B. occidentalis* exhibited a mean 52% reduction in leaf size on the diverted reach at Four Jeffrey, and *P. fremontii* exhibited three-fold higher total leaf area per unit stem length on the undiverted reach at Plant Six (Table 2).

Conclusions

A majority of our observations on mature trees showed few substantial differences in the water relations of riparian vegetation on diverted and undiverted corridors. One reason for this is an apparent morphological adaptation of the vegetation on diverted reaches to reduced flow regimes. As a result of a reduced community leaf area, these corridors should exhibit lower transpirational water loss under similar microclimatic conditions. Thus, effective stomatal control of water loss in concert with reduced community leaf area may allow the canopy to be retained during drought periods or in years of very low flow. Of primary importance in the physiological ecology of whole populations is the regeneration phase. Several studies have shown a shift in the age structure of riparian populations as a result of an inhibition of seedling establishment (Johnson et al. 1976; Boles and Dick-Peddie 1983). On Bishop Creek the absence of normal spring flooding due to control of streamflows may result in more xeric conditions for tree seedlings later in the summer and thus reduced seedling establishment. Our findings of increased stress in juvenile plants along diverted reaches suggests that lower, more controlled flow regimes may be detrimental to the regeneration process in these corridors. Indeed, we observed several cohorts of seedlings which did not survive the low flow year. Not surprisingly, many of these corridors with a history of streamflow diversion have been invaded by facultative riparian shrubs such as *Artemisia tridentata* and *Rosa woodsii.*

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RIPARIAN PLANT WATER RELATIONS ALONG THE NORTH FORK KINGS RIVER, CALIFORNIA[1]

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Abstract: Plant water relations of five obligate riparian species were studied along California's North Fork Kings River. Diurnal stomatal conductance, transpiration, and xylem pressure potentials were measured throughout the 1986 growing season and in mid-season in 1987. Patterns were similar for all species although absolute values varied considerably. Maximum stomatal conductance occurred early in the day and season during favorable environmental conditions and decreased as air temperature and the vapor pressure difference between the leaf and air increased. Maximum transpiration rates occurred in mid-morning and mid-summer resulting in estimated daily water losses per unit sunlit leaf area of 163-328 mol H_2O m^{-2}. Predawn xylem pressure potentials remained high in 1986 when streamflows averaged 1.41 m^3/s (50 cfs), however they were notably lower in 1987 at 0.7 m^3/s (25 cfs).

Riparian systems are heavily used for recreational and human resource values, for example, streams are often diverted for water and hydroelectric power generation. These uses sometimes conflict with inherent values of riparian systems, such as providing ecosystem stability and aquatic or terrestrial habitats. The conflict between natural values and diverting instream flows in riparian areas of the Sierra Nevada, California, has sparked several recent studies. These investigations are aimed at separating riparian vegetation responses to streamflow diversion from those vegetation responses resulting from natural community dynamics.

Streamflow diversion has been found to impact riparian vegetation both positively and negatively (Jones and Stokes 1985, Taylor and Davilla 1987, Taylor and Risser 1988). Harris and others (1987) found that the relative importance of these types of impacts depends largely on channel morphology and stream reach type. Remote sensing and stable isotope studies have been used to assess the hydrology, water sources and potential evapotransporation of Sierran watersheds with diversions (Hess and Smith 1987, Skibitzke and Associates 1987, Space and others these proceedings). These studies are providing data sets to generate a predictive model of vegetation responses to diversion.

The objectives of this study were to examine patterns of riparian plant water relations, determine how these patterns change as streamflow changes, and provide physiological data sets for a predictive model of vegetation responses to diversion. We attempted to determine if streamflow changes influence plant water relations, patterns of water use, canopy temperatures, and differential mortality of riparian individuals. We measured daily and seasonal patterns of stomatal conductance, transpiration, and plant xylem pressure potential of adult and juvenile riparian plants to determine how these patterns may be affected by diversion.

Materials and Methods

Study Sites and Species

Plant physiological measurements of riparian plants were made at two sites along the North Fork of the Kings River (36°48'N, 119°07'W, 370 m elevation). The primary site at One Mile Bar was located about 2.5 km downstream from Balch Camp where a uniformly deep, coarse, sandy substrate occurs. The second site, which was subject to less intensive sampling, was located at Balch Camp where a shallow substrate is composed of coarse sand, cobbles and boulders.

Five plant species were selected for measurement: *Alnus rhombifolia,* white alder; *Platanus racemosa,* California sycamore; *Salix gooddingii,* Goodding's willow; *S. hindsiana,* sandbar willow; and *S. laevigata,* red willow. The alder and sycamore are large trees with large, broadly ovate and palmate leaves, respectively. Goodding's and red willow are trees with large, lanceolate, and glabrous leaves, while the sandbar willow is a shrub with small, linear, and gray-villous leaves. All five species are considered to be obligate riparian plants. For each species 3-5 individuals of adults and juveniles were selected for measurement when present.

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Table 1 - Ambient air temperature, relative humidity, and streamflow at Balch Camp, and Soil moisture 2.5 km downstream from Balch Camp, North Fork Kings River, on dates of physiological measurements. Dashes indicate missing data values.

	T air (°C)		RH (%)		Stream-flow	Soil Moisture (%of dry mass
Date	Max	Min	Max	Min	(m³/2)	@1.2 m depth)
21 Apr 1986	----	----	---	----	49.3	22.7
8 May 1986	24.7	4.6	88.7	34.6	33.4	22.3
22 May 1986	25.6	5.4	81.4	27.7	38.0	22.5
4 Jun 1986	29.9	13.3	85.3	39.6	86.1	saturated
18 Jun 1986	28.8	13.7	83.6	34.5	35.1	21.3
2 Jul 1986	39.0	17.0	53.9	15.9	7.7	16.5
16 Jul 1986	33.3	15.6	51.1	15.0	2.4	14.5
30 Jul 1986	37.2	16.3	62.6	17.3	1.9	14.0
13 Aug 1986	----	----	----	----	1.4	13.0
27 Aug 1986	38.8	18.4	49.3	15.0	1.1	12.5
10 Sep 1986	30.3	9.8	36.2	15.0	1.0	12.3
24 Sep 1986[1]	18.6	14.6	89.6	80.0	3.1	----
8 Oct 1986	33.8	11.0	70.6	15.0	1.3	12.3
29 Oct 1986	----	11.2	78.7	----	1.1	12.0
30 Jul 1987	35.7	----	----	14.0	0.8	----
25 Aug 1987	33.7	----	----	12.0	0.7	----

[1] A storm on 23-24 Sep 1986 produced 8.9 mm rainfall.

Plant Water Relations

Diurnal patterns of stomatal conductance, transpiration, and leaf microclimate were determined for all plant species on given sample dates. Measurements were made biweekly from April through October, 1986, and once each in July and August, 1987. A Lambda Instruments LI-1600 steady state porometer (LI-COR, Lincoln, NE) was used at 90 minute intervals throughout each day. In general, two abaxial leaf surfaces were measured; however occasionally, measurements of adaxial surfaces were made. A Lambda Instruments LI-190S quantum sensor was used to measure incident photon flux density for individual leaves. In addition to the porometer thermocouple, an infrared thermometer (Everest Interscience, Tustin, Calif.) was used to measure leaf temperatures. A portable pressure chamber apparatus (Soil Moisture Equip. Corp., Santa Barbara, Calif.) was used to measure xylem pressure potentials of 2-3 leaves or shoots from each individual before dawn and at solar noon. In 1986, soil moisture was measured with a CPN 503 neutron hydroprobe (CPN Corp., Martinez, Calif.) at 0.3m depth intervals. Nine access tubes were arranged along three transects within the riparian corridor at One Mile Bar and five access tubes were arranged along two tran-sects at Balch Camp.

Results and Discussion

Climate, Streamflow, and Soil Moisture

Local climate at Balch Camp during the study period is presented in table 1. In 1986, air temperatures in excess of 25°C occurred throughout the growing season with the warmest days (to 39°C) occurring in July and August. Relative humidities remained high through June and then abruptly dropped in July when maximum air temperatures increased significantly. In October at the onset of senescence, maximum air temperatures remained high while minimum temperatures regularly dropped to 6°C. Light precipitation occurred in early May and late September. In 1987, similar hot and dry climatic conditions predominated.

Streamflows for the dates of physiological measurements are given in table 1 also. Streamflows peaked in early June, rapidly decreased during June and early July, and leveled at around 1.4 m^3/s for the remaining months of the 1986 season and around 0.7 m^3/s for the 1987 season.

Soil moisture was highest early in the 1986 season coinciding with the time of highest streamflows (table 1). Soil moisture declined gradually at all depths throughout the summer. The lowest moisture measurements were made in September when 11.2 and 23.0 percent water content by volume were measured at 0.5 and 1.2 m depths, respectively. Rains in late September, totaling 10.9 mm, increased soil moisture throughout the profile.

Plant Water Relations

A summary of seasonal predawn xylem pressure potentials and maximum daily stomatal conductance to water vapor is provided in table 2. Seasonal predawn xylem pressure potentials were high throughout the 1986 season for all species. In late season (October) at One Mile Bar, the xylem pressure potentials of *Salix gooddingii* and *S. laevigata* at -0.95 and -0.82 MPa indicated water stress for these species. Woodhouse (1983) found that *S. laevigata* is water stressed at -0.75 MPa. However, these lowered predawn measurements were more likely a result of increased root resistance to water uptake during the onset of dormancy than from insufficient soil moisture (Larcher 1980).

We found no consistent relationships between maximum xylem pressure potentials and maximum stomatal conductance for any species. Patterns in stomatal conductance were similar for all species, but absolute values varied considerably. Maximum stomatal conductance typically occurred in early June and declined gradually thereafter with the lowest observed conductances occurring in late October. *Platanus racemosa* and *Salix laevigata* had the highest maximum conductance at 0.229

and 0.254 mol m-2s-1, respectively. *Alnus rhombifolia* and S. *gooddingii* had moderate conductance at 0.158 and 0.128 mol m-2s-1, while *S. hindsiana* had the lowest maximum conductance at 0.108 mol m-2s-1. Lower stomatal conductance in all species in April and May may have occurred because of low soil and air temperatures and incomplete leaf expansion. High stomatal conductances in June coincided with ideal climatic conditions (moderate air temperatures, high humidities, high light, and warmer soil temperatures), abundant soil water, and mature leaves. The decline in stomatal conductance later in the season may have been the result of the combination of an increased vapor pressure difference (VPD) of the atmosphere and decreased soil moisture, while leaf senescence contributed to the decline in September. The broad-leaved willows appeared to have less effective stomatal control for maintaining high xylem pressure potentials during the period of high VPD in late season.

Table 2 - Seasonal trends in predawn xylem pressure potential (MPa) and maximum stomatal conductance (mol $H_2O/(m^2s)$) for adult riparian plants in 1986 along the North Fork Kings River.

One Mile Bar	*Alnus rhombi- folio* XPP max	(n=3) g max	*Salix laevi- gata* XPP max	(n=1) g max	*Salix hinsi- ana* XPP max	(n=2) g max
Apr 10	-0.24	0.173	-0.15	0.118	-0.13	0.091
Apr 24	-0.17	0.186	-0.10	0.251	-0.12	0.135
May 8	-0.26	0.179	-0.10	0.212	-0.13	0.102
May 22	-0.21	0.115	-0.18	0.263	-0.14	0.106
Jun 4	-0.22	0.152	-0.20	0.340	-0.17	0.139
Jun 18	-0.23	0.160	-0.28	0.286	-0.26	0.124
Jul 2	-0.31	0.083	-0.25	0.336	-0.24	0.086
Jul 16	-0.24	0.095	-0.40	0.296	-0.29	0.086
Jul 30	-0.20	0.133	-0.23	0.277	-0.23	0.122
Aug 13	-0.22	0.109	-0.37	0.307	-0.28	0.085
Aug 27	-0.23	0.122	-0.30	0.252	-0.23	0.113
Sep 10	-0.26	0.091	-0.35	0.211	-0.31	0.083
Sep 24	-0.13	-----	-0.23	-----	-0.19	-----
Oct 8	-0.27	0.143	-0.82	0.213	-0.34	0.116
Oct 29	-0.22	0.207	-0.68	0.195	-0.33	0.118
Balch Camp	*Alnus rhombi- folia* XPP max	(n=5) g max	*Platanus race- mosa* XPP max	(n=3) g max	*Salix good- dingii* XPP max	(n=1) g max
Apr 11	-0.18	0.138	-0.16	0.124	-----	-----
Apr 25	-0.21	0.180	-0.18	0.287	-----	-----
May 23	-0.25	0.221	-0.18	0.272	-----	-----
Jun 5	-0.23	0.235	-0.25	0.354	-----	-----
Jun 19	-0.23	0.288	-0.28	0.290	-----	-----
Jul 3	-0.21	0.164	-0.25	0.315	-----	-----
Jul 17	-0.20	0.154	-0.11	0.206	-----	-----
Jul 31	-0.20	0.194	-0.12	0.233	-0.20	0.269
Aug 14	-0.26	-----	-0.13	-----	-0.20	-----
Aug 28	-0.31	0.098	-0.10	0.186	-0.13	0.176
Sep 11	-0.38	0.099	-0.14	0.161	-0.18	0.190
Oct 9	-0.28	0.181	-0.17	0.168	-0.25	0.166
Oct 30	-0.29	0.161	-0.18	0.150	-0.20	0.114
Oct 8	-0.27	0.143	-0.82	0.213	-0.34	0.116
Oct 29	-0.22	0.207	-0.68	0.195	-0.33	0.118

Patterns of integrated daily transpiration rates were very similar for all species at the beginning and end of the season, but values diverged for each species during the mid-summer period of significant water consumption (data not shown). The greatest daily transpirational water losses occurred from mid-June through August corresponding with the period of greatest VPD. Mean integrated transpiration was relatively high for *Plalanus racemosa* and *Salix laevigata* at 239 and 328 mol m-2d-1, respectively. In contrast, *Alnus rhombifolia, S. gooddingii,* and S. *hindsiana* had relatively low integrated transpiration at 157, 170, and 177 mol m-2d-1.

Diurnal trends in photosynthetic photon flux density (PPFD), VPD, stomatal conductance to water vapor, and transpiration are shown for adult *Alnus rhombifolia* on three dates in figure 1. These trends were similar for all species measured. Typically, PPFD increased and levelled to a long midday maximum while VPD increased gradually and remained high until late in the day.

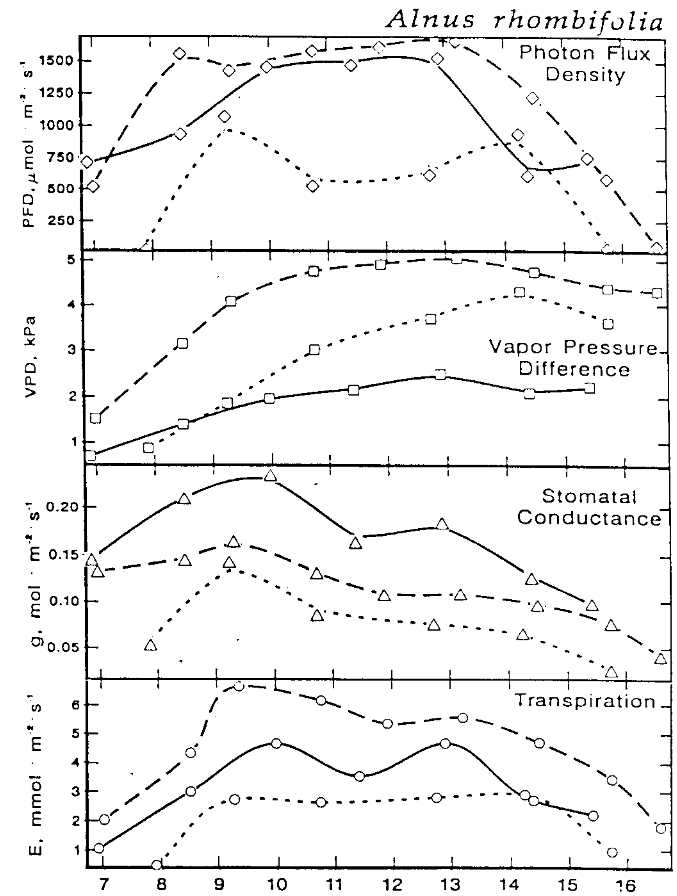

Figure 1. Diurnal patterns in photon flux density, vapor pressure difference, stomatal conductance, and transpiration for Alnus rhombifolia in June (——), July (---), and October (....) 1986.

Figure 1- Diurnal patterns in photon flux density, vapor pressure difference, stomatal conductance, and transpiration for *Alnus rhombifolia* in June (—), July (---), and October (...) 1986.

Stomatal conductance reached maximum values in mid-morning and gradually decreased during the remainder of the day. We found no consistent relationships between stomatal conductance and PPFD nor between stomatal conductance and VPD. Nevertheless, a decline in conductance as a result of increasing VPD is a well established relationship (Schulze 1986).

Diurnal transpiration patterns mirrored stomatal conductance with maximum transpiration occurring in conjunction with maximum stomatal conductance because leaf temperatures were close to air temperatures. Transpiration rates declined or levelled during midday even though VPD remained high, except for *Salix hindsiana* which typically increased transpiration rates to afternoon maxima.

Diurnal xylem pressure potential patterns showed a rapid decline by mid-morning coinciding with maximum transpiration (data not shown). The prolonged midday minimums in conjunction with increasing VPD probably triggered partial stomatal closure resulting in the observed decrease in transpiration rates.

In 1987, air temperatures and VPD were slightly less than in 1986. Measurements of stomatal conductance and transpiration were slightly less also. Both predawn and midday xylem pressure potentials in 1987 were notably lower than in 1986, however insufficient data were obtained to test significance. In 1986, we found that the riparian plants had an adequate moisture supply and were capable of absorbing sufficient water to compensate for their large transpirational water losses. In late summer of 1987, the internal water status of the plants indicated that they may not have had sufficient soil moisture available to offset transpirational losses. Further physiological measurements in conjunction with soil moisture measurements at low streamflows would help to clarify the lower water limits of these riparian plants.

Conclusions

The patterns of water relations in five riparian species along the North Fork Kings River showed similar diurnal and seasonal trends. Stomatal conductance was greatest early in the season when climatic conditions were mild. All species had reduced stomatal conductance during the late season low flow periods. In contrast, transpiration was greatest in mid-summer when air temperatures and VPD were greatest also. Predawn xylem pressure potentials indicated that plants were able to fully recover internal plant water status at night given the 1986 streamflows $1.4 m^3/s$. Xylem pressure potential data collected in 1987 are insufficient to draw conclusions from at streamflows of $0.7 m^3/s$.

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A RIPARIAN VEGETATION ECOPHYSIOLOGICAL RESPONSE MODEL[1]

Jeffrey P. Leighton and Roland J. Risser [2]

Abstract: A mathematical model is described that relates mature riparian vegetation ecophysiological response to changes in stream level. This model was developed to estimate the physiological response of riparian vegetation to reductions in streamflow. Field data from two sites on the North Fork of the Kings River were used in the model development. The physiological response of three adult white alders and one juvenile red willow were simulated as a function of the meteorological and streamflow conditions. Estimates of predawn leaf water potential, leaf temperature and transpiration rate were comparable to measured values, indicating our model can be used for predictive purposes.

Limited water availability in many montane streams has resulted in recent concerns to maintain adequate flows for fisheries, power production, human consumption, irrigation, recreation, and maintenance of riparian communities. Few studies have been undertaken to assess the streamflow necessary to maintain existing riparian vegetation. A quantitative study evaluating various low streamflows and the response of associated vegetation is extremely expensive, politically sensitive, and could impact an established riparian community. Modeling can be used for predicting these effects. Utilizing data from a study site, a model was developed which allows scientists to predict how changes in streamflow may affect existing riparian vegetation.

We developed a model that defines riparian vegetation physiological response to variations in streamflow, through a number of intermediate relationships (Leighton and others 1988). Stream level and streamflow are related by a stage-discharge curve, or rating curve. Variation in stream height and meteorological conditions are used as a determinant of the variation in predawn leaf water potential. Stomatal conductance is compared to leaf water potential, photosynthetically active radiation, and time of day. An energy balance formulation is used to compute transpiration rate and leaf temperature in response to meteorological factors, canopy geometry conditions and stomatal conductance. This formulation considers the available energy (incoming radiation) and its utilization in latent and sensible heat exchange. As a result of evaluating these interrelationships, the physiological response of the plant to incoming radiation and water availability is given by its leaf water potential, leaf temperature and transpiration rate.

Site Description and Study Design

Soil, plant and atmospheric conditions were monitored during the growing season (from April to October) in 1986 along the North Fork of the Kings River at elevation 1200 ft. Additional data were obtained during 1987. The North Fork of the Kings River has large, spatially intermittent stands of riparian vegetation. Two sites were selected: a small stand of vegetation on a sand bar (referred to as One Mile Bar), and a streamside area of plants rooted in sand within a boulder field (near Balch Camp).

Bi-weekly monitoring of plants of five species was made during 1986 (Smith and Nachlinger 1987). In 1987, data were obtained once each in July, August and September. Leaf temperature, leaf water potential, stomatal conductance, relative humidity, and photosynthetically active radiation, were measured. Moisture levels in soil columns were also measured once every two weeks in 1986, and once in 1987.

The stand of riparian vegetation at One Mile Bar is drawn in plan in figure 1. Thirteen individuals were monitored. Two plants at One Mile Bar were used throughout the model development (plants 111 and 221). Plant 111 is an adult white alder (*Alms rhombifolia*), with a leaf area index of 3, a height of 9 meters and horizontal area of 7 square meters. Plant 221 is a juvenile red willow (*Salix laevigata*), with a leaf area index of less than one, height of 2 meters and horizontal area of 3.8 square meters. Two adult white alders from the site near Balch Camp were also modeled, but will not be presented here.

Stream Height Versus Streamflow

In a stream where water flows from the stream to the ground, the stream condition considered most likely to predict soil moisture is the stream height. Within the riparian zone, we found saturation water levels within 0.5 ft (0.15 m) of the height of the stream (unpublished data). Stream height was measured during part of 1986 and 1987.

A gage site 2.4 kilometers south of Balch Camp on the North Fork Kings River measures streamflow. Mean minimum monthly summer flows averaged 50 cfs (1.4 cms) from 1975 to 1987. The average peak spring flow

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for the same period exceeded 1000 cfs (28 cms). This is not a stream that goes dry, but often shows persistent low flows in late summer.

A succession of hydraulic controls along the stream reach create pockets of ponded water. The channel bottom or accumulated rocks create what is effectively a weir, which determines the stream height as a function of streamflow. We recorded changes in stream height for flows from 25 to 3000 cfs (.71 to 84.3 cms). Based on the observed data, we established a rating curve (figure 2). To complete the rating curve at flows below 25 cfs (.71 cms), it is hypothesized that openings in the rocks act as an equivalent V-notch weir.

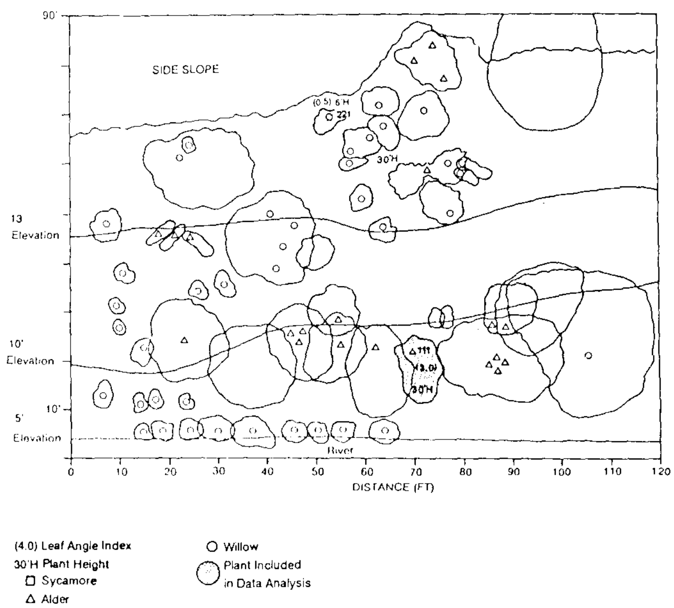

Figure 1– Site Map, One Mile Bar, Plan View.

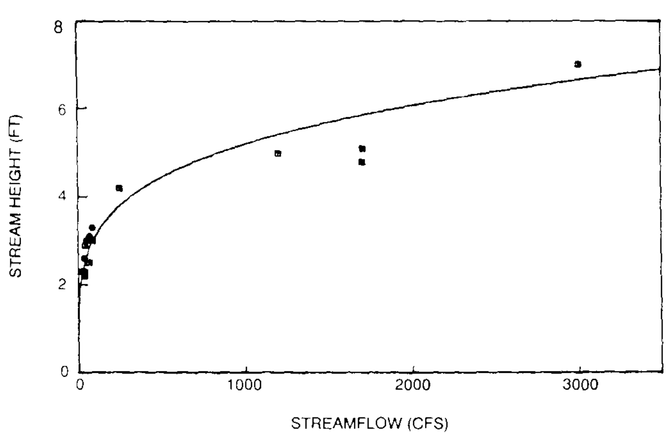

Figure 2– A Rating Curve.

Predawn Leaf Water Potential Versus Stream Height

As a plant transpires, it releases moisture and its leaf water potential (LWP) decreases. Leaf water potential reflects the water availability of a plant; the higher the value, the more water available. The leaf water potential recovered from midday values to reach maximum values by midnight. The predawn leaf water potential was found equal to values the previous midnight. The predawn leaf water potential was plotted in time and compared against stream height (an indicator of soil moisture) and the atmospheric demand for water (potential evapotranspiration, PET) during the leaf water potential recovery period; i.e., from 1300 to 2400 hours. We do not explicitly consider the effect of soil type on the capillary fringe, but we expect site-specific characteristics to be accounted for by the data comparison.

The predawn LWP was most negative when stream height was lowest and PET was highest. The recovery of the LWP appears to depend on the availability of soil moisture, and the demand of the atmosphere to continue to draw water from the plant following midday. This pattern is clearly indicated in late 1986 with Plant 221 at One Mile Bar (figure 3). In four successive test periods, the stream height remained low and constant; the predawn leaf water potential and the PET showed the same pattern of alternating high and low values.

The location of root mass in relation to soil moisture is important. The precise distribution of roots is not known, but we can compare the measured values of predawn LWP and stream height to develop what we will call a water availability factor. As the stream height remains relatively high, we expect that soil moisture will not be limiting (the water availability factor would equal one). At some point, as the water level decreases, the percent of root mass with access to extractable soil moisture reduces to a critical point. The amount of withdrawal is less, and the LWP remains more negative. The water availability factor was represented by a ratio of maximum rooting area (the elevation at which sufficient moisture is available and not limiting) to the amount of rooting area saturated by the present stream height conditions.

A preliminary analysis showed a less than linear decrease in LWP with rising PET. It also appeared that the predawn LWP was independent of PET for large values of PET (>3 mm). In physical terms, the atmospheric demand for water reaches a level where the moisture availability controls, and greater demand cannot be met. By using values of PET and the water availability factor, we obtain estimates of the predawn LWP versus streamflow (figure 4). Agreement is excellent.

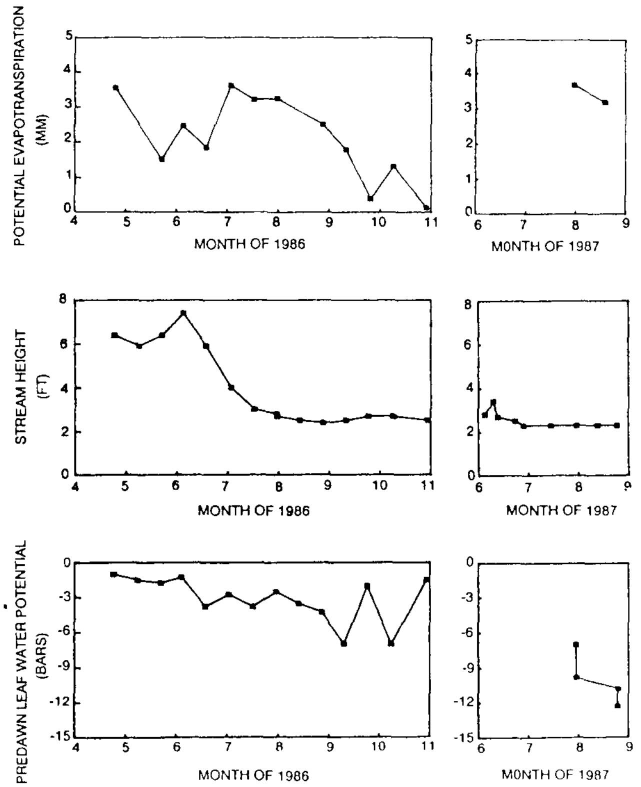

Figure 3— Variation in Predawn Leaf Water Potential, Stream Height and Potential Evaporation, Plant 221 at One Mile Bar.

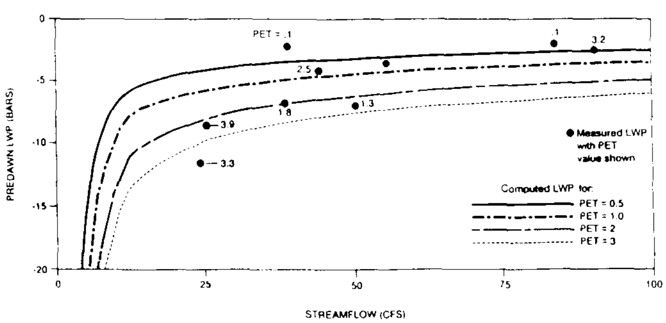

Figure 4— Measured versus computed predawn leaf water potential, plant 221 at One Mile Bar.

Of critical concern is the persistence of low flows (low water availability) accompanied by high PET. In late summer, a prolonged period exists where PET exceeds 3 mm. The model predicts that predawn leaf water potential will remain below -10 bars for plant 221 if streamflows remain less than 25 cfs (.71 cms).

Modeling Stomatal Conductance

We will use the estimate of predawn leaf water potential as one factor to predict stomatal conductance. Stomatal conductance represents the ease with which water is released from leaf stomates or openings. Measured stomatal conductance was compared to several variables: predawn leaf water potential, vapor pressure deficit, PAR, time of day and time of year. These variables were considered in the analysis because of their use in previous quantitative studies (Jarvis 1976; Simpson and others 1984). We included measured conductance values only for leaves with PAR values exceeding 300 watts per meter^2, to avoid stomate response to limiting light, although the leaf may have been shaded just prior to measurement. Predawn leaf water potential and time of day were the best predictors of stomatal conductance. A comparison of predicted versus measured stomatal conductance for a juvenile red willow is summarized in figure 5.

The Energy Balance Model

We use the concept that there is a balance of energy within a control volume the size of a tree. The incoming energy minus outgoing energy (net incoming radiation) equals energy used (the latent heat transfer and sensible heat transfer).

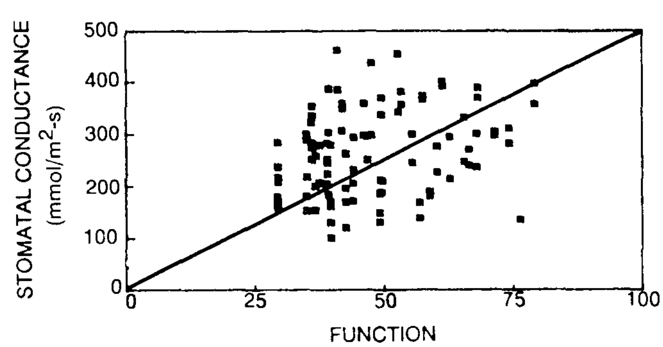

Figure 5— Relationship between measured stomatal conductance and the stomatal function, plant 221 at One Mile Bar.

Leaf surfaces may be exposed to direct and/or reflected short-wave radiation. The fraction of incident radiation available to the plant depends on the density and size of the surrounding canopy, the interference of leaves within the plant, the surrounding topography, and the sun altitude and azimuth. In a multiple layer tree, we assume the equivalent of one leaf layer to be directly exposed to incoming short wave radiation during sunlit hours. Other leaves may receive short wave radiation as a result of reflection from leaves or from the adjacent canopy or ground.

Long wave radiation exchange depends on emissivity, and surface temperature. We assume that long wave radiation losses occur in proportion to the leaf temperature and long wave radiation gains occur in proportion to the air temperature and adjacent leaf temperatures (Ross 1975).

The relative humidity within the stomatal cavity of the leaf is close to one (Tan and others 1978). Ambient air surrounding the leaf has less water vapor and the vapor density gradient between the air and the leaf is a driving force for plant water loss. Energy is needed to convert the liquid water leaving the plant to vapor. Latent heat transfer occurs in proportion to the vapor density deficit and inversely with the resistance to water vapor transfer. Two resistances in series comprise the transfer resistance: the internal resistance to transfer of water out of the leaf into the leaf boundary layer, and the aerodynamic resistance from the leaf boundary layer to outside the tree canopy, which accounts for the effects of wind speed (Campbell 1977). The cuticle or leaf surface resistance is very large, so internal transfer only occurs out of the stomatal cavity through the stomates (stomatal conductance).

Radiant energy impinging on a leaf surface will increase the leaf surface temperature. The sensible heat transfer is a function of the difference in leaf and air temperatures, the leaf area, and the leaf boundary layer resistance to sensible heat transfer.

We solve the energy balance model to determine plant transpiration and leaf temperature. The stomatal conductance relates back to streamflow.

Energy Balance Model Calibration

When the energy balance model is applied, with a shading factor of 0% (no shading), we overestimate the transpiration rate and leaf temperatures. The plants exist under varying degrees of shading. To calibrate the shading factor, we compare the measured leaf temperature excess and transpiration rates to computed values, as a function of stomatal conductance. Data and simulation results encompass sunlit hours from April to October.

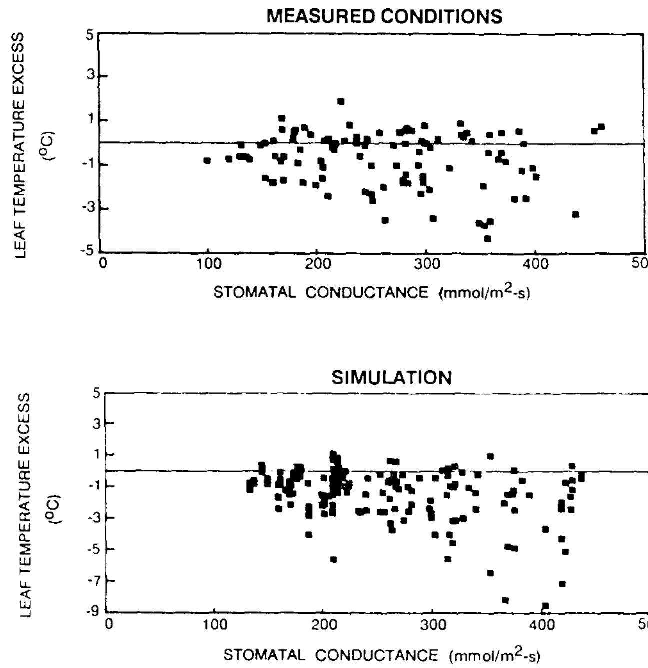

Figure 6— Measured versus predicted leaf temperature excess, plant 221 at One Mile Bar.

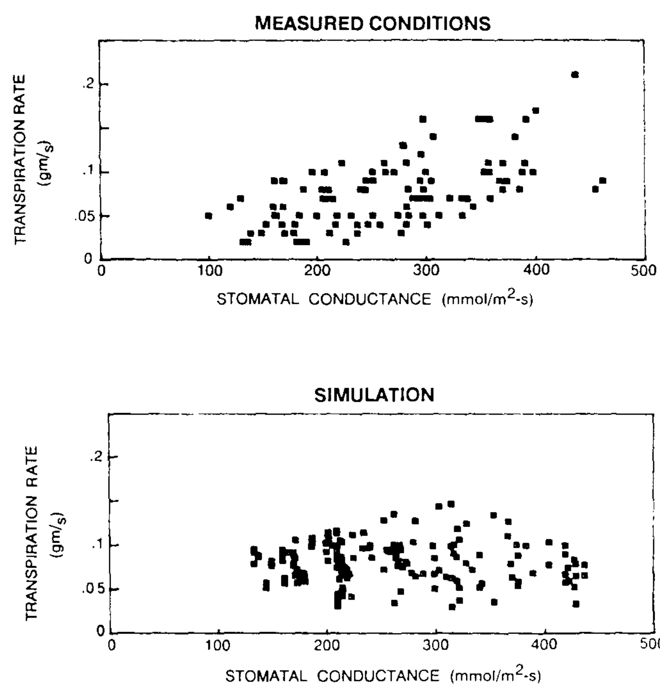

Figure 7— Measured versus predicted transpiration rate, plant 221 at One Mile Bar.

Transpiration rates and leaf temperatures were measured in the field on selected sunfleck leaves. Measured and computed leaf temperatures and transpiration rates are presented for plant 221 at One Mile Bar (figures 6 and 7). The energy balance model estimates of leaf temperature excess and transpiration rate are in excellent agreement with measured values, especially at low stomatal conductance, even though we assume a constant shading factor.

Model Predictions

The riparian vegetation response model has been developed to estimate physiological response in terms of predawn leaf water potential, leaf temperature excess on sunfleck leaves, and transpiration rates for each of four plants. Model simulations were made for various meteorological and time conditions, with streamflow variation from 5 to 100 cfs (1.4 to 2.8 cms). Figure 8 shows one set of results for Plant 221.

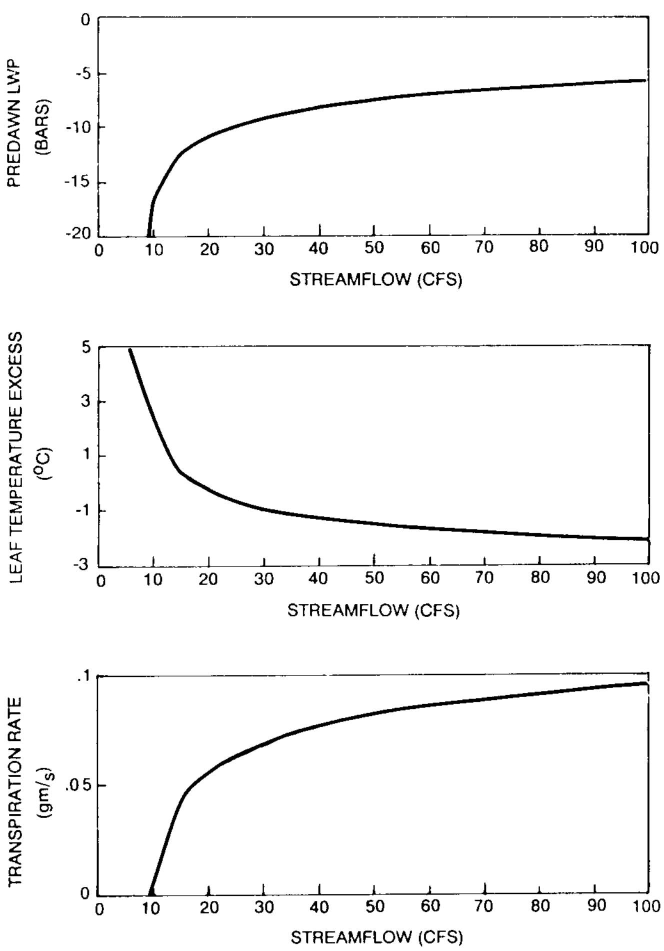

Figure 8– Predicted physiological response versus streamflow, plant 221 at One Mile Bar.

In general, the mature vegetation shows minimum stress except at very low flows. Cumulative indices of plant stress (based on reductions in transpiration from a potential rate) have been used in crop studies (Hiler and Clark 1971). The model allows us to consider streamflows leading to severe plant stress which we could identify by assuming a physiological threshold; e.g., the wilting point.

Conclusions

A mathematical model, based on field data from two sites on the North Fork Kings River, was developed to relate the physiological response of mature riparian vegetation to changes in stream height. The physiological response of white alder and red willow as a function of changes in stream height and meteorological conditions were simulated. Model simulation results were similar to measured values for predawn leaf water potential, leaf temperature, and transpiration rate. Our results indicate that there is little physiological plant "stress" relative to all but significant reductions in streamflow. This model may be used for these species at other locations to predict the physiological effect at reduced streamflow provided that site-specific data on stream height, predawn leaf water potential and meteorology are obtained.

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WATER RELATIONS OF WHITE ALDER[1]

Virginia I. Dains[2]

Abstract: White alder (Alnus rhombifolia) *is a potentially valuable indicator of water stress along California's waterways. Measurements of stomatal conductance, water potential and tissue water relations in conjunction with growth and morphological studies give evidence for the sensitivity of this species to changes in water availability. Potted seedlings and naturally occurring seedlings and trees were monitored during the 1986 and 1987 growing seasons to determine responses to artificial and natural water regimes. Osmotic adjustment provides a mechanism for drought hardening, but the process is less effective in preventing stress in seedlings than trees. Measurements of leaf area and mean instantaneous conductance were sensitive indicators of alder water status. These two parameters should be included in any physiological monitoring programs of white alder.*

White alder (*Alnus rhombifolia Nutt.*) *is* a dominant riparian tree along the western slope of the Sierra Nevada and in portions of the south coast ranges. It occurs at sea level in the Sacramento-San Joaquin Delta and at scattered locations in the Mojave desert. Its northern distribution extends into Canada and eastward to Idaho. Within California, white alder is restricted primarily to perennial watercourses (Griffin and Critchfield 1972). This habitat specificity makes white alder a potentially valuable indicator of water stress within many riparian communities. The purpose of this study is to provide a physiological framework for this key riparian species that will aid in the understanding of ecological processes along California's streams.

The effects of water stress on plants have been well documented. Initially, a plant may respond with conservative stomatal behavior, but continued water deficits can lead to permanent changes such as reduction in leaf size, the number or size of stomata, or an increased density of leaf hairs (Daubenmire 1974; Ehleringer 1984; Hsiao 1973; Levitt 1980). Flower and fruit production of stressed plants may be reduced or abandoned (Hinckley and others 1979). Seedlings may be more sensitive to water stress than mature plants (Kramer 1983). Riparian plants have not been the subject of extensive physiological studies. In a compilation of flooding and drought tolerances of wetland plants (Walters and others 1980), white alder is indicated as very tolerant of flooding, but there is no indication of the plant's tolerance to drought.

Methods

Study Populations

In 1986, 120 alder seedlings were grown under controlled watering regimes to induce drought stress. The experimental treatments were based on a dry-down trial where the condition of five seedlings was monitored over a 10-day period without watering. Moderate stress (stomatal closure, loss of turgor) appeared after 5 days and severe stress (loss of leaves, die-back) occurred after 10 days of no water. A control group was watered every day and showed no signs of stress. During the experiment, water was applied automatically according to 1-, 5-, or 10-day schedules. Seedlings were grown outside in Sacramento County and exposed to full sun from dawn to 1900. The experiment was terminated after 80 days by rainfall in September.

During the summer of 1987, 31 white alder seedlings were tagged along a gravel bar approximately 500 m downstream from Camanche Dam on the Mokelumne River within Van Assen Park, San Joaquin County, California. Seedlings were selected to represent the range of environmental settings being colonized by white alder. The seedlings were exposed to full sun from dawn until at least 1600. Water relations of white alder trees were studied at two locations along the lower American River in Sacramento County, California. Twelve (12) trees were selected from stands on coarse alluvium at the upstream end of Sailor Bar, approximately 1 km downstream from Nimbus Dam. Three (3) additional individuals were located on a silty terrace across from the Gristmill Access Area about 18 km downstream. Trees were selected to represent the wide range of leaf and canopy morphologies present along the river. Canopies of the selected trees were exposed to full sun from dawn until 1600 or later during physiological sampling. All of the study sites occur between 10 and 70 meters in elevation.

Physiological Measurements

Diurnal patterns of stomatal conductance were measured using a transient porometer (Model LI-700, LI-COR, Lincoln, Nebraska). Conductance curves for 60

[1]Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California

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experimental seedlings (20 plants in each of the three treatment groups) were recorded on initiation of the treatments (days 2-9), mid-way through the experiment (days 36-45), and at the end of the experiment (day 67 and days 69-72). Stomatal conductance curves for Mokelumne River seedlings were recorded on 29 and 30 August, and 30 September. For trees at Sailor bar, diurnal patterns of stomatal conductance were sampled five times over the months of June, July and August. Trees at Gristmill were sampled once in August.

A pressure chamber (PMS Instruments, Corvallis, Oregon) was used to estimate plant water potential. Pre-dawn measurements of three randomly selected seedlings in each treatment group were made once mid-way through the pot study. The diurnal course of water potential in Mokelumne River seedlings was recorded once during July. Diurnal water potential curves were recorded from trees at Sailor Bar in June and August, and pre-dawn and mid-day readings were recorded from these trees in July. Diurnal curves were recorded from trees at Gristmill in August.

The tissue water relations of white alder were examined using a pressure chamber and the pressure-volume (P-V) curve technique (Tyree and Hammel 1972). The plants chosen for this analysis included 3 control group and 3 stressed seedlings from the pot experiment, 5 randomly selected seedlings from the Mokelumne River field site, 11 of the 12 trees at Sailor Bar, and 2 of the 3 trees at Gristmill. In all, 24 individuals were sampled during September of 1986 or 1987, and 106 P-V curves were generated and analyzed. One of the plants failed to produce usable data due to mishandling of the samples.

In this analysis of P-V curve parameters, the osmotic line was laid by hand. Most plots contained 12 observations with 5 to 8 points falling on the osmotic line. The turgor loss point was calculated using the ratio technique reported by Schulte and Hinckley (1985). The osmotic potential at full turgor and the apoplastic fraction were estimated by a least squares regression of points falling along the osmotic line (Robichaux and others 1984). The bulk moduli of elasticity were calculated as a function of the slope of the P-V curve at full hydration (Stemmerman 1983).

Morphology and Growth

The effects of drought stress on morphology and growth of white alder were examined through measurement of leaf area, leaf shape index, leaf curling index, stomatal and hair densities, and an index of canopy coverage. Changes in the reproductive output of trees and root-to-shoot ratios of seedlings also were examined for responses to water stress.

Results

Stomatal Conductance

Experimentally stressed seedlings showed reduced stomatal conductance by the fourth day of the pot study. Highly significant differences were detected in mean stomatal conductance at the close of the experiment (where df is 2, F is 1,920, and P=.0). Less frequently watered plants endured the greatest degree of stomatal closure (table 1). As the experiment progressed, there was a decrease in the recovery of stressed plants upon watering. Individual responses to the treatments were more varied in stressed plants than in the control group. Control group seedlings had decreased conductance at the end of the experiment when they had become root-bound in the 1-gallon pots. The Mokelumne River seedlings were most similar to the control group of experimental seedlings and had the highest mean instantaneous conductances of all the white alders studied. Maximum conductance values for white alder of 0.400 mol/m2/sec were recorded from control group seedlings.

Table 1 - Stomatal conductance and water potential of white alder seedlings and trees.

	Conductance[1]	Water Potentia1[2] Pre-dawn	Mid-day
Seedlings:			
severe stress	.095± .008	-0.90	-
moderate stress	.181±.006	-0.40	-
control	.244±.003	-0.20	-
Mokelumne R.	.261±.003	-0.05	-0.75
Trees:			
(severe stress)			
GM-1	0.41±.005	-1.25	-1.50
GM-2	.050±.005	-0.45	-1.23
GM-3	.070±.012	-1.25	-1.40
SB-12	.134±.007	-0.20	-1.18
SB-6	.142±.009	-0.20	-1.53
SB-2	.143±.003	-0.20	-1.54
(moderate stress)			
SB-1	.173±.009	-0.20	-1.66
SB-4	.184±.011	-0.15	-1.80
SR-11	.204±.008	-0.20	-1.63
SB-3	.209±.011	-0.15	-1.75
(unstressed)			
SB-8	.214±.010	-0.20	-1.75
SB-5	.222±.011	-0.15	-1.80
SB-10	.230±.012	-0.25	-1.61
SB-7	.244±.011	-0.15	-1.43
SB-9	.251±.010	-0.10	-1.61

[1]Mean instantaneous conductance (mol/m2/sec) of sunlit eaves and standard errors.
[2]Mean maximum and minimum water potentials (MPa)

Field investigations of the stomatal conductance of trees revealed a similar range of response. Arbitrary condition classes were assigned to individual trees based on their mean instantaneous conductance. The designations of severe, moderate, or unstressed condition correspond to treatment classes of the seedling experiment. Trees with mean instantaneous conductances less than 0.150 mol/m2/sec suffered severe water stress.

Water Potential

Pre-dawn water potentials of stressed and unstressed plants differed by as much as 1.2 megapascals (MPa; 1 MPa = 10 bars). Mokelumne River seedlings had pre-dawn potentials of -0.05 MPa while severely stressed trees at Gristmill had predawn potentials of -1.25 MPa. Most trees were at or near full hydration. Observations of stressed trees indicate that water deficits may occur at pre-dawn potentials as high as -0.3 MPa. In general, pre-dawn potentials were poor indicators of plant water status.

Mid-day minimum potentials were lowest for moderately stressed and unstressed trees (-2.0 MPa). Severely stressed trees had mid-day potentials that were as much as 0.5 MPa greater (-1.5 MPa). Field seedlings had the highest mid-day potentials (0.75 MPa). A rise in mid-day water potentials of 0.2 MPa from June to August was recorded from 6 trees at Sailor Bar.

Tissue Water Relations

Osmotic potential at full turgor and water potential at the turgor loss point were the two parameters of alder tissue water relations most indicative of plant water status (table 2). Mokelumne River seedlings had the highest osmotic potential and turgor loss points of all plants studied. Seedlings in general had higher osmotic potentials and turgor loss points than reproductively mature trees (fig. 1). The osmotic potential of a non-reproductive sapling (SB-9) was intermediate between seedlings and trees. The range of osmotic adjustment due to water stress was similar for seedlings and trees (0.19 MPa and 0.18 MPa, respectively).

With lower osmotic potentials, turgor loss occurs at lower water potentials. Comparison of estimated turgor loss points and field measurements of water potential indicate that water stressed alders maintain high turgor pressure, while unstressed plants reach water potentials close to or even exceeding their turgor loss points during the day. The stomata of unstressed plants are responsive to changes in plant water potential and may close and open during the day in response to slight turgor changes; this responsiveness is diminished in stressed plants (Hsiao 1973).

Other components of tissue water relations showed little or no pattern in response to drought stress. Relative water content at turgor loss was high for all plants sampled. The apoplastic fraction was variable and did not correspond to other drought-induced responses. The range of tissue elasticity was less than 10 MPa. Differences greater than this have been considered as a genetically determined drought adaptation (Stemmerman 1983).

Morphology and Growth

The experimental treatments resulted in substantial differences in mean leaf area (table 1). At the end of the experiment, 17 of the 40 severely stressed seedlings were dead. Only 1 of the 40 moderately stressed seedlings died. All plants in the control group survived. Severely stressed seedlings lost their water-expensive leaves and replaced them with small sparse canopies (fig. 2). Moderately stressed seedlings were able to maintain their existing canopies but showed little growth. Seedlings in the control group experienced rapid growth and increased their canopy areas by as much as 2.4 percent per day.

End-of-the-season leaf morphology of Mokelumne River seedlings was intermediate between the moderately stressed and control groups of the pot study. The growth rates of these naturally occurring plants were less than would be expected from their consistently high stomatal conductance. Herbivory, competition, low nutrient availability, and shorter effective day length may account for their reduced performance.

Other morphological responses to water stress included a 15 percent reduction in the density of stomata on the abaxial surface (bottom) of stressed leaves and an increased root-to-shoot ratio in seedlings. No difference was detected in the density of leaf pubescence in relation to water status.

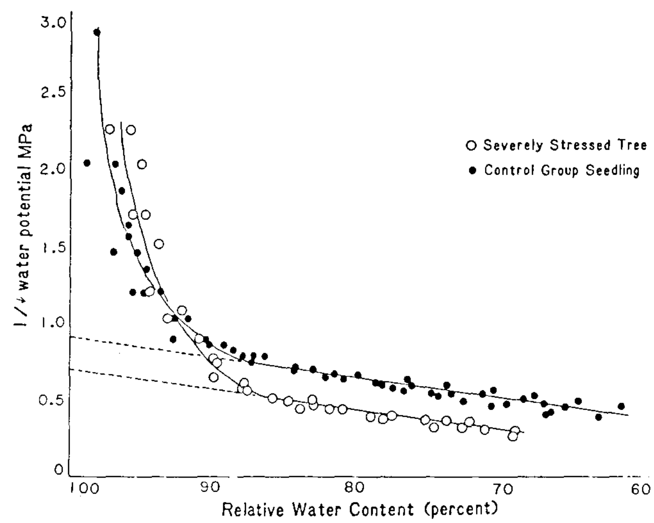

Figure 1– Pressure-volume curves for a control group seedling (closed circle) and severely stressed tree (open circle). The osmotic potential at full turgor is indicated by an extension of the curve's linear portion toward the Y axis (dashed lines). The tree has a more negative osmotic potential and is more resistant to water stress.

Table 2 - Tissue water relations of white alder seedlings and trees.

	Os^1_{FT}	WP^2_{TLP}	RWC^3_{TLP}	AF^4_{FT}	E^5
Seedlings:					
severe stress-1	-1.14 ±.04	-1.41 ±.06	.83±.02	.21±.02	1.84±.63
severe stress-2	-1.31 ±.01	-1.66 ±.03	.84±.01	.29±.03	4.78±.79
moderate stress	-1 .27±.05	-1 .61±.03	.78±.02	.13±.03	6.65±.76
control-1	-1.20 ±.02	-1.56 ±.03	.86±.01	.37±.04	4.75±.65
control-2	-1 .16±.02	-1 .44± .01	.85±.01	.43±.11	4.94±.79
control-3	-1.12 ±.02	-1.40 ±.04	.87±.01	.37±.03	5.48±.73
Mokelumne R.[6]	-0.26 ±.17	-0.81 ±.23	.88±.04	.19±.05	5.66±.45
Trees:					
(severe stress)					
GM-1	-1.42±.08	-1.88±.06	.80±.02	.13±.06	4.18±1.64
GM-2	-	-	-	-	-
GM-3	-1.30[7]	-1.70	.86	.51	3.19
SB-12	-	-	-	-	-
SB-6	-1.56±.04	-2.13±.86	.86±.001	.47±.02	4.50±.58
SB-2	-1.70±.11	-2.32±1.5	.82±.02	.41±.03	5.61±1.13
(moderate stress)					
SB-1	-1.55±.07	-2.08±.08	.83±.02	.28±.05	7.45±.09
SB-4	-1.45±.05	-1.92±.05	.89±.02	.38±.05	4.58±.45
SB-11	-1.35±.04	-1.80±.04	.86±.01	.41±.03	5.29±.74
SB-3	-1.57±.07	-1.96±.08	.84±.03	.29±.03	6.49±.47
(unstressed)					
SB-8	-1.59±.03	-1.95±.04	.90±.01	.39±.04	6.81±.73
SB-5	-1.54±.05	-1.98±.06	.86±.04	.50±.06	4.00±.86
SB-10	-	-	-	-	-
SB-7	-1.52±.12	-1.15±.04	.81±.02	.29±.04	3.95±.99
SB-9	-1.17±.02	-1.52±.04	.86±.01	.38±.04	4.07±.44

[1] Osmotic potential at full turgor (MPa)
[2] Water potential at turgor loss (MPa)
[3] Relative water content at turgor loss
[4] Apoplastic fraction at full turgor
[5] Bulk modulus of elasticity (MPa)
[6] Data are pooled from 6 individual seedlings
[7] 1 reading

Differences in the 3 arbitrary condition classes of trees could be detected by the mean leaf area of 60 randomly selected leaves with southern exposures (df=2, F=339, P=0; Shefe' post-hoc P=.05). Change in leaf shape, curling index, and canopy coverage could be detected in the severely stressed trees. Similarly, flower and seed production was altered by severe water stress. With exception of the severely stressed trees at Gristmill, stressed alders produced more flowers and fruit in relation to their respective leaf canopies than unstressd alders. The trees at Gristmill produced only a few small cones each. The relative germinability of seeds from stressed or unstressed trees was not tested.

Osmotic adjustment, or the accumulation of solutes in tissue, is most responsible for drought hardening in white alder (fig. 3). Lower osmotic potentials allow a plant to maintain favorable water status under drier conditions. The range of osmotic potentials was similar for seedlings and trees (table 2). However, the lower limit of osmotic adjustment is less for seedlings than for trees. When a plant's capacity for osmotic adjustment is reached, water stress occurs and results in reduced responsiveness of stomata, loss of leaves, cessation of flower and seed production, and an eventual increase in osmotic potentials.

Discussion

The lowered conductances and reduced leaf areas observed under moderate water stress did not threaten the lives of mature alders. Neither maintenance of a full canopy nor flower and fruit production were harmed by moderate water stress. In seedlings, moderate stress may endanger a plant's chance for establishment. Since leaves are photosynthetic organs, reduced leaf area reduces growth potential. As a colonizing species, alder depends on rapid growth to secure space, resources, and the firm anchorage necessary for successful establishment in the riparian zone.

Some water stressed alders in this study grew in close association with running water. White alder is shallow rooted and disruption of the roots can occur during floods. Field study along the lower American River took place the year after severe flooding in spring of 1986. Trees with an unbalanced canopy-to-root ratio could be subject to water stress. Large or rapid variations in streamflow during the growing season, particularly out-of-season flooding, may also lead to stress in white alder. A change of river stage of 12 inches in July of 1987 drowned hundreds of alder seedlings along the lower American River. While flooding, channel migration, downcutting and lowered water tables are natural consequences of life in the floodway, these same processes may lead to water stress in riparian plants.

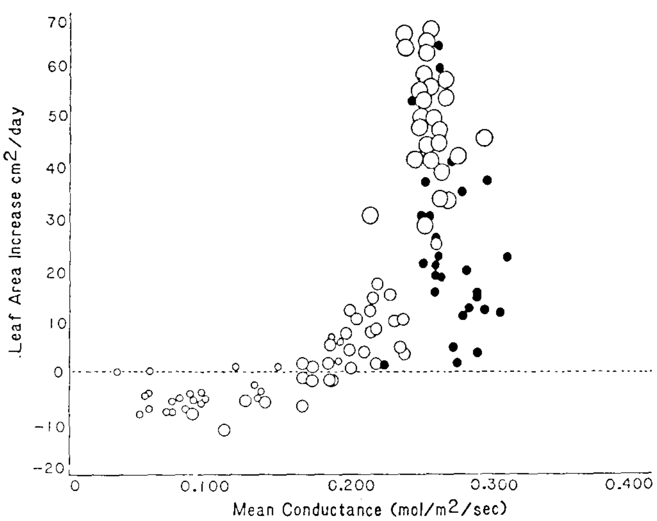

Figure 2— Growth in leaf area of white alder seedlings in relation to mean instantaneous conductance. Small, medium and large circles represent severely stressed, moderately stressed, and control group seedlings, respectively. Mokelumne River seedlings (black dots) had high conductances and a wide range of growth responses.

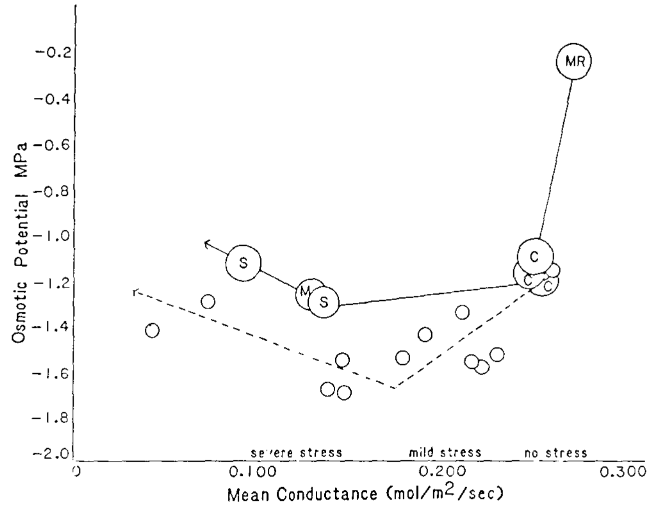

Figure 3— Drought hardening and water stress in alder seedlings and trees. The extent of osmotic adjustment for alder seedlings(large lettered circles: MR=Mokelumne River, C=control group, M=moderate stress, S=severe stress) is less than for trees (small circles).

The water relations of alder and other streamside plants need consideration as active agents in shaping riparian communities. Documentation of species differences in water relations parameters and rooting strategies will prove useful in understanding and managing riparian resources. In addition, effective monitoring of physiological condition requires knowledge of a species' limits and potentials under a variety of environmental settings. While the critical values detailed in this study may differ in other populations, reliable indications of white alder water status were obtained through measurements of mean instantaneous conductance and mean leaf area. Physiological monitoring programs involving white alder should include these two parameters.

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INTERPRETING PHYSIOLOGICAL DATA FROM RIPARIAN VEGETATION: CAUTIONS AND COMPLICATIONS[1]

John G. Williams[2]

Abstract: Water potential and stomata] conductance are important indicators of the response of vegetation to manipulations of riparian systems. However, interpretation of measurements of these variables is not always straightforward. An extensive monitoring program along the Carmel River in central California, carried out by the Monterey Peninsula Water Management District, provides examples of the complications that can arise in practice.

The Monterey Peninsula Water Management District (MPWMD) has monitored riparian vegetation along the Carmel River since 1981. A large data set has been developed, and been presented and analyzed in various reports (DMA Consulting Engineers 1985; McNeish 1986; Williams and Matthews in press; Williams and others submitted; Woodhouse 1983, 1984). This paper describes the history of this effort, and reviews some of the complications encountered in interpreting the data, particularly from the point of view of environmental management. A possible subtitle would be: "Problems in Proving the Obvious."

Study Area

The Carmel River is a small coastal stream in central California, draining 660 km^2 with an average annual discharge of 3.1 m^{3}s^{-1}. In the lower 25 km, the stream flows over alluvial deposits that make up Carmel Valley.

The undisturbed riparian forest along the lower Carmel River is dominated by Black Cottonwood (*Populus trichocarpa*), together with abundant Arroyo Willow (*Salix laseolepis*) and Red Willow (*S. laevigata*); White Alders (*Alnus rhombifolia*), Bay (*Myrica californica*), and Sycamore (*Plantanus racemosa*) and minor constituents. Large areas of riparian forest were cleared for agricultural and suburban development, but a nearly continuous stretch of forest existed along the lower river until recent decades (fig. 1).

Figure 1 – Relatively undisturbed riparian forest along the Carmel River; trees to the left in the picture grow over a layer of clay that buffers the effect of groundwater extractions.

Coastal California enjoys a Mediterranean climate. Within and between year variances in the precipitation and stream flow are large, with average annual precipitation varying over the drainage basin from 350 to 1050 mm, almost all falling as rain between November and April. In the summer demand for municipal supply for the adjacent Monterey Peninsula exceeds the supply available from the river and from two small reservoirs owned by the California-American Water Company (Cal-Am), and diversions for municipal use have made the river go dry in the summer for many years. Since the early 1960's, Cal-Am has relied increasingly on wells tapping the underflow of the river in the alluvial deposits.

Background

The effect of groundwater pumping on riparian vegetation and bank erosion along the Carmel River has been the subject of controversy for many years. Kondolf and Curry (1986), and Groeneveld and Griepentrog (1985) provide recent reviews. Local residents noticed the effects quickly, especially in the dry years of 1961

[1]Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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and 1966, when pumping increased sharply (Monterey Peninsula Herald, 1966). In 1971, local residents hired Paul Zinke of the Forestry Department at UC Berkeley, who wrote a brief report saying that the pumping appeared to be responsible for the death of vegetation near Cal-AM's wells (Zinke 1981).

Cal-Am hired Ed Stone, also of UC Berkeley, who wrote a report arguing that in the absence of floods and other disturbances, there would be natural ecological succession from cottonwoods and willows to more drought tolerant trees such as bays and oaks, so that even if the pumping were killing the willows and cottonwoods, it was only accelerating a natural process (Stone 1971).

This stand-off of expert opinion continued until 1977, when Cal-Am applied to Monterey County for permits to drill two more wells. Continuing local concern about the loss of riparian vegetation and associated bank erosion lead Monterey County to commission another study of the issue. Based primarily on a single field visit by a groundwater geologist and a remote sensing specialist, this study concluded that bank erosion was not related to the loss of vegetation (Carlson and Rozelle 1978).

However, the study recommended that some kind of riparian management system be developed, with all well owners contributing to the cost. Since there was at the time no feasible way to implement such a system, the county simply gave Cal-Am permits for the wells, although it did retain jurisdiction over the permits.

In 1979, Cal-Am applied for permits to drill four new wells farther down the valley, in an area previously unaffected by pumping. By this time, the Monterey Peninsula Water Management District (MPWMD) had been created, and as part of developing environmental mitigations to be required as conditions on the permits, the MPWMD had a physiological ecologist do a baseline study of the vegetation before the wells were installed.

Studies

In 1981, Woodhouse (1983) measured diurnal leaf water potential and stomatal conductance of Black Cottonwood and Arroyo Willow, along with environmental variables, at monthly intervals at the site of a planned well. He also measured dawn water potential (DWP) monthly at several other sites. One of these, near the mouth of the river where groundwater levels fluctuate only slightly, would serve as a control.

The 1981 data seemed unremarkable. Dawn water potentials were -0.1 to -0.3 MegaPascals (SI units of pressure - one MPa = 10 bars) as might be expected of trees tapping a water table, and the daily course of water potential and stomatal conductance also reflected environmental variables in expectable ways.

By 1984, Cal-Am was ready to put its new wells into production on a test basis, and a major monitoring effort was undertaken jointly by the MPWMD staff and a consulting engineer hired by Cal-Am. This effort emphasized measurements of depth to the water table, soil moisture, and DWP; unfortunately, stomatal conductance was not measured, and the necessary equipment was not acquired.

When the pumps were turned on, the effect of the pumping on nearby vegetation was rapid and obvious: leaves turned yellow and fell off (Williams 1986). However, the data collected were so confusing that the consulting engineer was able to conclude that "Based on all of the data collected and analyzed in this effort there is no indication that operation of the four Cal-Am wells in the Lower Carmel Valley have an adverse impact on the plant community along the Carmel River" (DMA Consulting Engineers 1985).

In response, the MPWMD undertook another summer of intensive work in 1985, which sorted out most of the confusion in the 1984 data, and firmly established that groundwater pumping did indeed severely stress riparian vegetation (McNeish 1986; Williams and others submitted).

Complications

Some of the problems in 1984 resulted from simple errors in judgement, such as monitoring trees that were irrigated by the overflow of a nearby well, or believing unrealistic data from soil moisture blocks. These had been installed in a slurry, which did not equilibrate with the soil until the profile was wetted the following winter.

Other complications were more interesting. These included incomplete nighttime stomatal closure in Black Cottonwood, spatial variation in substrate, differences between willow species, spatial variation in competition for soil moisture, historical effects, and "exogenous" water - water from sources other than the underflow of the river or directly infiltrated rainfall.

Incomplete Night-time Stomata) Closure in Cottonwoods

One striking aspect of the 1984 data was depressed DWP in late summer in cottonwoods in areas where the water table remained near the surface. In the most extreme case, DWP in a cottonwood was -1.0 MPa, while it was -0.2 MPa in a nearby willow, and -0.1 MPa in an alder (Woodhouse 1984).

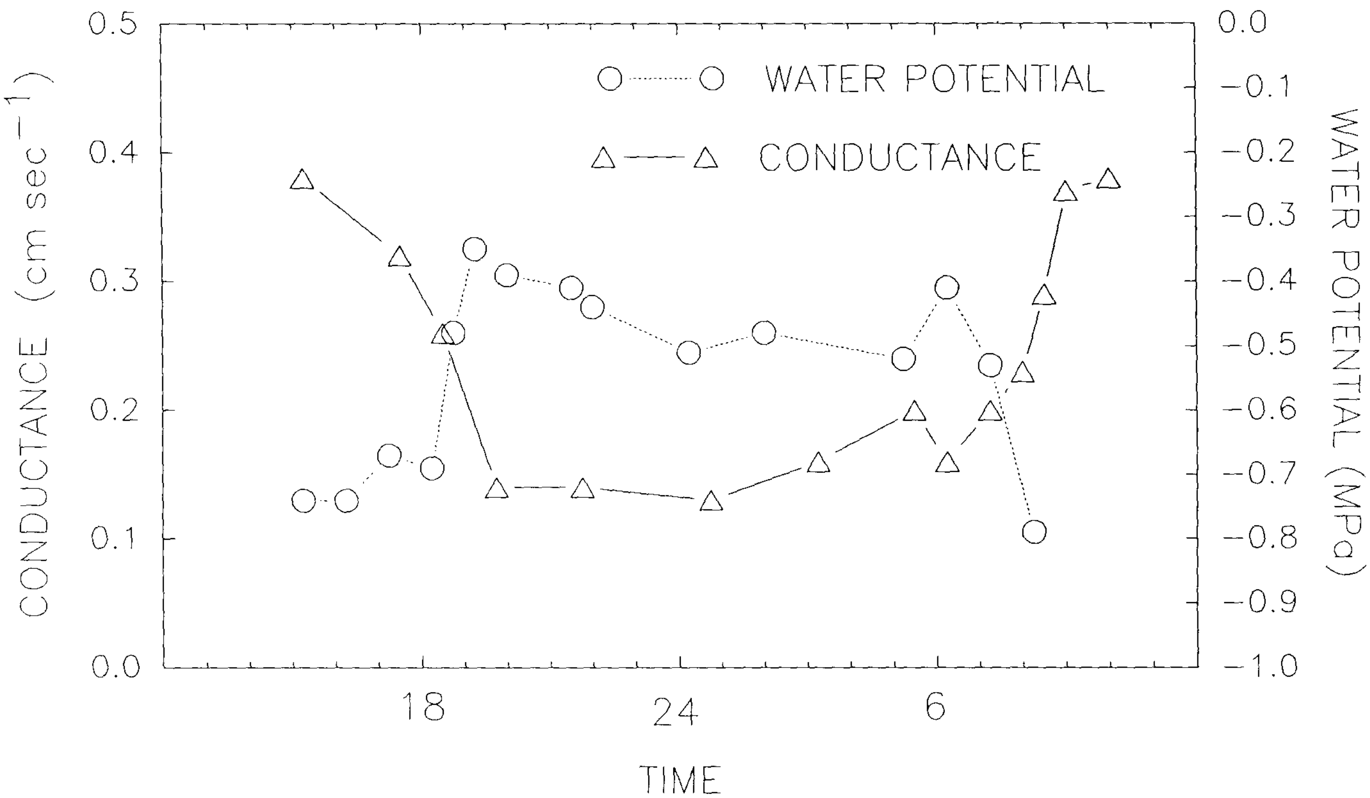

Figure 2– Stomatal conductance and water potential in an unstressed cottonwood, Sept., 1985, showing incomplete nighttime stomatal closure.

The more common situation was DWP in unstressed trees of -0.4 to -0.6 MPa, similar to values in stressed trees that had undergone significant defoliation. However, the depressed DWP was a sometimes thing; on some mornings DWP was -0.2 to -0.3 MPa, as observed in 1981. Together with data from trees receiving water from well overflow or other exogenous water, these resulted in a lack of a clear correlation between DWP and drawdown of the water table.

Based on a few mid-day measurements of water potential in 1984, incomplete nighttime stomatal closure seemed the likely reason. Mid-day water potential in the unstressed trees at the control site dropped to levels like those seen in 1981, around -1.5 MPa, indicating normal stomatal opening, while the water potential in the stressed trees remained above -1.0 MPa, indicating greater stomatal closure (Woodhouse, 1984). However, no porometer was available, so this was not confirmed until 1985.

Figure 2 shows stomatal conductance and water potential in a cottonwood on a September night at the control site, where the water table was within 2 meters of the surface. The stomates never fully closed, and the inverse patterns in conductance and water potential early in the morning show that the incomplete stomatal closure was keeping water potential down. Where trees were stressed, however, all night-time measurements found the stomates closed (McNeish 1986).

Presumably, Woodhouse missed this behavior in 1981 just by chance; his monthly samples were too sparse to provide a complete picture of baseline conditions. From the point of view of designing sampling programs within a reasonable budget, this is disheartening.

Spatial Variation in Substrate

Spatial variation in substrate, and perhaps in associated exogenous water, also complicated patterns in plant response to lowered groundwater levels. The stratigraphy in small valleys such as the Carmel can be quite complex, with landslide or mudflow deposits from the valley sides or side canyons interleaved with deposits laid down by the river itself. It appears that these fine grained deposits can act as conduits for lateral movement of groundwater from side canyons or sources such as septic tank drain fields, over-irrigated golf courses, etc.

The alluvial deposits are also heterogeneous. The lower Carmel Valley is moderately steep, with a channel gradient averaging 0.01, and the river tends to migrate discontinuously, with rapid changes during major floods, rather than by the more gradual migration of meander bends of the sort depicted in textbooks (Kondolf 1983). Consequently, the alluvial deposits consist largely of ribbons of course-grained channel deposits embedded in sheets of finer-grained overbank deposits, and even in the absence of exogenous water the difference in water holding capacity can be significant.

At the main monitoring site, near one of the new production wells, trees just around and to the east of the well were stressed much less than trees west of the well or across the river. Work in 1985 showed that there was a clay lens just beneath and to the east of the well, from which trees were able to extract at least 10 cm of water in September alone, at least around the neutron probe access tube (McNeish 1986).

Figure 3 shows the level of the water table and DWP in three cottonwoods: two to the west of the well (averaged) and one growing over the clay lens to the east. The water level shows clearly when the well was turned on, when it broke down, and when it was repaired. DWP in the cottonwoods west of the well followed the water table down, and then back up. However, when the well was returned to service and the depth to water increased again, DWP remained elevated, apparently because the trees were so far defoliated by that time that evaporative demand was much decreased. DWP did decline in adjacent willows that suffered less defoliation.

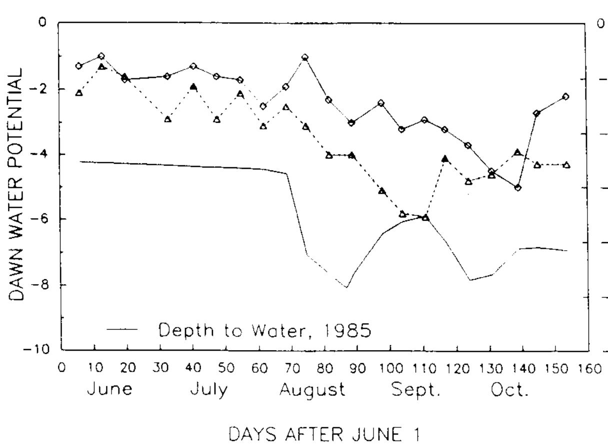

Figure 3 — Depth to water and dawn water potentials in one cottonwood growing over a fine-grained deposit (◊), and two nearby cottonwoods (Δ - averaged) growing away from it. DWP data are smoothed as described in McNeish (1986).

In the meantime, DWP in the cottonwood growing over the clay lens decreased slowly, and defoliation proceeded at about the same rate as at the control site until late October. If one first looked at the trees in mid-October, DWP would be identical, but trees west of the well would be prematurely defoliated, while the others were not.

Figure 4 shows the diurnal course of water potential and stomatal conductance in cottonwoods at the site in August of 1981 and 1985. The tree sampled in 1981 is west of the well, off the clay layer, as is one of the trees sampled in 1985. Mid-day stomatal conductance is higher and water potential is lower in 1981; the tree growing over the clay layer has intermediate values.

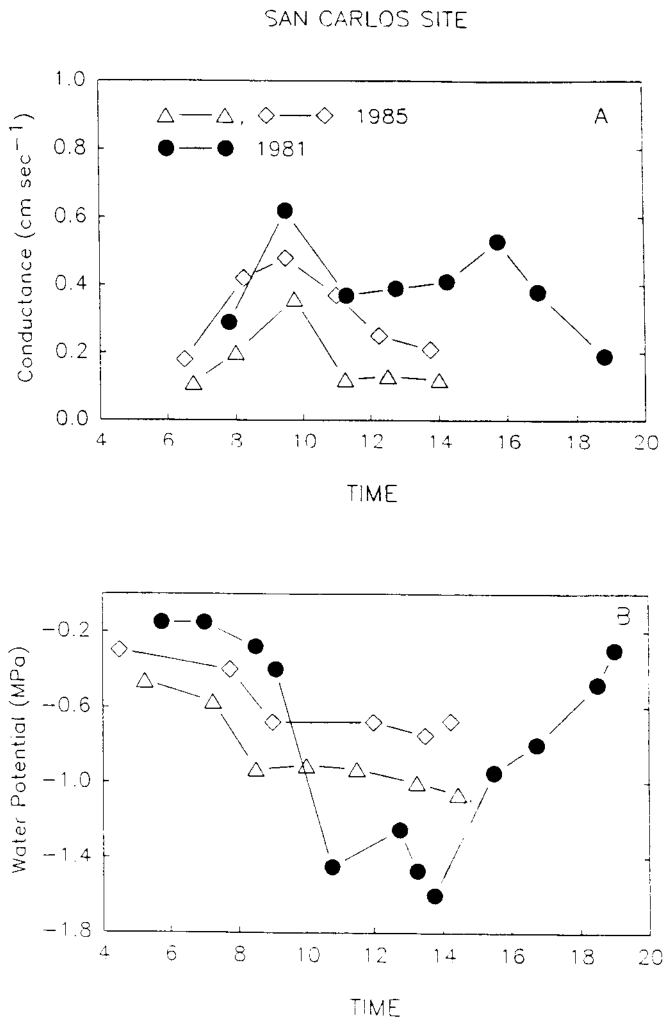

Figure 4 — A. Stomatal conductance in cottonwoods in August: 1981 (o); 1985, tree growing over (◊) and away from (Δ) a clay layer. B. Water potential: same symbols.

Besides the effects of variation in substrate, the figure shows that the mid-day depression of water potential is suppressed in stressed plants, as noted above. Evidently, cottonwoods and willows are like many crop plants, in that stomatal closure occurs at higher water potential if the plant has a history of water stress (Beggs and Turner 1976).

This effect may be exaggerated by the figure, however, as the 1985 data are mainly from shaded leaves. Based on several mid-day measurements, water potential was lower and stomatal conductance was higher in sunlit leaves of the tree growing over the clay lens; there was less difference with the more severely stressed tree.

In another example of the effect of previous water stress, one Arroyo Willow measured in 1985 had high water potential, -0.2 MPa, but very low stomatal conductance. This plant had been stressed and partially defoliated, and then irrigated by blow-off from the adjacent well a day previously. Apparently, the delayed stomatal opening is a response to abscisic acid levels. The acid levels are elevated by water stress, and stomates will not function normally after re-wetting until the acid levels decline (Bradford and Hsiao 1982).

Historical Effects

One group of trees monitored in 1985 are a stunted remnant of a closed canopy riparian forest that occupied the river terrace in this area until about 1970 (fig. 5). The cottonwoods here are probably root sprouts from larger trees that have died, fallen over, and decayed. A few large trees survive on this terrace around a well where they are watered by blow-off.

Figure 5 – Remnant, stunted trees in an area long affected by groundwater extraction.

The 1985 data shows that DWP in these stunted trees declined steadily after the river stopped running in June, and the trees also steadily lost leaves. There was nothing unusual about the few conductance data taken here, although leaves on these trees appear to be smaller and thicker than on trees in areas not subject to large drops in the water table. Smith (1984) noted similar changes in leaf morphology along dewatered Sierran streams.

The point here is simply that data from these remnant trees are not representative of what occurred when the adjacent wells were first installed, when competition for water in the unsaturated soil would have been much more intense, and, probably, the trees were less deeply rooted. What needs to be avoided is thinking along the lines of... The physiological data show that cottonwoods, while showing signs of water stress, can survive periods of lowered water tables. Therefore, the data show that earlier mortality was probably caused by other factors...

Differences Among Species

Differences among species can also be important. Arroyo Willow does not tolerate lowered water tables as well as Red Willow. Observations of water potential and stomatal conductance on paired trees indicate that Red Willow has more effective root systems (Williams and Matthews in press). Based on visual estimates of defoliation, the degree of differential response varies from place to place, and probably depends in part on substrate, being strongest where the roots of Red Willow can differentially exploit local variation in substrate or availability of exogenous water, and least where deposits in the root zone are relatively uniform.

Summary

Physiological measurements are often useful, and can be crucial for demonstrating the effects of human activities on riparian systems. In 1983, in a lawsuit involving bank erosion, "expert" witnesses for Cal-Am convinced a court that "...the condition of the vegetation was most probably the result of the unprecedented drought of 1976-77" (Agliano 1983). In light of the data collected in 1985, it is doubtful that the same verdict could be reached today.

However, it is hazardous to base conclusions on a few physiological measurements, especially on measurements of water potential alone. Conclusions can be based with much more confidence on diurnal measurements of both water potential and stomatal conductance, but even in this case results from one or a few sites may not be representative of the whole area of concern, and results from a few days may not be representative of the whole period of concern.

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RIPARIAN VEGETATION BASE-LINE ANALYSIS AND MONITORING ALONG BISHOP CREEK, CALIFORNIA[1]

Janet L. Nachlinger, Carl A. Fox and Patricia A. Moen[2]

Abstract: A base-line analysis and long-term monitoring study of the riparian system along California's Bishop Creek is being conducted to measure the effects that planned increases in streamflow may have on riparian vegetation and associated wildlife. Six sites located in different major physiographic valley types have been selected for study. Biotic, climatologic, hydrologic, geomorphologic, and edaphic response parameters are being measured to evaluate streamflow and riparian vegetation relationships. Biotic parameters being monitored include stand structural parameters, species composition and importance values (density, cover, and basal area), as well as productivity, growth, and regeneration characteristics.

Riparian vegetation responds to changes in streamflow in various ways. Changes in riparian plant cover, growth, density, composition, and aerial extent all have been attributed in some degree to increases or decreases in streamflow. Highly variable responses in the relationship between historical changes in streamflow (from diversion projects) and existing riparian vegetation characteristics have been demonstrated on the eastside of the Sierra Nevada (Harris and others 1987; Jones and Stokes 1985; Taylor 1982). Stream reach physiography (local geomorphology and hydrology), elevation and substrate characteristics appear to be important in determining riparian vegetation characteristics along these eastside stream courses (Kondolf and others 1987; Southern California Edison 1986). Unless site specific environmental information is known, predicting the responses of riparian vegetation could be difficult because these streams have been found to respond individualistically to changes in streamflow.

On Bishop Creek in Inyo County, California, Southern California Edison Company (SCE) is planning the release of additional water from all diversions to assure the maintenance and enhancement of the existing riparian vegetation. While actual increases in streamflow are yet to be determined, total streamflow in all reaches is likely to be maintained at 0.28 - 0.57 m^3/s (10-20 cfs).

To address the long-term effects of the anticipated increase in streamflow, SCE has initiated a monitoring study along Bishop Creek. The overall objective of this study is to measure the effects that the increase in streamflow will have on riparian vegetation and associated wildlife. Because of the difficulty in interpreting results of wildlife studies, the emphasis is on monitoring riparian vegetation and streamflow relationships.

Characteristics of the Bishop Creek riparian system expected to change as a result of increased flows include horizontal and vertical stand structure, species composition, species importance, productivity, growth rates, and regeneration patterns. Stand structural characteristics, including riparian canopy coverage and leaf area index are expected to increase, as well as the riparian zone width, where it is not limited by geomorphological constraints (Harris and others 1987). Species composition within the riparian zone is expected to change over the long term by an increase in the numbers of obligate riparian and associated wetland species and a decrease in the numbers of upland species within the riparian corridor. Increases in riparian species importance, for example, increases in relative densities, relative cover, and relative frequencies of plants, are expected. Increases in riparian plant biomass, seedling survival patterns, and possibly growth rates are expected also (Smith and Nachlinger 1987). Although a diversity of community-level responses are expected to occur as a result of increasing the Bishop Creek streamflow, selection of community parameters and methodologies for measurement have been limited to those that provide relatively easy spatial and temporal comparisons to meet the overall objective of the study.

The monitoring study is envisioned to span a thirty-year period and is structured in two phases. The first phase is to establish a base line and involves three consecutive years of sampling. The objective of this initial phase work is to define the existing riparian system under present streamflow conditions. The second phase begins after streamflows are increased and involves monitoring riparian community parameters for changes at approximately five-year intervals. The objective of this phase is to detect spatial and temporal changes in riparian community structure and dynamics, as well as to measure changes in the physical setting, that may be attributed to the increased flows. Effects that may result from chance events, time, or inherent variability in study sites necessarily are being considered. This paper describes the monitoring sites and parameters selected for monitoring, and outlines the data collection and analysis methods that are being used in the study.

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[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Materials and Methods

Monitoring Study Sites

The study area is located along Bishop Creek, southwest of the town of Bishop, in Inyo County, California (fig. 1). It encompasses the stretch of Bishop Creek between SCE Plant #6 at 1400 m elevation and SCE Intake #2 along the Middle Fork of Bishop Creek at 2440 m elevation. Three primary study sites and three potentially "sensitive" study sites have been selected for monitoring. Site selection and measurements of the responses of riparian vegetation to the proposed increased streamflows are being viewed within the context of the physical factors (stream reach physiography, elevation, and substrate characteristics) that generally determine the extent and characteristics of the riparian vegetation community. Three primary sites and three "sensitive" sites have been selected for monitoring. The three primary sites correspond to three major physiographic valley types present along Bishop Creek: U-shaped glacial valley, V-shaped glacial valley, and alluvial valley fan. The three sensitive sites are areas judged to be sensitive to changes in streamflow or have vegetation (or wildlife) of special interest. The primary site plots are 0.5 ha in size and are being monitored relatively more intensively than the sensitive site plots which are 0.25 ha in size. Three to six transects have been placed perpendicular to the stream at regular intervals within each site plot to aid in measuring some of these parameters. Site locations are shown in fig. 1. General site characteristics of the six monitoring sites are summarized in table 1.

Field Methods

To monitor potential changes in the Bishop Creek riparian system, several physical and biological parameters are being observed or measured at the study sites. Table 2 lists fifteen physical site parameters that are being measured at different intervals depending on the parameter. All of the edaphic and geomorphologic, and two of the hydrologic parameters (reach type and active channel width), were measured in summer 1988 when the sites were set up. They will be remeasured at the end of the study period to detect changes in these physical site characteristics that may be attributable to increased streamflows.

Soil water content and depth to the water table are being measured monthly during the April-October growth season. At the primary sites, soil water content is being determined gravimetrically on samples collected at 10 cm depth intervals at three points along a transect from streamside to upland locations (Donahue and others 1983). Depth to the water table will be measured in wells proposed for drilling at the primary sites during the first year of sampling. Three wells will be drilled along the streamside to upland gradient at these sites. Ground water depths will be recorded at each well providing important hydrologic information especially during the spring recharge period.

Streamflow and several climatologic parameters already are being monitored daily at several locations along Bishop Creek. Streamflow data are being obtained from SCE gaging stations. Climatologic data from stations near the monitoring sites are being obtained from SCE, as well as from the National Climate Data Center and the California Data Exchange Center.

Table 3 lists the biological parameters selected for monitoring on an annual or monthly basis. Stand structural parameters (canopy cover, canopy height, and leaf area index) are being estimated annually at peak production before plant senescence commences. Canopy cover of trees and shrubs are being estimated using the crown-diameter method (Mueller Dombois and Ellenberg 1974). All individual tree and shrub heights are being estimated by triangulation or measured directly using meter sticks. Leaf area index (LAI) is being estimated for riparian trees and shrubs by sampling representative individuals within the plots. Three methods for estimating LAI are being tested during the initial field season: 1) point (rod)-intercept (MacArthur and MacArthur 1961); 2) fish-eye photography (Anderson 1971); and 3) destructive harvesting (allometric relationships). The method that proves to be the most precise and efficient will be used in the future. Additionally, width of the riparian zone is being measured directly along the transects within each plot.

The relative importance of riparian trees and shrubs are being determined at all sites. Tree density is being tallied for an entire plot, while shrub density is being sampled in subplots. Measurements of trunk diameters at breast height (DBH) are being made and then converted to basal area for all trees present in the plot. Since the DBH of multi-stemmed individuals can be difficult to assess, only the number of stems of multi-stemmed shrubs are being tallied in the subplots. Tree cover is being determined for the entire plot, while cover of shrubs and herbaceous plants are being measured by sampling along 7-12 line transects perpendicular to the stream. Cover of all species in three strata (trees, shrubs and herbaceous) is being estimated using the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974). The frequency of species in all strata will be determined by calculating the number of plots or subplots that contain at least one individual.

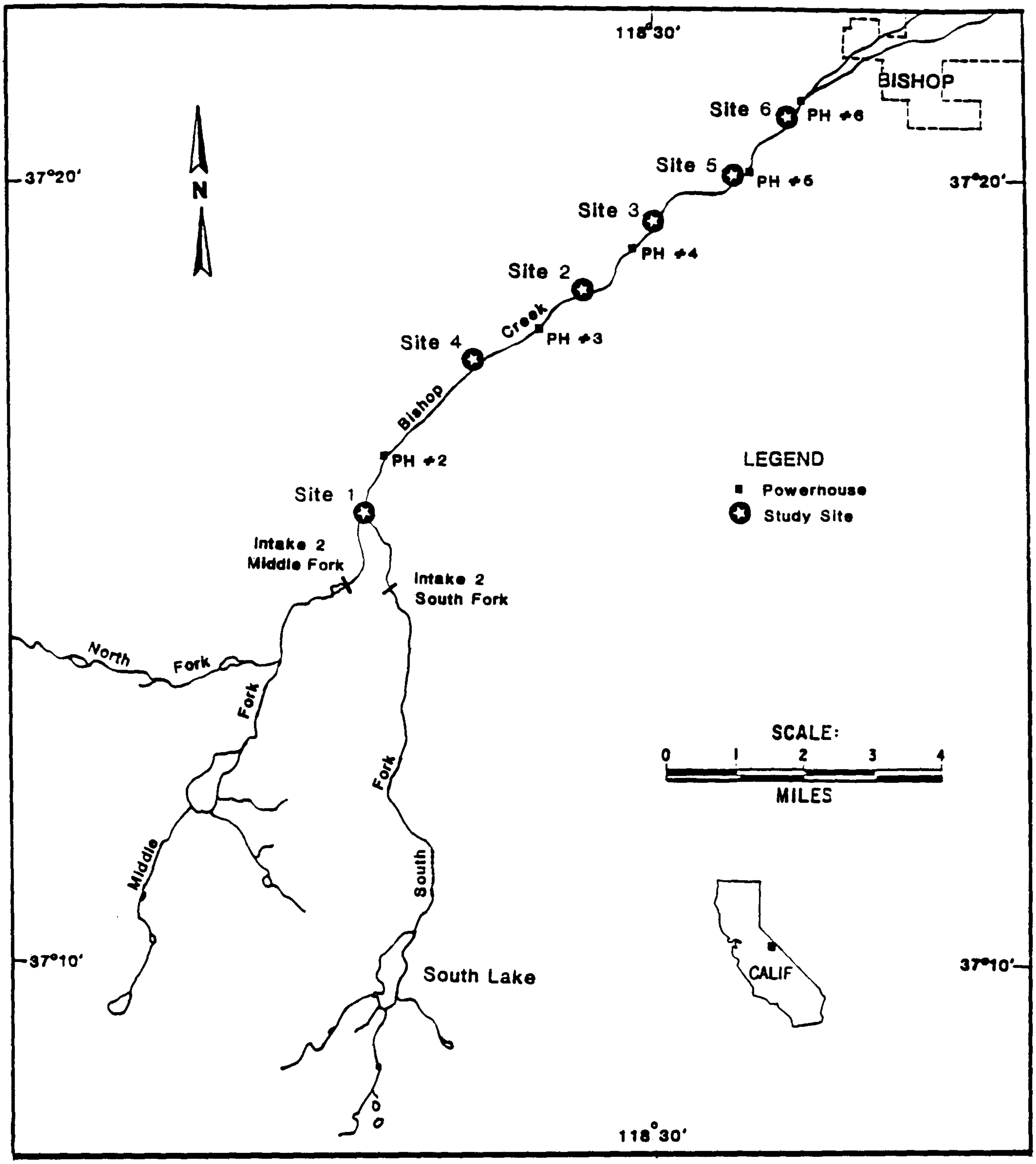

Figure 1 — Map of monitoring study site locations along Bishop Creek.

Table 1. General locations and characteristics of the selected primary and sensitive sites along Bishop Creek.

Site	General location	Elevation	Physiographic valley type	Vegetation type
Primary				
1	At the confluence of the South and Middle Forks adjacent to USDA Forest Service Big Trees Campground, and 1 km upstream from Plant #2	7400 ft 2255 m	U-shaped glacial valley	*Betula occidentalis-Salix lutea*
2	On the Main Fork, upstream of the confluence of Coyote Creek, and 1.8 km upstream from Plant #4	5640 ft 1720 m	V-shaped glacial valley	*Populus trichocarpa-Rosa woodsii*
3	On the Main Fork, at the head of the alluvial fan, and 1.8 km downstream from Plant #4	4920 ft 1500 m	Alluvial valley fan	*Populus trichocarpa-Rosa woodsii*
Sensitive				
4	On the Main Fork, 1.4 km upstream from Plant #3	6560 ft 2000 m	V-shaped glacial valley	*Betula occidentalis-Salix lutea*
5	On the Main Fork, 0.2 km upstream from Plant #5	4790 ft 1460 m	Alluvial valley fan	*Chrysothamnus nauseosus-Artemisia tridentata*
6	On the Main Fork, 0.5 km upstream from Plant #6	4575 ft 1395 m	Alluvial valley fan	*Chrysothamnus nauseosus-Artemisia tridentata*

Table 2. Physical parameters being measured or observed along Bishop Creek.

Parameter	Definition	Units	Sampling Frequency
Climatologic			
Air temperature	Maximum, minimum, and mean ambient temperature	Degrees C.	Daily
Precipitation	Total	Millimeters	Daily
Relative humidity	Maximum, minimum, and mean humidity	Percent	Daily
Wind speed	Mean wind speed	Meters/second	Daily
Edaphic			
Soil profile description	Description of soil horizon characteristics including color, structure, texture, and degree of alkalinity or acidity		Initially and at end of study
Surface substrate	Classification of substrate by size of particles (e.g. silt, sand, gravel, cobbles, boulders, and bedrock)		Initially and at end of study
Geomorphologic			
Physiographic valley type	Classification of valley types based on landform features (e.g. U-shaped glacial valley or alluvial fan)		Initially and at end of study
Elevation	Altitude above mean sea level	Meters	Initially and at end of study
Channel gradient	Slope of stream channel along length of stream	Degrees	Initially and at end of study
Valley slope	Slope of gently sloping surfaces perpendicular to the stream and beyond the active channel edge	Degrees	Initially and at end of study
Hydrologic			
Reach type	Classification of stream as gaining, losing, or in equilibrium		Initially and at end of study
Active channel width	Width across stream at height where the relatively steep bank slope breaks to a more gently sloping surface beyond the channel edge	Meters	Initially and at end of study
Streamflow	Volume of water in the channel passing a given location per unit time	Cubic meters/second	Daily
Soil water content	Percentage of water weight per unit soil weight	Percent	Monthly
Depth to water	Distance below ground surface to top table of saturated zone	Meters	Monthly (possibly daily)

Table 3. Biotic parameters being measured or estimated within the riparian corridor along Bishop Creek. These parameters are being sampled annually at the period of peak production, except for litter accumulation, seedling growth, seedling survival, and midday xylem pressure potential, which are being measured monthly during the growth season.

Parameter	Definition	Units
Stand Structure		
Canopy cover	Percentage of plot covered by tree and shrub canopies	Percent
Canopy height	Mean height of individual tree and shrub canopies	Meters
Leaf area index	Total leaf area (one surface only) per unit ground area	$Meters^2$ per $Meters^2$
Riparian zone width	Width of riparian vegetation perpendicular to stream and excluding the channel width	Meters
Relative Importance		
Tree diameter at breast height	Diameter of tree trunk 1.3 meters above the ground	Meters
Tree, shrub and seedling density	Number of individuals per unit area	Number per hectare
Tree and shrub height	Height of individual shrubs in the plot	Meters
Shrub stem number	Number of stems of multi-stemmed shrubs	Number
Absolute cover	Percentage of plot (or subplots) covered by a given species	Percent
Frequency	Percentage of total plots (or subplots) which contains at least one individual of a given species	Percent
Productivity		
Shrub and herbaceous biomass	Dry weight of plant material per unit area per year	Kilograms per hectare
Litter accumulation	Dry weight of litter per unit area	Kilograms per hectare
Growth and Survival		
Tree and shrub branch growth rate	Rate of branch elongation during a growth season	Meters per year
Seedling height growth rate	Rate of seedling stem elongation during a growing season	Meters per year
Seedling survival rate	Rate of seedling survival per unit area	Number per hectare
Species Composition	Identification of species present	
Species Richness	Total number of species present	Number
Water Relations		
Midday xylem pressure potential	Leaf or branchlet xylem pressure measured at solar noon	Megapascals

At the primary sites, annual measurements of riparian plant biomass and litter accumulation are being taken at the primary sites to monitor productivity (Chapman 1976). Biomass samples are being acquired at peak productivity using destructive sampling techniques, and are being done in conjunction with the LAI harvests for trees and shrubs. Subplots, totalling 50 m^2 (approximately 0.01 of each total plot) are being used to sample the herbaceous component. To sample litter accumulation, 16-18 wire and cloth litter traps, have been placed randomly along the transects. Plant materials in the traps are being collected monthly during the growth season, and then weighed and totalled for seasonal accumulation values.

Annual measurements of plant growth are being determined at all sites for riparian trees, shrubs, and seedlings. Branch elongation is being measured on five lateral branches of three individuals per species of riparian trees and shrubs. To determine seedling spatial patterning, current seedlings of riparian dominants have been located and identified. Seedlings are being measured in 5-9 1 m^2 subplots regularly placed along the length of the stream near the channel edge. Seedling shoot growth is being determined by measuring the heights of main shoots of all individuals present in the subplots.

Species composition and species richness also are being determined annually. Composition is determined at each site by identifying all species present and classifying them as riparian (wetland) or upland.

A few biotic parameters are being sampled monthly during the growth season, including midday (assumed minimum) xylem pressure potential, seedling survival rates, and litter accumulation rates. Xylem pressure potentials are being measured to monitor riparian plant water status. Selected adult and juvenile individuals of riparian tree and shrub species are being measured at midday (the assumed time of minimum water potential) using a pressure chamber apparatus (Scholander and others 1965). These measurements may provide useful information on general periods of water stress. Seedling survival rates are being measured monthly at all sites so that survivorship curves can be constructed. These curves will be useful tools to monitor patterns of riparian plant regeneration (Begon and Mortimer 1981). Also, monthly rates of litter accumulation will provide information on patterns of riparian plant productivity.

To aid in monitoring long term changes, a site map is being drawn annually to delineate existing vegetation with respect to the locations of all transects and subplots for monitoring shrubs, herbaceous plants, and riparian plant seedlings.

In conjunction with this ground monitoring program, some aerial monitoring is being conducted. Aerial photographs are being taken by SCE once annually for the first three years and then every five years thereafter to help document changes in the riparian community.

Data Analysis

To define the physical and biological variables at a given site for a given year, we will use descriptive statistical procedures. These analyses will provide information on central tendencies and their dispersion, thus yielding comparisons among the six sites and three physiographic valley types. To compare mean values of physical and biological variables among sites grouped by physiographic valley type in a given year, ordinary t-tests and a one way analysis of variance will be used, unless assumptions of equal variances cannot be met. If the latter, appropriate nonparametric tests for independent samples, such as the Kruskal-Wallis test, will be used.

Allometric relationships between DBH, basal area, or crown cover and LAI in a given year, will be determined using multiple regression and correlation analysis. Scatterplots will be used to visualize these relationships and correlation coefficients will be determined to test the strength of the relationships. These analyses will help determine which method of measuring LAI will be used in future sampling.

For temporal comparisons of physical and biological variables at a given site or valley type at different streamflow regimes and at different intervals since change of flows, analysis of variance (ANOVA) will be used with data having enough replicates. ANOVA will be used to test for significant changes in biological variables resulting from increasing the streamflow in V-shaped valley and alluvial valley fan settings. Since only one site (site #1) is being measured at a U-shaped glacial valley type site, no statistical procedures can be used to test for significant change in biological variables as a result of altering the streamflow regime. Only descriptions of any changes measured, without tests of significance, are possible. However, this site has been divided into three subplots on the South Fork, Middle Fork, and Main Fork of Bishop Creek for sampling, so we may be able to analyze the data by separating the subplots.

Conclusions

Measurement and analysis of the biotic and abiotic parameters included in the Bishop Creek study is expected to provide an improved understanding of the relationship between streamflow and riparian vegetation community dynamics. Collection of data over the next thirty years will result in an evaluation of the effects of streamflow alteration on the riparian ecosystem on a time scale more suitable for ecological interpretation.

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RIPARIAN COMMUNITIES OF THE SIERRA NEVADA AND THEIR ENVIRONMENTAL RELATIONSHIPS[1]

Richard R. Harris[2]

Abstract: Data on riparian community composition and environmental conditions were collected on over 20 streams in the Sierra Nevada as part of hydropower licensing studies. Over 1,000 samples were analyzed using two-way indicator species analysis (TWINSPAN), to determine riparian dominance types. Ordination techniques were applied to evaluate associations between environmental conditions and community characteristics. Results indicate that at least 15 communities are found in riparian settings at altitudes ranging from 300 to 3000 m on eastern and western slopes of the Sierra Nevada. These communities are arranged in the landscape in apparent response to climatic and geomorphic gradients.

The published literature contains few descriptions of riparian communities in California montane settings. In recent years, these communities have been subject to intensive ecological investigations performed in conjunction with agency permit requirements for hydroelectric development. Reports of these investigations fall into that elusive category of "grey" literature which is rarely accessible to scientists and managers. Fragments have been published in the refereed literature (Harris and others 1987; Harris 1988) and symposia proceedings (Harris and others 1985; Taylor and others 1987).

The purpose of this paper is to summarize some of the ecological studies conducted by consultants to Pacific Gas and Electric Company (PG and E) and Southern California Edison Company (SCE) with the specific aim of presenting an overview of the physical and botanical characteristics of riparian communities in the Sierra Nevada. These consultant studies encompass many of the communities occurring at altitudes from 300 to 3000 m in the central Sierra Nevada. Because field studies and analysis techniques were to some degree standardized, the results represent a valuable data base on montane riparian communities of the region. This data base is available to other scientists who may be stimulated by the introductory materials contained in this paper.

Methods

Study Area Location

Detailed ecological studies were conducted by PG and E, SCE and other hydropower developers throughout California's central Sierra Nevada Mountains. This paper is confined to the results of studies undertaken by Jones and Stokes Associates (1984,1985) and Taylor and Davilla (1985,1986). Jones and Stokes Associates (1984) sampled existing streamflow diversion sites from Fresno County north to Plumas County to analyze effects of existing hydropower projects on riparian communities. They also conducted an intensive field study in the upper Kings River basin, Fresno County. Taylor and Davilla (1985,1986) conducted intensive studies in Madera and Fresno Counties, respectively, in the upper San Joaquin and Kings River basins. Thus, the data base includes both extensive and intensive sampling programs.

Jones and Stokes Associates (1985) sampled existing SCE hydropower sites and unregulated stream reaches in the eastern Sierra Nevada from Bishop north to Lee Vining (Inyo and Mono Counties). Although numerous other hydropower developments have been proposed in the eastern Sierra Nevada, data collection efforts have not been coordinated except in the case of SCE projects.

Field Sampling Techniques

Field techniques used by Jones and Stokes Associates (1984, 1985) were described by Harris and others (1987) and more recently by Harris (1988). Except for an additional procedure described below, the same techniques were used by Taylor and Davilla (1985, 1986). Briefly, the initial step was to stratify streams into reaches using physiographic and hydrologic criteria. Typical criteria included stream order, altitude, valley geomorphology and substrate. After field reconnaissance, sample sites were selected in stratified reaches. Sample sites were homogeneous with respect to vegetation and geomorphology, as subjectively judged in the field.

Two sampling procedures were used. Jones and Stokes Associates (1984,1985) used transects perpendicular to channels and spanning the floodplain to collect

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California

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vegetation and environmental data. Taylor and Davilla (1985,1986) also used transects but complemented the transect sampling with a plotless stand survey sampling scheme i.e. releves, (Mueller-Dombois and Ellenberg 1974).

In transect sampling, plant cover values were measured, while in releves they were estimated by using a scale. In either method, various environmental data were collected at each sample site. The releve method was advantageous for rapid collection of compositional data from an extensive area. The transect method was most useful for obtaining detailed data to study community-environmental relationships.

Further information on sampling procedures may be obtained from published accounts and reports available from the sponsoring utility companies. Considering all studies conducted by Jones and Stokes Associates and Taylor and Davilla, a total of 851 transects and 392 releves were sampled. Only 105 of the transects were sampled in the eastern Sierra Nevada.

Data Analysis Methods

Vegetation and environmental data were analyzed using univariate, bivariate and multivariate methods. Only techniques relevant to the presented results will be noted. To identify patterns of vegetation variation in relation to environmental conditions, combined ordination-classification techniques were used (Gauch 1982). Two-way indicator species analysis –TWINSPAN (Hill 1979a) was utilized to classify vegetation samples of equivalent floristic and compositional structure. Detrended correspondence analysis (Hill 1979b) and multiple regression were applied to investigate patterns in vegetation correlated with environmental conditions.

Results And Discussion

Riparian Community Types

The dominant environmental controls on riparian community composition in the Sierra Nevada are climate and stream valley geomorphology. Communities initially segregate by aspect, i.e. east or west slope of the range. On either slope, they are further distinguished by altitude. Both aspect and altitude are strongly correlated with climate (Major 1977). At a given altitude on either slope, community composition and structure are strongly affected by geomorphic factors such as steam size (order), floodplain development and surficial geology.

Jones and Stokes Associates (1984) classify west-slope communities at altitudes ranging from 1200 to 2500 m into five dominance types. Lower altitude communities (less than 1600 m) are dominated by *Alnus rhombifolia,* often in association with *Rhododendron occidentale* and *Fraxinus latifolia.* Mid-altitude streams (1600 to 2200 m) support communities dominated by *Alnus incana* ssp *tenuifolia* or *Salix lasiolepis* or mixtures of *Cornus stolinifera* and *Salix lasiolepis.* At higher altitudes, *Pinus contorta* var *murrayana* and *Spiraea densiflora* often dominate riparian communities, particularly in meadow-like settings.

The general classification presented by Jones and Stokes Associates (1984) was derived from data obtained throughout the central Sierra Nevada and is applicable to many perennial streams in the region. The work of Taylor and Davilla (1985, 1986) considerably expands understanding of communities existing at altitudes of 300 to 2200 m in the Fresno-Madera County area. Taylor and Davilla (1985) distinguish 20 community types in their watershed-study area. Nine are variants of the *Alnus rhombifolia* community separated on the basis of shrub and/or herb associates. Three additional community types are dominated by *Fraxinus latifolia.* Six are classified as dominated by conifers (*Abies magnifica* or *A. concolor*). These would be comparable to the shrub-dominated types of Jones and Stokes Associates (1984) in which the riparian community is bordered by, or in part composed of non-obligate conifers. In the latter work, non-obligate conifers were excluded as a basis for naming types. The remaining two types are identified as an *Alnus incana* ssp *tenuifolia* community and another dominated by *Populus balsamifera* var *trichocarpa.*

Taylor and Davilla (1986) classify streamside communities in their study area into four types; two dominated by *Alnus rhombifolia* and two by *Alnus rhombifolia* and *Fraxinus latifolia.* All of these were reported in their previous work.

Differences between the classifications of Jones and Stokes Associates and Taylor and Davilla are due to the objectives of each study, choice of classification level, choice of indicator species (in the case of conifers) and geographical area covered. Taylor and Davilla's work may be considered a finer resolution classification applicable to a watershed rather than a region. Considering all studies, there appear to be seven major dominance types that characterize west-slope riparian communities (table 1). These may be subdivided into variants on the basis of associated shrub and herb species, as demonstrated by Taylor and Davilla (1985, 1986). The need for subdivision, of course, depends on the objectives of the investigator. It is probable that intensive evaluation within the major dominance types at other locations would reveal additional floristic variation and associates.

Table 1 – Riparian Dominance Types of the Western Sierra Nevada

Dominance Type	Dominant Tree/Shrub	Indicator Shrub/Herb
Pinus contorta var *murrayana*	*Pinus contorta* var *murrayana*	*Spirea densiflora, Carex fracta, Deschampsia elongata*
Abies magnifica	*Abies magnifica*[1] *Salix lasiolepis*	*Salix drummondiana, Cornus stolinifera, Senecio triangularis, Athyrium filix-femina*
Alnus incana ssp *tenuifolia*	*Alnus incana* ssp *tenuifolia*[2]	*Rhododendron occidentale, Glyceria striata*
Populus balsamifera var *trichocarpa*	*Populus balsamifera* var *trichocarpa*	*Rhododendron occidentale*
Abies concolor[3]	*Abies concolor Cornus stolinifera, Salix lasiolepis*	*Rhododendron occidentale, Ribes nevedense, Rubus parviflorus, Boykinia major, Athyrium filix-femina*
Alnus rhombifolia[4]	*Alnus rhombifolia*	Many shrubs and herbs. See Taylor and Davilla (1985).
Fraxinus latifolia	*Fraxinus latifolia Alnus rhombifolia*	Many shrubs and herbs. See Taylor and Davilla (1985).

[1] *Abies magnifica* may be absent (*Salix lasiolepis* type of Jones and Stokes 1984).

[2] *Abies concolor* on valley slopes may provide substantial cover.

[3] *Abies concolor* is a facultative riparian species. Obligate riparian shrubs dominate near-stream cover.

[4] *Mixed conifer* forest dominates zonal vegetation. Subdivided into variants by Taylor and Davilla (1985).

In the eastern Sierra Nevada, Jones and Stokes Associates (1985) distinguish eight community types at altitudes ranging from 1200-3000 m. Streams on alluvial fans at lower altitudes are dominated by a *Chrysothamnus nauseosus - Artemisia tridentata* association and streams at highest altitudes are dominated by a *Pinus contorta* var *murrayana* - meadow community. The other six types (table 2) do not sort out simply along an altitudinal gradient. Their occurrence seems dependent on geomorphic and land use factors. They include communities dominated by *Populus balsamifera* var *trichocarpa, Populus tremuloides, Betula occidentalis* and *Salix* spp. The work of Jones and Stokes Associates (1985) focused on a fairly narrow range of streams and is not a comprehensive classification for the region.

Taylor (1982) presents a preliminary classification for eastern Sierra Nevada riparian communities. Taylor (1982) recognizes 18 "habitat types" divided into lower altitude, middle altitude and upper altitude communities. These include 5 dominated by *Salix* spp., 6 dominated by herbs, 4 dominated by conifers and 3 dominated by other deciduous trees or shrubs. Superficially, some of his communities appear similar to those of Jones and Stokes Associates (1985). Differences in objectives, methods, nomenclature and perhaps, taxonomy impair direct comparisons between the classifications. In particular, Jones and Stokes Associates (1985) did not encounter herb and conifer-dominated communities. Additional studies are needed in this region to derive a comprehensive classification.

Environmental Relationships of Dominance Types

Western Sierra Nevada riparian communities array themselves along an altitudinal/climatic gradient from the crest to the foothills. In addition to strong correlations between species' dominance and altitude, there is a strong negative correlation between altitude and percent tree cover and a strong positive correlation between altitude and herb cover (Jones and Stokes Associates

Table 2 – Riparian Dominance Types of the Eastern Sierra Nevada

Dominance Type	Dominant Tree/Shrub	Indicator Shrub/Herb
Pinus contorta var *murrayana* - meadow[1]	*Pinus contorta* *var murrayana,* *Salix* spp.	*Alium validum,* *Carex* spp.
Salix - Glyceria	*Salix* spp.	*Salix geyeriana*
Populus tremuloides	*Populus tremuloides* *Salix* spp.	*Elymus triticoides,*
Salix - Cornus[2]	*Salix* spp. *Corpus stolinifera*	*Equisetum, Deschampsia*
Betula - Saliz[3]	*Betula occidentalis* *Salix* spp.	*caespitosa, Carex lanuginosa*
Populus tremuloides -	*Populus tremuloides*	*Salix lasiolepis,*
Populus balsamifera var *trichocarpa*[4]	*Populus balsamifera* var *trichocarpa*	*Corpus stolinifera,* *Carex lanuginosa*
Populus - Rosa	*Populus balsamifera* var *trichocarpa* *Rosa woodsii*	*Salix exigua,* *Artemisia tridentata*
Chrysothamnus - *Artemisia*[5]	*Chrysothamnus nauseosus* *Artemisia tridentata*	*Salix exigua,* *Betula occidentalis,* *Phragmites australis*

[1]Comparable to higher altitude pine type of western Sierra Nevada.

[2]0ccasional *Populus balsamifera* var *trichocarpa* or *Pinus jeffreyi* may occur.

[3]Dominated by *Salix lasiolepis* according to Taylor (1982). Occasional large *Pinus jeffreyi* may occur.

[4]Complex vertical structure often with reduced herb cover.

[5]*Salix exigua* and *Betula occidentalis* typically dominate near-stream cover.

1984). Total canopy cover decreases with increasing altitude (Taylor and Davilla 1985).

Gradient i.e. channel slope, substrate and stream power are also correlated with occurrence of communities or with community structure (Jones and Stokes Associates 1984; Taylor and Davilla 1985,1986). In general, as gradient increases and substrate coarsens, communities tend to simplify. At the extreme, steep bedrock channels usually have little if any riparian cover. For example, of over 46 km of streams in the upper Kings River basin studied by Jones and Stokes Associates (1984) over 15 km were completely barren of vegetation. Canopy cover increases on gentle gradient reaches, especially with gravel and sand substrates (Taylor and Davilla 1985).

Particular riparian dominants are also associated with specific substrates or positions on floodplains (Jones and Stokes Associates 1984; Taylor and Davilla 1985; Harris and others 1985). Willows and some common riparian herbs (*Glyceria striata* and *Pteridium aquilinum*) are often associated with sand and cobble substrates. Many species can be grouped into classes based on their position of occurrence relative to the stream channel. *Alnus rhombifolia, Alnus incana* ssp *tenuifolia* and *Salix lasiolepis* all tend to occur immediately adjacent to channels (Jones and Stokes Associates 1984; Taylor and Davilla 1985). Conversely, *Abies concolor* and oaks are often associated with peripheral, outer floodplain locations. Intermediate positions on floodplains are occupied by facultative riparian conifers, principally pines, and *Calocedrus decurrens* (Taylor and Davilla 1985).

The effects of streamflow diversions on western Sierra Nevada riparian communities vary depending on site-specific environmental conditions (Harris and others 1987). Taylor and Davilla (1985) observed a general trend for increased canopy cover on diverted reaches relative to undiverted reaches in the upper San Joaquin watershed. Harris and others (1987) saw similar responses on some western Nevada streams but also found decreased cover on other streams. Investigators have also noted changes in community structure and density and sizes of riparian dominants on diverted reaches relative to comparable undiverted reaches.

Environmental relationships of eastern Sierra Nevada riparian communities have been described elsewhere (Harris 1988). Stream valley geomorphology i.e. valley shape and surficial geology, floodplain geomorphology and substrate show significant associations with different dominance types. Correlations between altitude and geomorphic conditions cause the gradient to be complex on the eastern slope and associations between communities and altitude are not as clear as on the western slope. Instead, communities tend to be associated with valley environments occurring at various altitudes. For example, glaciated bedrock streams at higher altitudes are vegetated by the *Pinus contorta* var *murrayana* - meadow community if the channel is incised with sand or cobble substrate. In the same valley type, if the channel is braided in gravel, the *Salix* spp - *Glyceria striata* community tends to dominate (Harris 1988).

Land uses such as grazing, tree cutting and streamflow diversion have also profoundly affected the areal extent and composition of riparian communities in the eastern Sierra Nevada (Taylor 1982; Harris and others 1987). The severe climate in this region, especially at arid lower altitudes, may affect the ability of a community to recover after disturbance or may exacerbate impacts. Streamflow diversions, in particular, have been responsible for extensive losses of riparian habitat on low-altitude, arid alluvial fans (Taylor 1982). The presence of the *Chrysothamnus nauseosus* - *Artemisia tri dentata* community on alluvial fans may reflect compositional changes from obligate riparian dominants to facultative riparian species due to diversions and other land use impacts (Harris and others 1987).

Additional analyses, and in the eastern Sierra Nevada particularly, additional data are needed to clarify environmental relationships with riparian dominants. Also, the ecological functions and successional processes of these communities have not been studied to date.

Management Implications

The resource values of riparian dominance types in the Sierra Nevada vary, depending on the composition and structure of the community at a specific location. Riparian communities should be considered multiple re-source settings. It is reasonable to expect the greatest number and diversity of values (i.e. wildlife habitat, fisheries, aesthetics, economics and recreation) to be associated with the most complex and diverse communities. Included in the western Sierra Nevada might be communities dominated by *Alnus rhombifolia* with well-developed shrub and herb layers. In the eastern Sierra Nevada, communities dominated by *Populus* may have highest resource values. Communities comprised exclusively of shrubs or dominated by conifers which have simple structure and low species diversity may not have the same range or magnitudes of resource values. They nevertheless are critical for specific ecological functions and deserve careful management and protection. Obviously, greater knowledge of resources associated with montane riparian communities is required before sound management prescriptions can be developed and impacts avoided.

Development of the classification presented here was possible because of standardized data collection and analysis techniques. Valuable data that could be used to enhance classification and management has been and continues to be collected by other investigators. This classification is a starting point for developing a regional riparian typology at a scale suitable for management. For the western Sierra Nevada, the range of occurrence of known dominance types and their environmental relationships need to be better understood. It is possible that additional major types might be disclosed by further field sampling. The need for refinement of major types into floristic variants, as was done by Taylor and Davilla (1985) could be determined by potential users and accommodated within a hierarchical system. In the eastern Sierra Nevada there has not been additional standardized sampling for expansion and refinement of the classification proposed by Jones and Stokes Associates (1985). There are undoubtedly dominance types in the region which were not included in their sample. The standardized format and methods used by prior investigators and documented in the literature cited should be used for future sampling if the value of the extensive existing data base is to be realized.

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EARLY RECOVERY OF AN EASTERN SIERRA NEVADA RIPARIAN SYSTEM AFTER 40 YEARS OF STREAM DIVERSION[1]

Julie C. Stromberg and Duncan T. Patten[2]

Abstract: Rush Creek, which feeds Mono Lake, has been diverted below Grant Lake, totally or in part, for over 40 years. In the early 1980's, because of above normal snow packs, runoff was released into the creek. Minimum flow releases have also been established. The riparian vegetation has responded to these releases. In a few areas, riparian trees and shrubs (e.g., black cottonwood and willow) survived the diversion period but with high stem mortality. These plants are resprouting in response to the 1980's floods. In other areas, new plants are establishing within the floodplain; however, on areas away from the floodplain most riparian plants died and are not regenerating. The patterns of riparian regeneration and environmental requirements of each riparian species have been preliminarily determined.

Rush Creek, located in the eastern Sierra Nevada of California, is one of several streams that feed Mono Lake (fig. 1). Rush Creek, as is true of many eastern Sierra Nevada streams, has a long history of water management. Around 1915, a dam was constructed below Grant Lake depression forming Grant Lake, and the impounded waste was used to convert sagebrush desert to irrigated fields (Stine and others 1984). More intensive water management began in 1941 with completion by the Los Angeles Department of Water and Power (LADWP) of an extension of the Los Angeles Aqueduct to the Mono Basin.

Since 1941, LADWP has annually diverted varying amounts of water from Rush Creek (Grant Lake) for use by the city of Los Angeles (fig. 2). The diversion pattern is characterized by periods of relatively abundant release into Rush Creek interspersed by periods of almost total diversion into the aqueduct, such as occurred in the 1970's. The result has been mortality of riparian vegetation and invasion by upland shrubs along stretches of Rush Creek during the 1970's (Jones and Stokes 1985, Stine and others 1984, Taylor 1982).

In the early 1980's, above-average snowpack resulted in releases of large amounts of water into Rush Creek. These flows, coupled with recent litigation-required minimum flow releases, have stimulated regeneration of some riparian vegetation. In 1987, we began studying the riparian vegetation of lower Rush Creek, with two objectives:

1. Inventorying the riparian vegetation for composition, structure, and size classes.
2. Evaluating the amount of regeneration of each riparian species and the relationship between this reestablishment and the stream environment, especially substrate, channel morphology, and proximity of the species to the channel.

Methods

The methods used in this study included general reconnaissance, inventorying vegetation along transects, data analysis, and interpretation of aerial photographs. Rush Creek from Grant Lake (elevation of 2170 m) to Mono Lake was surveyed in fall 1987 to determine general types of stream morphology, vegetational communities, and to identify species. Species names follow Munz and Keck (1968).

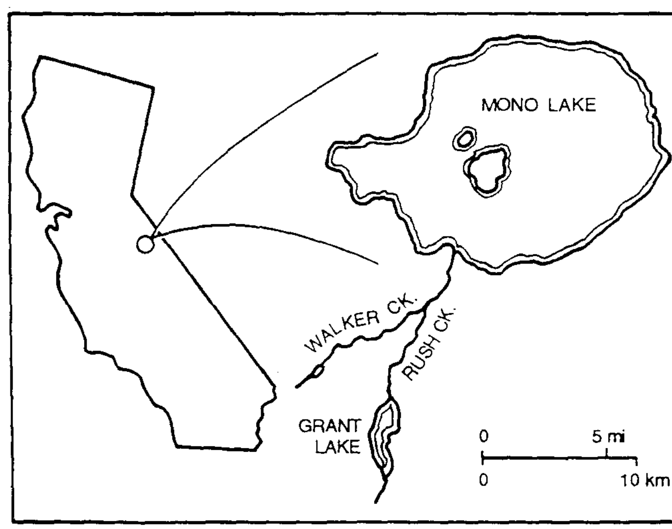

Figure 1– The study area includes Rush Creek from Grant Lake to Mono Lake.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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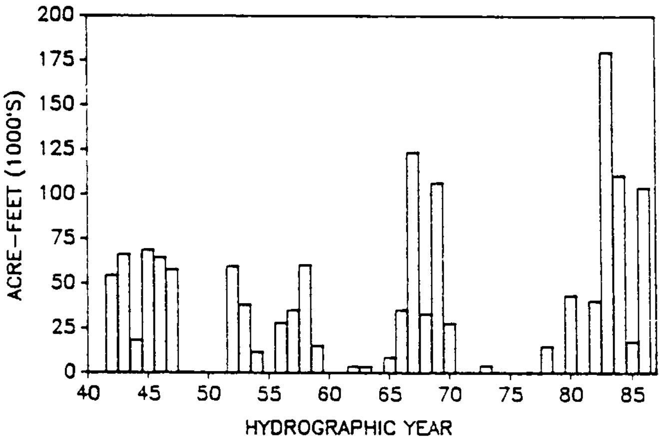

Figure 2– Water releases into Rush Creek through Mono Gate #1 and over Grant Lake spillway in thousands of acre-feet for hydrographic years (Oct. to Sept.) 1942-1986. About 3465 acre feet for 3 months equals a constant flow of 0.53 cubic meters per second.

An inventory characterizing the vegetation along Rush Creek was developed using 51 transects (20 of which were permanent). Locations of transects were based on reconnaissance and on analysis of August 1987 aerial photographs, and reflect the diversity of stream channel and floodplain morphologies and vegetation communities. Transects were sampled during September-October 1987. The transects were laid out perpendicular to the stream, running from the stream edge until riparian vegetation was no longer encountered. They ranged in length from 5 to 180 m. The transects were 2 m wide and divided into 5 m segments. For each segment, the following information was recorded: woody and herbaceous litter cover, total herbaceous cover, species cover and density for woody species (divided into height strata of <1 m, 1-3, and >3), and age of seedlings and saplings. Age was estimated from counts of internodes. Abiotic information recorded included substrate texture for the surface and at 1 to 10 cm, and height above the stream channel. Stream gradient at the transect site, and slope and aspect of the transect were also recorded.

Correlations between species and abiotic factors and in particular between regeneration and site characteristics were determined by developing correlation coefficients using SAS statistical packages (SAS Institute 1982). Correlations were based on a sample size of 651 transect subplots; P values less than 0.05 were considered significant. Additionally, means from each transect were used to determine commonality of transects using detrended correspondence analysis (DCA). DCA is a multivariate ordination technique that is useful in determining community relationships, since it reduces multivariate data into "low-dimensional space" such as a two-dimensional axis plot. Stands with similar vegetation structure occupy close positions on the plot. Information generated by DCA helped to determine relationships among species and to delineate stream reaches. Reaches were defined by homogeneity of the vegetation and stream morphology, and were numbered consecutively from Grant Lake to Mono Lake. Data from reaches 9 and 10 are not presented because these reaches are presently disturbed by gravel operations.

Results

Vegetation Structure

Total riparian zone vegetative cover at Rush Creek in 1987 averaged 48 percent, while woody cover in the zone averaged 35 percent (tables 1 and 2). This cover was located along riparian zones of variable widths, ranging from 5 to a maximum of 180 m per side of the stream). Most of the vegetation was less than 1 m in height, reflecting the dominance of small shrubs rather than trees. Tree density within the riparian zone averaged 3 per 100 m^2, and only 5 percent of all woody plants were taller than 3 m (table 2). Herbaceous cover, which contributed 30 percent of the total cover, grew as understory to the woody plants and, in certain reaches, as the dominant vegetation in wet meadows.

Two shrub species–one obligate to riparian habitats, coyote willow (*Salix exigua*), and the other facultative, mountain rose (*Rosa woodsii*)–contributed over one half of the total woody cover. The third most abundant species was big sagebrush (*Artemisia tridentata*), which dominates the surrounding uplands. The combined cover of all species that are considered to be obligate riparian (that is, grow only in wet, streamside habitats) was 14 percent, or 40 percent of the total cover, while upland and facultative riparian species comprised 60 percent of the total cover. Five obligate woody riparian species were present in the transects: black cottonwood (*Populus trichocarpa*), aspen (*P. tremuloides*), red willow (*Salix laevigata*), white willow *(S. lasiolepis),* and coyote willow. Facultative species included two trees: Jeffrey pine (*Pinus jeffreyi*) and silver buffaloberry (*Shepherdia argentea*), and a shrub (mountain rose). Three upland shrubs also were recorded: big sagebrush, rabbitbrush (*Chrysothamnus nauseosus*), and bitterbrush (*Purshia tridentata*).

Table 1-Reach length, mean length of transects, plant cover (total and by strata- >3 m tall, 1-3 in tall, and <1 m tall), woody plant density (total and by strata), and species richness (number of woody species in transects), of lower Rush Creek as of 1987. Values are means for 1 to 7 transects per reach type.

Reach No.	Reach Length	Transect Length	Plant cover Total	>3	1-3	<1	Woody plant density Total	>3	1-3	<1	Species Richness
	km	m	percent				sterns/10m²				
1	NA	35	12	6	3	3	5	0	1	4	4.0
2	NA	5	25	0	2	23	13	0	4	9	2.0
3	0.15	15	60	1	29	30	91	0	46	45	4.0
4	0.49	28	71	28	19	43	35	3	16	16	5.7
5	0.85	51	76	8	25	47	69	6	34	31	4.5
6	0.55	74	11	0	3	8	11	0	4	7	3.0
7	0.61	27	60	7	16	37	49	5	21	24	4.4
8	0.73	40	23	2	8	14	29	0	11	18	5.5
11	0.28	60	18	6	5	7	7	0	3	4	5.3
12	0.58	148	54	3	12	39	23	0	12	12	5.0
13	0.21	130	93	39	18	42	23	6	14	4	6.0
14	0.82	115	36	5	11	21	30	4	14	12	5.0
15	0.24	53	28	6	0	22	43	0	1	43	4.0
16	0.64	68	51	3	17	32	20	2	11	8	5.7
17	0.76	130	49	12	11	26	27	3	14	11	4.5
18	0.37	35	27	1	7	20	41	0	9	32	3.0
Entire creek			48	8	13	29	36	2	16	18	4.5

Table 2-Cover by species] for woody plants within reach types at Rush Creek. Values are means for 1 to 7 transects per reach type.

Reach no.	Obligate riparian SX	PC	SV	SL	Facultative or upland RW	AT	CN	SA	PU	PJ	PM
	percent										
1	0	0	0	3	1	0	0	0	1	0	6
2	3	0	0	0	0	13	0	0	8	0	0
3	18	0	0	0	28	8	2	0	0	0	2
4	1	16	9	0	22	6	1	2	0	0	4
5	13	2	0	3	27	5	3	3	1	0	0
6	5	0	0	0	0	3	1	0	0	0	0
7	8	4	0	0	21	4	2	1	0	0	0
8	8	4	2	0	3	0	3	0	1	0	0
11	3	9	0	0	0	0	1	0	2	0	0
12	5	1	0	1	11	7	4	3	1	0	0
13	9	1	31	8	9	3	0	1	0	0	0
14	7	1	0	3	7	3	1	2	0	0	0
15	0	0	4	2	0	2	0	3	0	0	0
16	6	0	0	9	5	8	1	2	0	0	0
17	1	1	1	0	15	5	0	2	0	0	0
18	14	0	1	0	0	0	0	0	0	0	0
Entire creek	7	3	3	2	12	4	2	2	1	<1	<1

SX= *Salix exiqua*, PC= *Populus trichocarpa*, SV= *S. laevigata*, SL= *S. lasiolepis*, 1LW= *Rosa woodsii*, AT= *Artemisia tridentata*, CN= *Chrysothamnus nauseosus*, SA= *Shepherdia argentea*, PU = *Purshia tridentata*, PJ= *Pinus jeffreyi*, PM= *P. tremuloides*.

Vegetation cover, height, and species composition varied considerably within the 11 km stretch of lower Rush Creek. The nature of the stream differs above and below a natural quartzite gorge located about 3 km below State Highway 395. Below the gorge, riparian zones are generally wider, and in some areas, extensive wet meadows occur adjacent to the riparian zone. Vegetation characteristics varied even within these two broad zones, and 18 reach types were recognized. Two notably distinct reaches were 4 and 13, which formed an endpoint of one axis of the DCA analysis. These reaches were unusual in having high cover of tall, riparian trees, including mature red willow (table 2). Reach 4 is a steep-walled canyon area probably underlain by shallow bedrock, while reach 13 is a broad wet area. Both reaches receive water from stream flow and from supplemental sources, including run-off from irrigated fields. Other distinct reaches included 2, the sparsely vegetated transition area between the diversion point (Mono Gate #1 Canal) and the river channel, and 6 and 11, sparsely vegetated alluvial floodplains.

Regeneration

Obligate Species

Most of the riparian species at Rush Creek, although having suffered high mortality from prior water diversion, are now regenerating in response to the high flows of the early 1980's and the subsequent controlled minimum flows which have not since dropped below 0.5 cubic meters per second (at Grant Lake release point). Individual species have responded in different fashions. Of the obligate riparian woody species, one (black cottonwood) is regenerating by asexual root sprouts, two (white and red willow) by seed, and one (coyote willow) by both sprouts and seed.

Black cottonwood, a dominant tree at Rush Creek, survived the prior diversion in low densities in most reaches of the stream. Although most of the survivors have crown dieback to the extent of death of the entire above-ground portion of the tree, all are vigorously resprouting and many are producing root sprouts. Sprouts were recorded in 14 percent of the transects (7 of 51). Many of the largest sprouts (up to 3 m tall) were esti-mated to have established in 1982 or 1983. Figures 3 and 4 show a cobble floodplain vegetated almost exclusively by cottonwood survivors or root sprouts.

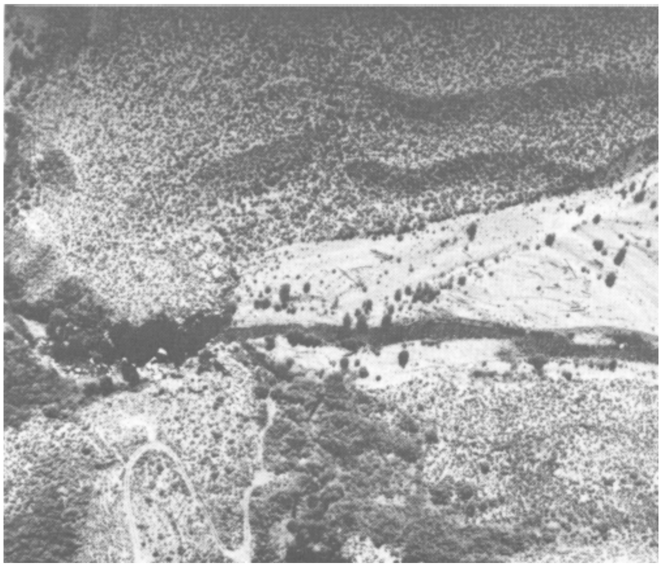

Figure 3– 1987 aerial photograph of a portion of Rush Creek. The cobble floodplain above the quartzite gorge is being revegetated in large part by sprouting roots from black cottonwood.

Figure 4– 1988 ground photograph of the floodplain shown in Figure 3, showing root sprouts and resprouted black cottonwoods.

Of the three willow species, coyote willow has shown the greatest amount of regeneration following increased flows. Asexually or sexually established plants were abundant in all but one of the sampled reaches, and stem density of plants less than 1 m tall averaged 3 per 10 m^2 for the study area as a whole. Young plants were most abundant along the stream edge (significant correlation coefficient of 0.27 between cover and proximity to stream, and -0.31 between cover and height above the channel). Along streamsides, plants occurred in mixed age classes, ranging from 1 to 5 years old. In certain reaches (e.g., no. 6), coyote willows grew throughout the broad, gravel/cobble floodplains in even-aged stands that established from seed in 1983.

Seedlings and saplings of white willow and red willow were also present, but in fewer reaches than coyote willow. Young plants were most abundant in the lower half of Rush Creek, below the quartzite gorge. Cover was significantly negatively associated with height above the channel (correlation coefficient of -0.28) and with stream gradient (-0.26). Young plants ranged in age from 1 to 5 years (established in 1983). Highest densities were on point bars where the subsurface soil was moist; combined seedling densities in such areas, such as reach 15, were 37 per 10 m^2. Many of the 5 year old plants were still very small, some under 0.1 m tall, due to heavy grazing by sheep.

Facultative Species

The facultative riparian species have also responded in distinct ways. Mountain rose appears to have increased in abundance as a result of past periodic dewatering of Rush Creek, and is now the dominant woody plant. Abundance of rose was significantly correlated with abundance of woody litter (correlation coefficient of 0.42), indicating invasion by rose in areas where obligate woody riparian species had died. Ability to reproduce sexually and vegetatively has contributed to its current abundance. Rose is continuing to regenerate by seed and root sprouts at the perimeter of large clonal populations. Current research is documenting the continued expansion or decline of these clones.

Aspen survived the water diversion in a few scattered reaches, including the silty-soiled canyon slopes of reach 4 and upper terraces of reach 5. Most of the survivors are regenerating by asexual root sprouts. However, grazing by sheep in the riparian zone is inhibiting growth of many of these sprouts. Scattered mature Jeffrey pines grow within the Rush Creek riparian zone, primarily in the upper canyon area (reaches 4 and 5). These pines are regenerating at very low rates; only one seedling, and no saplings or small diameter trees were observed within the riparian zone.

Small clusters of silver buffaloberry (a small tree) occur on silty-soiled, raised terraces along Rush Creek. Although buffaloberry trees have suffered much crown dieback as a result of prior diversion, many are now regenerating by sprouts and seed. All of the young plants recorded in transects were adjacent to adults.

Upland Species

The abundance of the three upland shrubs (big sage, bitterbrush, rabbit brush) is a result, in part, of their past invasion into previously dewatered areas. These shrubs are dying and declining in certain streamside floodplains, perhaps because of the recent high flows. These upland shrubs have become well established on some terraces; however, there was no evidence of continued regeneration of these shrubs anywhere along the stream.

Discussion

The riparian vegetation along Rush Creek has shown some resistance to decades of periodic water diversion. Although prior years of sporadic diversion of streamflow resulted in heavy mortality of obligate riparian species and increase in abundance of facultative and upland species in some areas, the riparian vegetation has not been totally eliminated as suggested by some researchers (Stine and others 1984). The riparian vegetation has also demonstrated potential high resilience, that is, ability to return to predisturbance state, as demonstrated by the recovery of key riparian species in response to recent high flows. The scattered surviving riparian plants are serving as seed sources and clonal parents, allowing regeneration of the riparian community in response to the above-average flows of the early 1980's, and to the controlled minimum instrearn flows that followed this period of flooding.

Regeneration response has not been uniform among species or among reaches of the stream. The causes of these variations include differences in stream geomorphology and hydrology as well as differences in species biology.

The influence of stream geomorphology and hydrology is evidenced by the markedly higher survival of riparian individuals in areas with shallow bedrock versus deep alluvium, and in areas that are fed by water sources supplemental to surface streamflow. Other examples include the abundance of willow seedlings and saplings on perennially wet point bars, and the absence of young willows (or presence only of plants that established in years with large spring floods) on floodplains with greater height above the stream channel. There is a need for detailed quantification and documentation of hydrology and geomorphology to more thoroughly understand their influence on riparian communities (Kondolf and others 1987).

Ability to reproduce sexually and vegetatively has contributed to the abundance of the two species which currently dominate lower Rush Creek. Answers to why certain key riparian species (e.g., the two *Populus* species) are not regenerating by seed in response to current flow conditions may lie in their particular autecological requirements. Aspen, for instance, is known to have exacting, and thus infrequently met, requirements for seed establishment (McDonough 1985). As for black cottonwood, available information on related species suggests a requirement for spring flooding that coincides with the short period of spring seed dispersal (Bradley and Smith 1985, Fenner and others 1985), followed by a period of low water stress (Strahan 1984, McBride and Strahan 1984). The potential requirements of this species' sexual regeneration for high spring flow pulses is being researched.

Although the riparian community along Rush Creek is regenerating following periodic flooding in the early 1980's and subsequent controlled flows, definitive answers to questions about the probability and timing of recovery to prediversion conditions await further monitoring and research. Whether current levels and patterns of controlled flows will allow complete recovery remains to be determined. Our first-year study of this recovery has answered some questions, and raised more, pertaining to the reasons for differences in recovery of the various components of the riparian community.

Acknowledgments

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THE EFFECT OF WATER MANAGEMENT AND LAND USE PRACTICES ON THE RESTORATION OF LEE VINING AND RUSH CREEKS[1]

Peter Vorster and G. Mathais Kondolf[2]

Abstract: This paper describes water management and land use practices in the Rush and Lee Vining Creek watersheds and evaluates the effect they have had on the stream environment. The management practices will continue to have effects on the flow regime and consequently habitat conditions on lower Lee Vining and Rush Creeks. The implications of existing and potential management practices for the restoration of the stream habitat are discussed.

From 1940 to 1982, the riparian and aquatic habitat along the lower reaches of Rush, Lee Vining, Walker, and Parker Creeks was greatly reduced by the diversion of the streamflow for export to the City of Los Angeles. Since 1981 a combination of wet years and subsequent court injunctions has led to the rewatering of the formerly desiccated reaches of Rush Creek and Lee Vining Creek. In response to a court request, the California Department of Fish and Game (CDFG) is administering cooperative studies to determine the necessary flows for restoration and maintenance of the trout fishery on lower Rush Creek; similar investigations are expected for lower Lee Vining Creek. By analyzing the biological and physical properties of the stream, the in-stream flow studies provide the basis for relating the potential aquatic and riparian habitat to different flow regimes.

If the flow regime could be controlled by dam releases alone, the restoration and maintenance of the habitat could proceed fairly confidently from the recommendations of the in-stream studies. In the Mono Lake watershed, any prescribed flow regime for lower Rush and Lee Vining Creeks must be coordinated with the water management practices of the Los Angeles Department of Water and Power (LADWP) and Southern California Edison's (SCE) as well as any water management that will be required for maintenance of Mono Lake levels. Likewise, land use practices in the watershed will affect the condition of stream habitat and should be considered in any restoration plan. The in-stream studies can thus be viewed as the initial steps in developing a restoration plan.

This paper examines how water management and land use practices in the Mono Basin will affect the flow regime, and consequently, the restoration and maintenance of stream habitat on lower Rush and Lee Vining Creeks.

Setting

Rush Creek and Lee Vining Creek drain the 10,000-to 13,000-foot crest of the Sierra Nevada east of Yosemite National Park (fig. 1). They emerge from the mountain front at about 7200 feet and flow about 4 miles (Lee Vining Creek) to 8 miles (Rush Creek) across alluvial, lacustrine, and aeolian sediments of the Mono Basin before emptying into Mono Lake.

Under natural conditions, Rush Creek and Lee Vining Creek are the two largest tributaries of Mono Lake, a hydrographically closed lake (i.e. a lake with no outlet). The combined runoff of 50,000 acre-feet per year from Lee Vining Creek and 75,000 acre-feet per year from Rush Creek (including the inflow from Walker and Parker Creeks) accounts for over 80 percent of the natural surface inflow to Mono Lake. Runoff is primarily derived from the snowpack of the Sierra Nevada and about two-thirds of it occurs in the peak snowmelt months of May, June, and July. After snowmelt, summer precipitation and groundwater sustains streamflow.

The flow regime of the two streams has been altered since the 1860's when European settlers diverted streamflow for irrigation, mining, and milling. From 1915 to 1925, dams were constructed on natural lakes in the upper reaches of both streams to provide storage and outflow regulation for the production of hydroelectricity. Increased irrigation demands in the early part of the twentieth century prompted the construction of a dam at Grant Lake in 1915 which was subsequently enlarged in 1926. The most dramatic alteration of the flow regime occurred after LADWP completed the Mono Basin extension of the Los Angeles Aqueduct in 1940. The Mono Basin facilities gave LADWP the ability to divert the entire flow of Rush Creek and Lee Vining Creek in most years.

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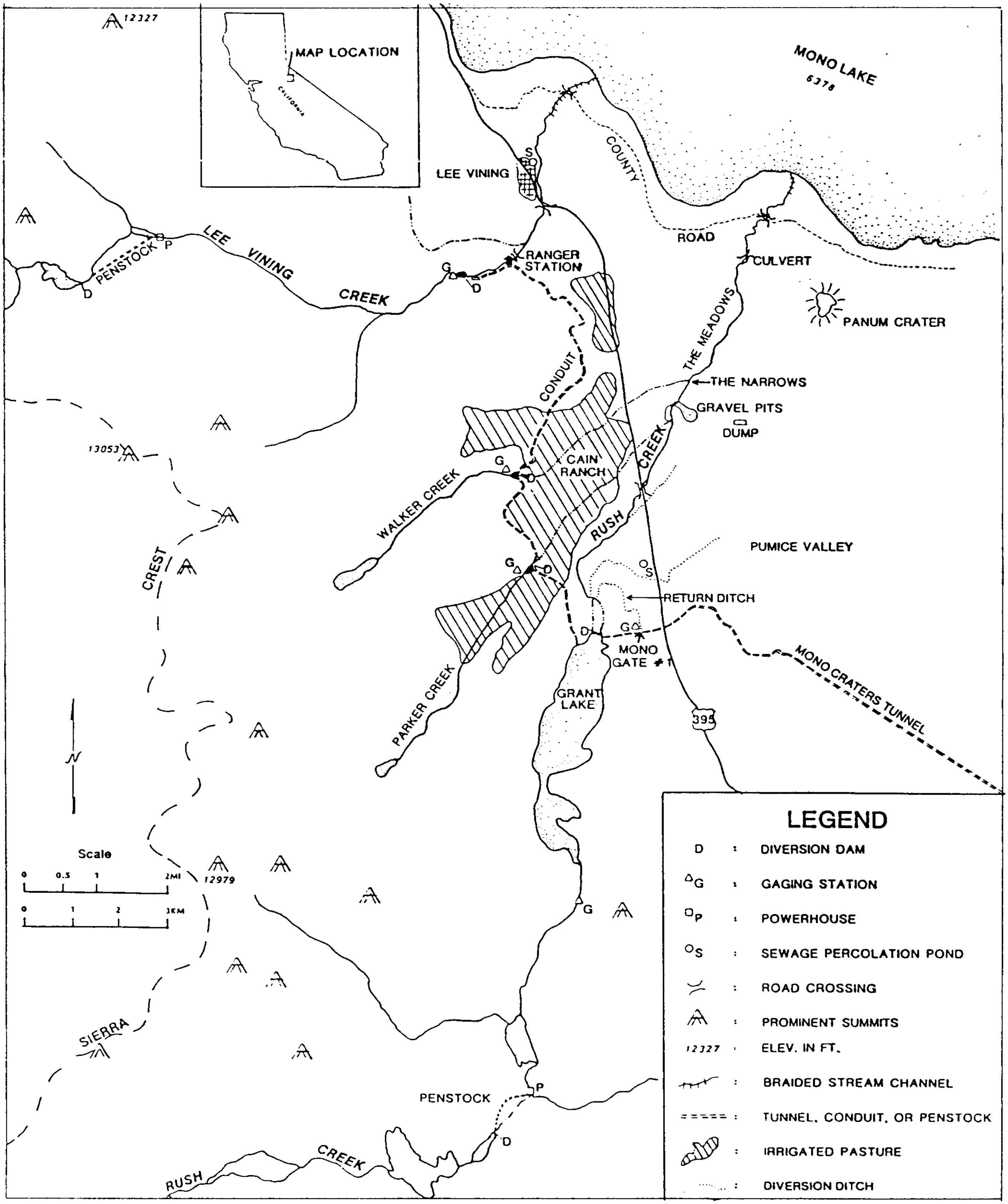

Figure 1- Location Map.

Abnormally high runoff from 1982 to 1984 forced the LADWP to release water into lower Rush Creek. A naturally reproducing population of brown trout reestablished itself in the rewatered lower Rush Creek. With the advent of drier conditions, LADWP announced the shut-off of the Rush Creek releases in late 1984, prompting a coalition of local fishermen, California Trout, and the Mono Lake Committee to file suit to prevent the shut-off and consequent destruction of the fishery. The court initially granted a temporary restraining order and later a preliminary injunction requiring that a 19 cubic feet per second (c.f.s.) release into lower rush Creek be maintained (Dahlgren et al vs. City of Los Angeles, Mono County Superior Court No. 8092). Similarly, involuntary releases on Lee Vining Creek led to the reestablishment of a fish population in formerly desiccated reaches of lower Lee Vining Creek. When LADWP ended the releases in August of 1986, a separate court action was initiated (Mono Lake Committee vs. City of Los Angeles, Mono County Superior Court No. 8608). In the fall of 1987 the trial court issued a preliminary injunction requiring a minimum release of 4-to-5 c.f.s. in order to maintain fish habitat in the first 2 miles of lower Lee Vining Creek. Both lawsuits assert that (1) California Fish and Game code section 5937 requires dam owners to release enough water to provide for a downstream fishery and (2) the public trust doctrine requires that sufficient water be released to protect riparian and aquatic habitat.

Water Management

Runoff from the upper reaches of Lee Vining and Rush Creek is stored and regulated by Southern California Edison (SCE) reservoirs. SCE's Rush Creek reservoirs can store up to 23,000 acre-feet, and their Lee Vining Creek reservoirs store up to 13,000 acre-feet. The outflow from the reservoirs is regulated by hydropower production; regulation can reduce downstream flows in the snowmelt months by 40 percent and increase flows in the fall and winter months by 400 percent (Vorster 1985). Water released through (and around during peak snowmelt) the power plants combines with downstream tributary inflow and becomes available for diversion by LADWP. LADWP diverts the water of Lee Vining Creek with a small check dam into a conduit; the Lee Vining conduit collects the runoff from Walker and Parker Creeks and transports the diverted water to the Grant Lake Reservoir on Rush Creek. Water from Grant Lake Reservoir is exported out of the Mono Basin through the Mono Craters tunnel. The reservoir's 47,500 acre-foot capacity regulates the seasonally variable runoff to the planned exports. LADWP tries to divert and export all of the runoff except for about 10,000 acre-feet that is released in the spring and summer from Walker and Parker Creeks and the Lee Vining conduit for irrigation of land around Cain Ranch. In years of high runoff all or most of the Los Angeles Aqueduct demand is satisfied by the Owens River Basin supplies, so the Grant Lake Reservoir water in excess of LADWP requirements is released back into lower Rush Creek through a control structure off the Mono Craters tunnel known as Mono Gate #1. The spillway can also be used to discharge water into Rush Creek when the reservoir is full, although it is not the preferred method since the release is uncontrolled. On Lee Vining Creek, water is spilled over the check dam when the holding pond (7 acre-foot capacity) is full, and the inflow exceeds the 300 c.f.s. capacity of the conduit or if Grant Lake Reservoir is full. Because of the limited on-stream storage capacity, Lee Vining Creek spills occur not only during peak snowmelt but also from intense summer precipitation. Controlled releases, such as the current 5 c.f.s. court-ordered release, are made immediately below the diversion dam.

Land Use

Nearly all of the land in the upper Rush and Lee Vining Creek watershed is owned by the USDA Forest Service. A few SCE parcels and some private inholdings in the June Lake Loop area are the only exceptions. In the lower Rush and Lee Vining Creek watersheds most of the land is owned by LADWP or the Forest Service; SCE owns about a 1 mile stretch along lower Lee Vining Creek. Private inholdings are gradually being acquired by the Mono Basin National Forest Scenic Area.

Both LADWP and the Forest Service permit grazing on their land, mainly by sheep. Grazers rotate their stock from the approximately 2000 acres of irrigated pasture around LADWP's Cain Ranch to the surrounding dry land under the Forest Service and LADWP control. Sheep graze in and along parts of the lower reaches of both creeks and dead sheep are commonly encountered in the creeks.

Unlike lower Rush Creek, the lower Lee Vining Creek watershed has a significant population of year round inhabitants and seasonal tourists. The Forest Service maintains a district ranger station and employee housing within a few hundred yards of the creek. SCE operates a switching station right below the Highway 395 crossing; the creek is routed into a steep concrete-lined channel at the switching station. The town of Lee Vining overlooks the creek below Highway 395. Lee Vining has 300 to 400 year-round residents and tens of thousands of visitors– mainly in the summer. Its wastewater is delivered to percolation ponds that drain into the creek.

Recreational use of stream corridors includes hiking, fishing, sightseeing, dirt-bike riding, snowmobiling, and cross-country skiing. Recreational use of lower Rush Creek has increased substantially since the fishery has been reestablished. Several sections along both streams are readily accessible to vehicles.

A number of active and abandoned gravel mining operations exist near lower Rush Creek. The largest active mine operates on the right (east) bank just above the Narrows (fig. 1). Wash water is disposed in a series of percolation ponds. Across the creek on the left (west) bank, and intermittently active gravel operation appears to use heavy equipment alongside and in the creek. Other land uses in the lower Rush Creek watershed are the Mono County dump and the June Lake Public Utilities District sewage treatment plant, both located less than a mile from the creek.

Impact on Flow Regime and Habitat

Flow in lower Rush and Lee Vining Creek was not significantly affected until 1947. A sequence of dry years from 1947 to 1951 caused LADWP to divert all of the runoff and eliminate all releases. From 1952 to 1969 releases were generally confined to periods of high runoff. The completion of the second barrel of the Los Angeles Aqueduct in 1970, which increased the delivery capacity from the Owens Valley to Los Angeles, allowed LADWP to eliminate releases in all but the very wettest years. Absent any releases by LADWP, the lower reaches of Rush Creek below the Narrows was able to sustain a small residual flow (0.1 c.f.s. to 5 c.f.s.) due to irrigation return flow and other groundwater contributions. The residual flow disappeared in the 1970's in part because irrigation return flow was reduced. Similarly in the reach of lower Lee Vining Creek from 1 to 2 miles below the LADWP diversion dam, a small residual flow (0.5 c.f.s. in summer up to 4 c.f.s. in winter) persisted, absent any releases or spills.

The flow regime of no releases for long periods punctuated by brief, catastrophic high flows had substantial impact on the stream environment of lower Rush and Lee Vining Creek. The great decline in riparian acreage and fish habitat was a direct result of the streamflow diversion and has been documented by Stine and others (1984), Taylor (1982), and Vorster (1985). The high flows caused bank erosion, vegetation removal, road washouts, channel migration and other alterations of the stream environment. The die-off of stabilizing riparian vegetation contributed to the channel instability. Channel instability is also accentuated during high flows if the stream has not kept up with changes in the level of Mono Lake which acts as the base level for lower Rush and Lee Vining Creek. As the level of Mono Lake declined from 6417 feet in 1941 to 6372 feet in 1982 in response to the diversion of up to 60 percent of its natural inflow, the creek channels incised in response to the lowered base level.

LADWP's irrigation management also influences the flow regime and habitat of lower Rush Creek. Prior to 1970, return flow from irrigation diversions helped to maintain the residual surface flow and remnant riparian vegetation in lower Rush Creek. Since 1970, about 10,000 acre-feet of water from the Lee Vining Conduit and Walker and Parker Creeks has been used to irrigate approximately 2,000 acres of land around the Cain Ranch from April through September. Consumptive use is about 2 feet per acre, so about 6,000 acre-feet is potentially available to lower Rush Creek via surface or subsurface drainage. This 6,000 acre-feet may still be important in sustaining spring flow (and consequently riparian vegetation) in lower Walker Creek and spring flow in the meadows section of lower Rush Creek.

Regeneration of riparian species is occurring as a result of the continuous flow releases of the last several years; the higher release on Rush Creek has led to greater regeneration than on Lee Vining Creek. The concomitant increase in fish habitat is responsible for the reestablishment of reproducing fish populations.

Implications for Restoration

The lack of regulating storage on Lee Vining Creek at the LADWP diversion facility means that the flow available for lower Lee Vining Creek will be directly affected by the operation of SCE's hydroelectric facilities. During dry periods very little water runs through the power plant because watershed runoff is very low, and the reservoir release is kept low in order to maintain minimum storage levels for recreational and other contractual purposes. Little or no release may also occur during power plant maintenance. Even with no outflow from the power plant there will always be some flow available for release into lower Lee Vining Creek because the Creek gains 3 to 5 c.f.s. of flow between the power plant and the LADWP diversion dam in low runoff periods (Torn Felando, Inyo National Forest, Bishop, CA, personal communication). In the summer evapotranspiration and percolation losses require that releases into lower Lee Vining Creek exceed 5 c.f.s. in order to maintain flow down to the stream mouth. The lack of upstream storage on Lee Vining Creek also means that high flows cannot be regulated as readily as on Rush Creek.

Grant Lake Reservoir has enough storage to insure that a minimum release into Rush Creek, such as the presently required 19 c.f.s., can be sustained through a drought. An extended period of low reservoir levels, however, can cause the temperature of the outflow water to become dangerously warm for trout in the downstream reaches (Stacy Li, Beak consultants, Sacramento, CA, personal communication). The outflow water is also very turbid when the reservoir is low because it incorporates fine bottom sediment.

Grant Lake Reservoir is not large enough to prevent high releases after heavy snowfall winters. In high runoff periods the reservoir will fill rapidly and force LADWP to release and/or spill Rush Creek inflow (and any incoming Lee Vining conduit water) into lower Rush Creek. As in the past these high flows may cause stream environment changes especially if the Mono Lake level continues to decline.

It is unlikely that the current flow releases of 19 c.f.s. into lower Rush Creek and 5 c.f.s. into lower Lee Vining Creek will lead to the regeneration of the pre-1940 acreage of riparian vegetation (Botkin and others, 1988). Because of the downstream flow losses, only a portion of the release is available to the vegetation. In addition the vegetation needs overbank flooding to stimulate recruitment, although the timing and magnitude of these flood flows has not yet been determined. Grazing in the stream corridor is hindering the establishment of young plants (Patton, Arizona State University, Tempe, AZ, personal communication). Stream-side erosion will also retard the establishment of seedlings (Botkin and others, 1988). The erosion will be exacerbated if Mono Lake drops below its historic low stand of 6372 feet in elevation. Currently the lake level is about 6377 feet, and if releases are maintained at their present level, the lake will drop below 6372 feet in about 3 years.

Mono Lake Management

At the current time Mono Lake levels are not managed. The level will continue to decline because up to 50 percent of its average natural inflow is still being diverted by LADWP. Lake level rises will occur in very wet years. If Mono Lake drops below its historic low level of 6372 feet, a new episode of stream incision would result; if it rises above its recent high of 6381 feet, the stream channels will likely aggrade and become more sinuous in their lower reaches in response to the higher base level.

It is likely that the lake level will be managed in the future because of a number of recent actions: (1) in 1983 the California Supreme Court directed that a balance should be struck between the public trust values of Mono Lake and LADWP's water needs; (2) the Forest Service has recommended that the lake level be managed between 6377 and 6390 feet in the draft management plan for the lands surrounding the lake (Inyo National Forest, 1988); (3) the adverse consequences of further declines in lake level on lake-dependent resources has been documented by two different panels of experts (National Academy of Sciences 1987, and Botkin and others 1988). The maintenance of Mono Lake levels between the current (6377 feet) elevation and 6390 feet will require, on the average, about an additional 50,000 acre-feet (70 c.f.s.) of stream releases over the current level (24 c.f.s.) of releases. There has been no specification of the flow regime for the additional releases, although the Mono Lake Committee (1988) has suggested a wet year/dry year management approach for the stream releases. This approach would involve releasing most if not all of the stream runoff in wet years to take advantage of the lake rises that can occur in those years and releasing the minimum necessary for stream habitat maintenance in drier years so that LADWP can export the runoff when they have the most need for it. The management of the Mono Lake levels between 6377 feet and 6390 feet could enhance channel stability and riparian vegetation colonization.

Conclusion

This paper describes water management and land use practices in the Rush and Lee Vining Creek watersheds and suggests that they will continue to influence the flow regime and habitat on lower Lee Vining and Rush Creeks. If the streams are to be successfully restored, the implications of the management and land use practices must be considered along with the biological and physical properties of the stream. A restoration plan will have to balance the optimum flow requirements for restoring and maintaining fish habitat, riparian habitat, and Mono Lake levels as well as meeting LADWP export needs.

The agencies that actually have the operational control over the flow of water in the creeks–LADWP and SCE–will probably continue to operate as they have in the past until the courts require a permanent flow of water down Rush and Lee Vining Creeks. If and when that happens, an integrated plan involving all interested public agencies, landowners, and private citizens will need to be developed to restore not only the stream ecosystem but adjoining terrestrial and lacustrine ecosystems as well. Nature will presumably take care of the rest.

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SESSION I: IMPLEMENTING REVEGETATION PROJECTS

The field of restoration ecology is still in its infancy. Renewed interest in the restoration of riparian systems has developed out of our recognition that far too much riparian habitat has been lost in California (Sands 1977, Warner and Hendrix 1984) to accept this as a permanent condition. It is essential that we learn how to restore some of what has been lost by turning fallow agricultural bottomlands, degraded grazing land, barren flood control channels, etc. back into streamside riparian forests.

The papers presented in Section I discuss the many factors which must be taken into account during design and implementation of riparian restoration projects. The authors discuss their approaches to restoration and the results of testing specific restoration techniques. The projects presented are representative of the wide variety of riparian restoration projects, ranging from biotechnical streambank stabilization, to mitigation for project impacts, to fish and wildlife habitat enhancement (including the restoration of riparian habitat for endangered species and species of special concern). Both direct (i.e., revegetation involving the planting of native riparian species) and indirect (e.g., installation of grade stabilization structures, fencing etc. to create the proper conditions for natural revegetation) measures for restoration are described and evaluated. Graciously, the authors have recognized the importance of reporting on both successful and unsuccessful restoration efforts and emphasize the need for experimentation and documentation so we can learn which techniques will produce the desired restoration in each given situation.

Riparian restoration is both an art and a science; thus riparian restorationists must be both scientist and artist. By restoring the proper conditions for riparian plant growth and controlling unnatural disturbances, man can accelerate the natural processes of land healing. Fortunately, riparian plant species are relatively fast growing, so we will soon be able to ponder the results of our restoration work and rejoice in our successes.

John T. Stanley
President
The Habitat Restoration Group and John Stanley Associates
Scotts Valley, California

RESEARCH AS AN INTEGRAL PART OF REVEGETATION PROJECTS [1]

Bertin W. Anderson[2]

Abstract: Little data concerning autecological needs of desert riparian plant species is available, but the need for revegetation is great. This need results in projects being initiated without knowledge of on site conditions or needs of species planted. Research, superimposed on revegetation projects, can yield data necessary to intelligently implement revegetation projects. Our approach involves: (1) selecting sites on the basis of appropriate preliminary sampling, (2) preparing a planting design after determining distribution of soil/salts on site, (3) planting experimental/control trees at soil sampling points (4) monitoring these experimental trees during the irrigation phase. Research data are used to increase vigor and/or reduce or maintain future costs.

In 1977 the U. S. Bureau of Reclamation provided us with funds to summarize knowledge and to undertake studies of the autecology of native riparian plant species found along the lower Colorado River. Time was devoted to learning known procedures used to grow these species in revegetation projects. We discovered that little was known about autecological requirements or revegetation procedures; immediate research attention was needed concerning a large number of factors. This paper deals with just these; effects of tillage, length of irrigation period, salinity and browsing on growth.

Careful record keeping is the first requisite. Simple experiments can also be built into many projects, once the observation starts to yield information that can be translated into testable hypotheses. Here I present an approach permitting data acquisition that is relatively easy and inexpensive, that can be used for management and research. The approach involves (1) preliminary analysis on prospective sites as a prelude to wise site selection, (2) random soil sampling at points where plant species will be planted to map soil/salinity distribution on the site, (3) use of these points for planting trees for addressing research objectives, and (4) use of the research trees for monitoring the project's irrigation phase.

Definitions

Foliage volume—The space, expressed in cubic meters, occupied by a tree. For cottonwood (*Populus fremontii*) and willow trees (*Salix* spp.) this space is roughly approximated as: foliage volume = $(-1.14 + 1.4\ \text{height})^2$, $r^2=0.985$, $P<0.001$. This equation is based on 678 cottonwood and willow trees from the Colorado and Kern Rivers in California.

Browsed—any tree with several centimeters of one or more limb tips, including but not restricted to, the tallest limb, bitten off by deer. Control—In experimental situations controls represent a random sample of the "normal" situation; in our work "normal" conditions include:

1. Tilling with an auger 4.7 cm in diameter to the water table.
2. Planting cottonwood/willow trees where electroconductivity is <2.0 millimhos/cm[3].
3. Irrigating for 72 days over a 90 day period at a rate of 32 liters delivered over a 4 hour period through pressure compensating emitters or at modified rates that would maximize growth during the irrigation phase. During the irrigation period the objective was to maximize growth for all trees, including experimental trees—effects after irrigation ends are those we're interested in.
4. Planting healthy appearing saplings 40 cm tall or taller 8-12 weeks after potting. Cuttings are started from local genetic stock in 4-liter pots.

Electroconductivity (EC)—a measure of the total dissolved ions measured in millimhos/cm[3]. Soil EC's are determined from distilled water extracts of saturated soil pastes.

Growth—height from ground level to top of tallest upstretched leaf at planting subtracted from height similarly measured at any time after planting. It is a simple measure of vigor, related to crown diameter of cottonwood/willow trees as: Crown Diameter = 0.44 +0.84height. (Anderson & Ohmart 1982).

Vigor—measure of change in plant growth or foliage volume through time after planting.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Experimental Approach

Experimental design should include, among other things (Green 1979), clear statements of questions being investigated, sample sizes large enough to yield meaningfully interpretable data, random sampling ("representative" or "typical" places are not random), (4) controls.

To illustrate the experimental approach I present data for one revegetation project. The site, on the Kern River Preserve, Weldon, Kern Co. California encompassed 12 ha. Tree spacing was 6.2 m in rows 6.2 meters apart. Allowing for some loss for road construction, there are about 100 trees per 0.4 ha (total 3000 trees). To map soil and EC conditions, 8 percent (240) of the planting points were sampled. The question was whether vigor would differ for two sets of trees: (1) those irrigated at 32 liters per day for 90 days versus those irrigated (same rate) for less than 40 days and (2) for trees planted after tillage to 65-75 percent of surface to water table depth versus those planted after tillage to the water table. Labor cost associated with irrigation for less than a 90-day period and tilling less than to the water table could be substantial. Thus, irrigation and tilling were good points on which to launch research. In all experimental and test situations we endeavor to maximize growth during the irrigation phase. We can quite confidently predict results during this phase. We must also be able to predict what will happen after we leave the site. The research data will allow us to develop this predictability. Data for additional variables are presented by Anderson and Laymon (1989).

Controls were 150 trees chosen randomly from the grid. The first set of trees-those irrigated for less than 45 days–were subdivided into three equal sized categories; those irrigated 17, 27, and 37 days. For the second set of trees, soil was tilled 65-75 percent of the surface to water table depth for 25 trees.

Several ancillary questions were addressed, two of them are discussed in this paper: What effect will salinity and browsing have on vigor? Evaluation began during the second growing season (care during the first year reduces impacts). Since I found nothing in the published literature specifically stating the tolerance of cottonwood/willow trees to salinity levels, they were investigated early because salinity problems abound in desert areas (Fig. 1). Browsing is common in riparian areas; it seemed reasonable to what impacts this might have on affected trees.

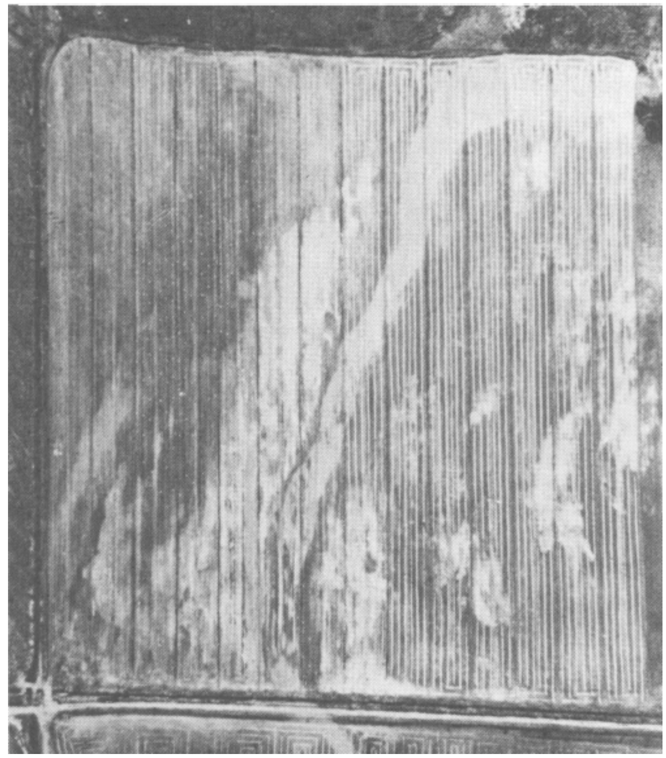

Figure 1– Aerial photograph of a field illustrating the variation in superficial soil characteristics.

Results

Length of Irrigation Period

After two growing seasons cottonwood trees irrigated for less than 90 days did not differ significantly ($P>0.05$) from controls in height, total growth, foliage volume, or mortality (table 1).

Because of the small sample size ($n=78$) and the restriction of the work to this single set, I am reluctant to reduce the length of the irrigation period to less than 90 days. The work should be repeated at least once more in the same general area (Kern River) with a larger sample.

Earlier experimentation involved irrigation periods spanning 150-480 days along the Colorado River, near Blythe, California. That study included data from two full-scale revegetation projects together encompassing 50 ha and including 1349 experimental trees of four species (Anderson and Ohmart 1982). Trees irrigated for 150 days were equally as productive after 3 years as trees irrigated for a longer period, other factors being equal. Irrigation time was reduced to 90 days for 60 experimental trees. In this time roots grew to the water table, 3 meters below the surface. The 90 day period was tried on a full scale project, involving 1200 trees, along the Rio Grande near Presidio, Texas

(Anderson and Ohmart 1986). Success there led to use of this irrigation period as the control; thereafter, shorter periods represented experimental variables.

While the Kern River results alone would not warrant using even a 90-day irrigation period in another valley, our total research experience suggests that a 90-day period is safe over a large portion of the desert Southwest.

Depth of Tillage

On the Kern River project trees planted after tilling to the water table were significantly taller, total growth was greater, foliage volume was significantly greater and mortality was lower after two growing seasons than for those trees planted after tilling to 65-75 percent of the depth to the water table (Table 2). While the difference in mean height was 30 percent of the height of controls, the difference in mean foliage volume was 73 percent of the foliage volume of controls. This relationship between height and foliage volume is expected, since as height doubles foliage volume is approximately squared.

Table 1 - Table 1-Data after two growing seasons for cottonwood trees irrigated for 17 days, 27 days and 37 days at 32 liters per day. Controls were irrigated for 90 days. For all trees tillage was to the water table.

Characteristics	Days Irr.	N	Mean	S.E.	Percent mortality
Height (cm)	17	26	233.0	12.1	7.7
	27	26	237.2	12.0	3.8
	37	26	232.1	14.5	11.1
	90	144	220.2	6.7	8.9
Growth (cm)	17	26	51.6	5.94	
	27	26	49.0	6.07	
	37	26	49.1	10.59	
	90	144	43.8	4.37	
Foliage volume (m^3)	17	26	2.92	0.07	
	27	26	3.05	0.08	
	37	26	3.02	0.43	
	90	144	2.84	0.22	

Growth=growth in the second growing seasons in

Table 2 - Effects of tillage after two season on height, growth, and foliage volume of cottonwood trees planted along the Kern River. For experimental trees tillage was to about 75 percent of the depth to the water table; tillage was to the water table for controls. Average water table depth was 1.2 meters.

Characteristic	N	Mean	S.E.	Percent mortality
Height (cm)				
Tillage 75 pct	21	153.9	20.1	41.2
Controls	14	220.2	6.7	8.9
Growth (cm)				
Tillage 75 pct	21	-7.0	38.3	
Controls	14	111.3	11.1	
Foliage Volume (m3)				
Tillage 75 pct	21	1.03	0.31	
Controls	14	3.77	0.29	

Growth=growth in the second growing season in cm.

These data (Table 2) taken alone speak strongly against tilling to depths short of the water table. In fact, by the time the Kern River revegetation project had begun I had already experimentally determined (Colorado River) with 936 trees where tillage was the only variable being tested that tilling less than to the water table for cottonwood/willow trees would almost certainly result in large losses in vigor (Anderson and Ohmart 1982). This finding was substantiated with data where tillage was one of the variables in multivariate tests for an additional 2000 trees (Unpublished data on file, Revegetation and Wildlife Management Center, Blythe, California.) When work began on the Kern River there was little doubt that tillage to the water table should be the control condition and deviations in tillage depth should represent experimental variables. The relationship to vigor is so predictable that an equation developed for cottonwoods on the Colorado, where depth to the water table is 3 meters, can be used to accurately predict the observed data presented here for the Kern River, where average depth to the water table is just over 1 meter. Failing to till soil to the water table will result in large decreases in productivity and high mortality.

Electroconductivity

Electroconductivity effects were evaluated by comparing trees planted at points where EC's were less than 2.0 millimhos/cm^3 with trees at points where EC's were greater than 2.0 millimhos/cm^3 at a depth of 1.2 meters or this level and at the water table (high EC groups). These divisions were based on previous work (e.g. Anderson and Ohmart 1986) indicating that losses in productivity have begun at ECs of 2.0 millimhos/cm^3.

Within the high EC group were three subgroups: (1) soil EC's greater than 2.0 millimhos/cm^3 at 1.2 meters but less than this at the water table; (2) soil and water table EC's greater than 2.0 millimhos/cm^3; (3) water table EC's greater than 2.0 millimhos/cm^3 but EC's at 1.2 meters less than 2.0 millimhos/cm^3. For trees in subgroups (1) and (2) height was less than for trees in the low EC group, but not significantly different ($P=>.05$). Trees growing with water table EC's greater than 2.0 millimhos/cm^3, but <2.0 at 1.2 m, mean height differed significantly ($P<0.05$) from the low EC group (table 3). Growth in the second season revealed that for all groups of trees in soil with high EC's growth was significantly ($P<0.05$) less than trees in low EC soil.

Table 3 - Effects of electroconductivity (EC) in millimhos/cm³ on vigor of cottonwood planted along the Kern River. Tillage was to the water table and no trees were affected by browsing. Data are for two growing seasons.

	EC's at 1.2 m	WT	N	Mean	S.E.	Percent mortality
Height	>2.0	<2.0	27	224.4	12.6	For groups
	>2.0	>2.0	18	237.2	11.6	>2.0=12.1
	<2.0	>2.0	31	245.2	8.8	
	<2.0	<2.0	65	256.6	8.0	0.0
Growth	>2.0	<2.0	27	91.4	24.4	
	>2.0	>2.0	18	105.2	14.2	
	<2.0	>2.0	31	127.5	11.2	
	<2.0	<2.0	65	158.0	10.7	
Fol.Vol.	>2.0	<2.0	27	4.00	0.47	
	>2.0	>2.0	18	4.75	0.60	
	<2.0	>2.0	31	5.25	0.52	
	<2.0	<2.0	65	6.01	0.55	

WT=water table, Growth=growth in the second growing seasons in cm. Fol.Vol (Foliage Volume) is in m^3; height in cm

These data alone suggest not planting where EC levels exceed 2.0 millimhos/cm³. One might tentatively conclude that cottonwood/willow trees are salt sensitive. However, we have tested the tolerance of salinity for 574 willows and 726 cottonwoods in two separate full-scale revegetation projects on the Colorado River (Unpublished data on file, Revegetation and Wildlife Management Center, Blythe, California.) On the Rio Grande planting where ECs were less than 2.0 millimhos/cm³ was the normal situation, but 52 experimental trees were planted where EC's were greater than 2.0 millimhos/cm³. Equations from the Colorado River quite accurately predicted the level of loss on the Rio Grande (Anderson and Ohmart 1986).

By the time work began on the Kern River, new predictive equations had been developed, which predicted losses on the Kern River within 4.3 percent on average for 273 trees after 2 years (Anderson 1988). Collectively these data support arguments against planting cottonwood/willow trees at points where EC levels exceed 2.0 millimhos/cm³ unless foliage volume losses of 30 percent are acceptable after two seasons. Losses increase with time. Data presented (table 3) are for two growing seasons; by 9 July of the third season trees in soils with EC's greater than 2.0 millimhos/cm³ had an average foliage volume of 3.8 m³. Those growing where EC's are less than 2.0 had foliage volume of 7.1 m³. Thus, midway through the third growing season trees in the high EC group have 46 percent less foliage volume than those in the low EC group. Colorado River equations indicate that by year's end the difference will be in the order of 67 percent.

Browsing

Trees browsed by deer were significantly (P=<0.05) smaller in all measurements than trees not browsed (table 4). After 2 years the difference in height between browsed and not browsed was 27 percent of trees not browsed, the difference in foliage volume was 60 percent (table 4).

Table 4 -Effects of browsing by deer on height, and growth during the second growing season, and foliage volume of cottonwood trees planted along the Kern River. For all trees tillage was to the water table. Mean EC values did not vary significantly between browsed and unbrowsed trees.

	Category	N	Mean	S. E.	Percent mortality
Height	Browsed	46	193.7	9.4	11.8
	Not browsed	141	264.1	6.1	0.0
Growth	Browsed	46	99.3	15.4	
	Not browsed	141	122.7	9.8	
Fol.Vol.	Browsed	46	2.47	0.36	
	Not browsed	141	6.25	0.32	

Alone these data suggest that browsing has a large negative impact on growth of cottonwood trees browsed trees one or more times during the first year. Loss of apical meristem results in considerable damage; below ground damage is often more extensive than that above ground (Harper 1977). Data presented above are from the end of the second growing season. Midway through the third season the browsed trees had 75 percent less foliage volume than nonbrowsed trees.

These data (table 3) are from a single site in one locality, thus more data are needed on the effects of browsing on cottonwood/willow. However, the literature cited above and reviews by Belsky (1986, 1987), in concert with these data indicate that browsing will damage trees; we recommend that trees be protected if extensive browsing is expected.

Site Selection, Planting and Irrigation Monitoring

Site Selection

Wise site selection is not possible until a relatively large data base exists concerning autecological requirements of various species. Results summarized in this report provide at least a modest basis for determining site suitability. Preferably a number of sites will be available for revegetation, thus permitting selection of the one most suitable for the species one wishes to plant. For example, for cottonwood/willow trees, the site should have low EC's, well-drained sandy soil, and a relatively shallow (4 meters or less) water table. In many localities soil type is highly correlated with salinity.

Site suitability was determined by (1) dividing the area on paper into 0.4 ha plots; selecting at random half of these for sampling, (2) collecting soil samples at plot centers and determining surface to water table depth, (3) classifying soil samples from the first and third quarters of the profile and determining ECs at these levels, (4) noting vegetation on each plot for determining competitive potential, and determining the best method of site preparation, and (5) determining EC's on water table samples.

Greater sampling intensity than suggested here (Anderson and Ohmart 1982, 1986) indicated this abbreviated method, a compromise between data needs and cost, will yield data adequate for evaluating general field suitability. A 20 ha site would include 25 samples.

Although 25 samples provide some indication of EC distribution on the site, for mapping it would result in too much guessing–and large losses in productivity. Maps of EC distribution (fig. 2) are based on samples from 5-10 percent of all points 6.8 meters apart (250-500 samples in 20 ha). Distribution of soil types and depth to the water table can also be mapped. With this information the planting design can put trees only in places where the chances of loss because of poor soil or salinity conditions are low.

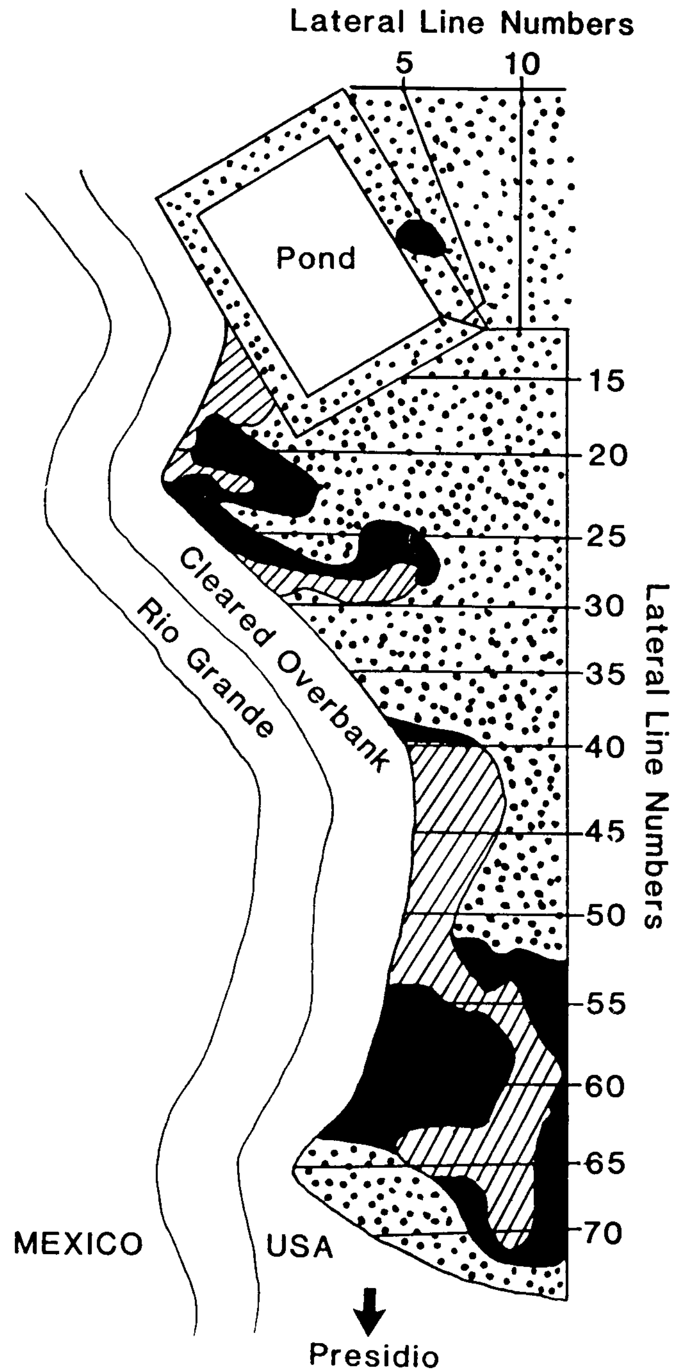

Figure 2– Electroconductivity (millimhos/cm^3) of soil 61 cm below the surface. Stippled = EC<2.0; black = EC 2.0-4.0, diagonal = EC>4.0.

Planting and Monitoring Irrigation

Trees are planted at all points, (augered holes) including those sampled for mapping, and can be used to monitor the project during the irrigation phase. Tree height is measured weekly and expressed as growth per day since the last measurements were taken. These data are entered on the computer immediately after collection. Interpretation involves paying close attention to trees growing most and those growing least. In the areas where we have worked (Rio Grande near Presidio, Texas, Colorado River near Blythe, California, to Kern River near Weldon, California) altitudes vary from about 75 meters to 750 meters, and growth rates during June-July average 10-15 mm/day. If daily growth rates fall below this it can be assumed that something is wrong.

Recognition of problems involves considering the location of trees showing poorest and best growth on the site. Slow growers often share an autecological factor. For example, if EC levels are high in the general area where trees are not growing, the problem may be alleviated by increasing irrigation rates, thus increasing leaching. In one project, slow growing trees were located where depth to the water table was above average. Growth rates were increased immediately by increasing the irrigation rate. On the same site, another group of slow growing trees was located, primarily, in places where depth to the water table was less than 1 meter. In this case growth rates increased dramatically by decreasing the irrigation rate. The initial hypothesis here should be that these trees were probably insufficiently aerated. Sometimes interpreting monitoring data requires sophisticated considerations; the best informed staff should do the monitoring.

This process of monitoring, even though it includes experimental trees, in no way compromises the experimental efforts, in fact, it enhances such efforts by ensuring that experimental trees do not suffer from improper irrigation during the irrigation phase. Since all experimental (including control) trees are randomly distributed on the site, and sample sizes are reasonably large, irrigation merely becomes a controlled variable. Ordinarily no impacts of treatments are apparent at the end of the irrigation phase; the experiment really doesn't begin until after irrigation ends.

Conclusions

Hopefully the four part approach outlined above will be useful to others doing revegetation projects in Southwest desert riparian situations. The first step, preliminary site analysis, allows for selection of a site generally suitable for the plant species one desires to plant. The second step, intensive random soil sampling on the chosen site, allows mapping soil/salinity conditions across a site. This done, a planting design can be tailored to site conditions—few trees will be planted where productivity will be low. Salt tolerant species can be planted on the saline portions of the site. Trees planted at points where soil sampling was done can be used to monitor growth during irrigation. Monitoring on a weekly basis permits early recognition and treatment of problems. Finally, the same sampling points can be used for planting trees for research purposes. Well designed research studies yield data valuable for increasing productivity (e.g. recognition of the extent of salt tolerance by various species) and reduce costs (e.g. by recognizing that shorter irrigation periods do not reduce productivity). The process is obviously cyclic; one must have done research (step 4) before preliminary data (step 1) can be meaningfully interpreted. The value of the procedure improves with completion of each cycle.

What is sacrificed if one or more of these steps is omitted? This is an important and difficult question to answer. I have been developing and refining the approach for a decade but cannot provide a precise answer. However, I offer the following, that we use in our work, as guidelines.

Elimination of the weekly monitoring may reduce productivity by 20 percent. On the Colorado River and lower Rio Grande failing to do preliminary sampling in concert with a decision to plant cottonwood/willow trees could result in nearly total failure half or more of the time; on the Kern River 5-10 percent of the time (Anderson 1988). Failure to map salinity levels could cost 30 percent in productivity on the Kern River and 50-75 percent on the Rio Grande and Colorado River. Uncontrolled competition for nutrients, space and light by weeds could account for 40 percent loss (Anderson and Ohmart 1984, 1986). Losses can quickly mount to disastrous proportions. The procedure helps us and will hopefully help others to reduce these losses.

Although helpful, the procedure still needs refinement, including more data on some of the fundamentals discussed in this paper. Fertilization has been held constant in all experiments, but productivity can probably be increased with refinements in the use of fertilizers. More work is needed on irrigation rates that will maximize productivity and leaching. Needed refinements will be made when—if—funding agencies recognize the need for it.

Acknowledgments

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JUNIPER FOR STREAMBANK STABILIZATION IN EASTERN OREGON[1]

Guy R. Sheeter and Errol W. Claire[2]

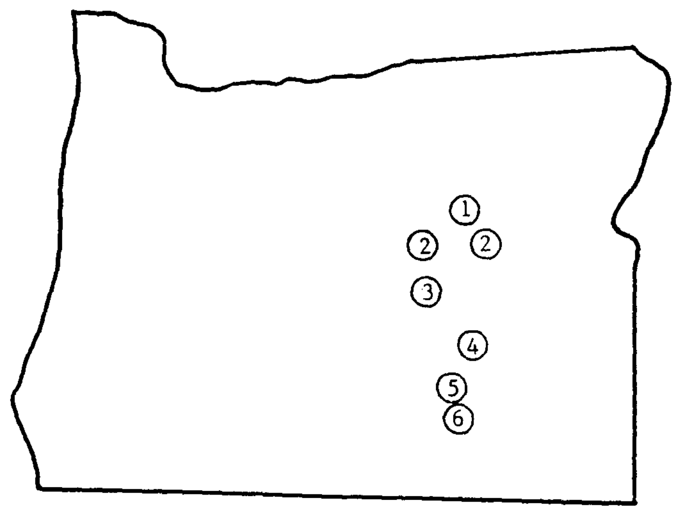
*Abstract: Cut juniper trees (*Juniperous osteosperma *Hook.) anchored along eroded streambanks proved beneficial in stabilizing 96 percent of the erosion on eight streams evaluated in eastern Oregon over a 14-year-period. Juniper revetment was a successful substitute for costly rock structures on straight or slightly curved banks, but failed when placed on outside curves or when poorly anchored. Water velocities were reduced by 65 percent where juniper revetment was evaluated. Sediment buried tree tips the first and second year after treatment. Juniper revetment should last at least 20 years with proper grazing management and allow full recovery of riparian vegetation and bank stability.*

Streambank stabilization may be required for the improvement of water quality, fish and wildlife habitat and the maintenance of productive riparian areas. Rock revetment, gabions and other structures are often used for bank stabilization.

This paper describes a technique used for streambank stabilization that has been in use for over 14 years in eastern Oregon.

Range of Habitat Conditions of Treated Streams

Six streams in eastern Oregon served as the study sites (fig. 1). Stream characteristics were gentle gradients (1 to 2 percent) with a substrate ranging from silt to cobbles. Streams varied from ephemeral drainages to perennial ones with a peak annual flow of .01 cubic meters/second (4 cubic feet/second) up to 169 m3/sec (6000 cfs), (table 1). Elevations in the study area ranged from 715 to over 2,700 m. These streams are typical of many streams found in the shrub-steppe and coniferous forest regions of the western United States (Bowers and others 1979, Thomas and others 1979). The vegetation is primarily basin big sagebrush (*Artemisia tridentate* subsp. *tridentata* Nutt.) and herbaceous species at lower elevations. Upper elevations have a predominant tree cover of ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.), Douglas-fir (*Pseudotsuga menziesii* Mirbel) and lodgepole pine (*Pinus contorta* Doug].) in the Blue Mountains and mountain big sagebrush (*Artemisia tridentata* subsp. *vasyana* Rydb.) and aspen (*Populus tremuloides* Michx.) in other drainages. Western juniper (*Juniperous osteosperma* Hook.) is found between the lower and upper elevations. Common riparian shrubs and trees include red-osier dogwood (*Cornus stolonifera* Michx.), thin-leaved alder (*Alnus incana* Moench), several species of willow (*Salix* spp.), black cottonwood (*Populus trichocarpa* T.& G.) and water birch (*Betula occidentalis* Hook.).



1. Fox Creek
2. John Day River
3. South Fork John Day River
4. Rattlesnake Creek
5. Krumbo Creek
6. Blitzen River

Figure 1 – Map of Oregon showing juniper revetment sites evaluated.

Methods

Methods used to stabilize eroding banks utilizing rock riprap are often costly and unsightly (Henderson and others 1984). Due to the high cost of treating extensive erosion problem areas, a technique was needed that would accomplish bank stabilization with minimal costs and equipment and would be more esthetically acceptable. Juniper tree revetment had been used on a limited scale by some private landowners in the John

[1] Presented at the California Riparian Systems Conference, September 22-24, 1988, Davis, California.

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Table 1-Characteristics of six study streams, eastern Oregon

	Fox Creek	John Day River at John Day	John Day[1] River at Dayville	South Fork[2] John Day River	Rattlesnake Creek	Trib. to Krumbo Creek	Krumbo Creek	Blitzen Creek
Drainage area (kilometers²)	91	622	2,544	1,528	52	14	21	982
Peak flow since treatment (m³/sec)	2	21	169	28-85	.5	.1	.3	121
Years since treatment	2	1	14	9-11	2	2	2	10
Stream gradient at site(pct)	1.5	2.0	72.0	1.0-2.0	2.0	1.0	1.0	1.5
Length treated(m)	236	289	213	1,966	30	15	30	30
Height of eroded bank(m)	.6-3.0	1.3-1.7	1.0-4.0	1.0-3.0	1.0	3.3	1.5	3.3-4.0
Average channel width at site(m)	4	30	46	15-23	4	3	4	40

[1] Treated at two locations.
[2] Treated at 30 locations.

Table 2 - Cost of juniper revetment contracted in eastern Oregon and southern Idaho.

Stream	Length treated (m)	Year	Placement method	Agency[1]	Cost/m ($)
Juniper Creek	914	1983	Horses	BLM Boise, ID	5.48
Fox Creek	236	1986	Tractor	ODF&W John Day, OR	38.13
John Day River	290	1987	Tractor	ODF&W John Day, OR	24.13
Chewaucan River	1365	1982	Tractor	USFS Paisley, OR	4.36
Chewaucan River	1177	1983	Tractor	USFS Paisley, OR	4.36

[1]BLM = Bureau of Land Management
ODF&W = Oregon Department of Fish and Wildlife
USFS = United States Forest Service

Day River Basin with variable success. Since juniper is abundant in much of eastern Oregon, it has now been used extensively on many problem areas. We evaluated 2,809 m of juniper revetment used on eight eastern Oregon streams treated from 1974 to 1987. During that period we found the following conditions to be important to the success of these projects:

3. Juniper trees should be green and full limbed with a heavy crown and in a "Christmas tree" or cone configuration.
4. The minimum tree butt diameter should be 15 to 30 cm d.b.h..
5. Trees should be placed in a shingled, overlapped pattern beginning downstream and working upstream (fig. 2).
6. Trees should be packed tightly and placed firmly against the bank.
7. Trees should form a downstream angle between the tree and the bank of about 45 degrees and be placed about 1 to 1.5 m apart.
8. The top of the tree should extend into the stream channel 1 to 1.3 m.
7. Tree butts should rest on top of the streambank but should not extend above the top of the bank by more than 0.3 m.

1. A 1814 to 2721 kg (2 to 3 tons) tilt-bed truck or flatbed trailer with solid sideboards was most practical for hauling trees.
2. Anchoring
   A. Steel fence posts should be driven back from the bank edge no less than 2.7 m from the top edge of the streambank in undisturbed soil.
   B. Posts should be driven so the top of the post is 5 cm below the ground.
   C. Post length should be 1 m. Full size posts were cut in half for use.
   D. Final wire position should lie flat on the ground to reduce hazards to humans, livestock and wildlife. Scrap powerline wire (4 CSR) was used extensively in place of cable to reduce costs.

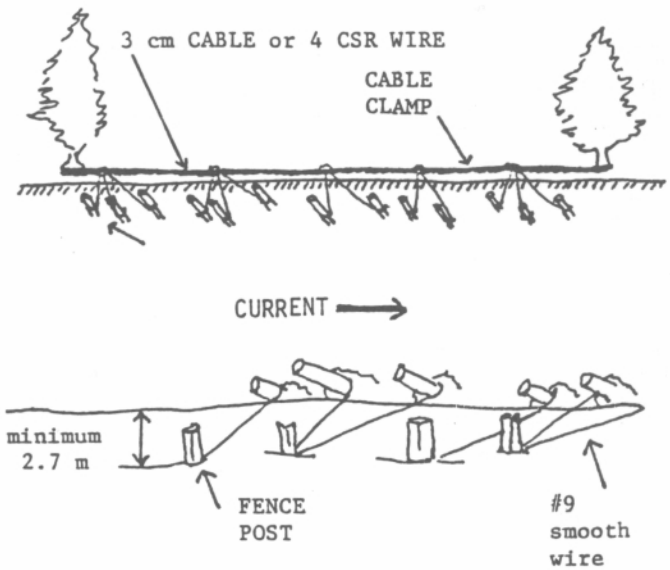

Figure 2 — Methods for installing juniper revetment along a streambank.

On the South Fork of the John Day River, labor was provided by Youth Conservation Corps (YCC) crews who worked for 2 weeks each summer from 1976 to 1978. Four hundred and fifty work days were needed to treat 1,372 m of eroded bank. YCC travel and environmental education time, etc., reduced actual work time by at least 20 percent. The other areas treated were done by Oregon Department of Fish and Wildlife and Bureau of Land Management crews or by contract.

Prior to juniper placement on the South Fork of the John Day River, flows were determined at one 30 m long site 0.3 m from the bank using a Gurley Current Meter. Following treatment, water velocities were reduced to such a low level that current meter cups would not turn. Since these low velocities could not be determined by that method an estimate was obtained by diluting red food coloring in 18.9 liters (5 gal) of water in a bucket and pouring the colored water into the river upstream and adjacent to the treatment area. As the labeled water moved downstream, it was timed, the distance measured, and a water velocity determined.

Results and Discussion

Juniper revetment was successful on 2,697 m (96 percent) of eroded streambanks. The average water velocity at one site evaluated was 0.28 m/sec before treatment and decreased to 0.08 m/sec after treatment. Many sites had tree tips buried under 0.6 m of silt the first year after placement. A slope below the vertical bank was formed by siltation and inhabitated by species indicative of early stages of plant succession (fig. 3). These native plants occupied these sites during the first growing season.

A study completed on the Chewaucan River near Paisley, Oregon, found that 1.46 m^3 of sediment, or 1070 kg, was deposited per meter of bank 2 years following treatment with juniper revetment (Otani and Anderson 1988).

Among the juniper revetments we evaluated, 112 m (4 percent) failed. The failures were caused primarily by placement of trees on outside curves of the stream and/or by poor anchoring. Individual junipers placed on more severe turns with high water velocities were the most susceptible to failure. These failures were prevented on severe sites when junipers were used in combination with rock deflectors (fig. 4). Fence post anchors driven too close to streambanks caused banks to slough off and trees to detach. When trees were not tied tightly to cables, water circulated behind trees causing erosion and failure. This could also occur on streams having narrow channels with vertical banks and no area available for deflection of flows. Where junipers were placed adjacent to camping areas some trees were occasionally cut for firewood.

The use of structures, such as juniper, to restore streambanks should be used only as a tool to reach bank stability. Where bank stabilization can be accomplished by livestock management alone these structural techniques should not be used. Juniper revetment should always be combined with proper grazing management. Overgrazing by livestock is a major cause of streambank erosion and degraded riparian habitat in eastern Oregon (Thomas and others 1979, Elmore and Beschta 1987).

Figure 3 — Juniper revetment 8 years after placement. Trees were sodded in and barely visible.

Figure 4 - Juniper revetment used in combination with rock deflectors.

Although the mat of juniper limbs against a bank hampers livestock grazing, domestic animals will still attempt to graze the succulent forage under the limbs and cause a breakdown of the revetment. We found that continued uncontrolled livestock use in areas treated with juniper reduced the effectiveness of the project, causing additional bank sloughing. A change in the season of livestock use or other range management technique may be required (Platts and Nelson 1985).

Our data show that the cost of juniper revetment may be less than that of rock riprap. Our costs may not be the, same as similar treatments on watersheds with different conditions. However, these values show relationships between costs of juniper revetment as compared to riprap. The cost of juniper revetment work contracted in eastern Oregon and southern Idaho ranged from $4.36/m to $38.13/m (table 2). Soil Conservation Service costs for rock jetties in the John Day, Oregon, area range from $1,690 to $2,210/30 m of bank treated (table 3). Juniper revetments costs are substantially lower than rock jetties where this treatment is appropriate. As eroded bank height increases, juniper revetment costs vary little; however, due to the marked increase in volume of rock needed, rock work costs increase proportionately. Another factor that may favor the use of juniper revetment is the avoidance of undesirable turbidity caused by heavy equipment excavation prior to rock placement. Juniper revetment work does not cause an increase in turbidity. If esthetics are a consideration, juniper revetment may be obscured by vegetation screening the trees from view. Eventually natural vegetation will obscure or replace the juniper as the rehabilitation of streambanks occur and trees deteriorate with time.

Table 3 – Estimated installation costs of rock work and juniper revetment for 30 m of bank erosion control, John Day area, Oregon.

Erosion control	Bank height (m)	Quantity required	Cost ($)
Rock jetties[1]	1.299.4 m^3	1690	
Rock jetties[1]	1.8	154.7 m^3	2210
Juniper revetment[2]	1.2	30 trees	728 to 1144
Juniper revetment[2]	1.8	30 trees	728 to 1144

[1] Assumes $17/$m^3$ rock cost including delivery and excavation needed to construct three 50 m^3 jetties.
[2] Cost of $24.28 to 38.13/m.

Conclusions

Juniper revetment proved to be a successful substitute for costly rock structures on straight or slightly curved banks on those streams evaluated. With proper installation, juniper revetment can provide bank protection for at least 20 years. This project life can be extended for an indefinite period if management of the area allows for full recovery of riparian vegetation. Eventually, full riparian recovery will replace the juniper, thus providing long-term erosion control and bank stability.

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A LOW COST BRUSH DEFLECTION SYSTEM FOR BANK STABILIZATION AND REVEGETATION[1]

Mary Elizabeth Meyer[2]

Abstract: A series of brush deflectors were installed along an eroding, undercut streambank on Lindo Channel in Chico, California. Pieces of brush were wired to sets of metal fenceposts driven into the bank perpendicular to stream flow and at strategic points upstream. Dormant cuttings of riparian plants were added for revegetation and long-term bank protection. To date (two years deployment), the system has stopped erosion.

Streaminders received funding from the California Department of Water Resources Urban Stream Restoration Program to develop a low cost brush deflection system to reduce bank erosion and restore riparian vegetation along a segment of Lindo Channel. Excessive costs associated with traditional bank protection such as rock rip rap, combined with undesirable environmental impacts has generated considerable interest in identifying other solutions to stabilize and slow bank erosion while preserving natural stream processes.

Bioengineering techniques which utilize biological materials such as brush, logs and living plants have been successful in achieving bank protection while maintaining environmental values (Schiechtl, 1980). A variety of bank stabilization techniques utilizing natural materials were explored along Prairie Creek with mixed results (Schwabe, 1986). Techniques which provided toe protection were the most successful in slowing erosion.

The Palmiter River Restoration Techniques, originated by George Palmiter of Ohio, involve a six step system which removes log jams, protects eroded banks with brush deflectors, removes sand and gravel bars and potential obstacles, and provides revegetation while requiring periodic maintenance (Institute of Environmental Sciences, 1982). Palmiter observed that obstacles such as log jams frequently forced currents against the bank causing erosion. By removing the log jam and placing brush deflectors at key points along an unstable bank, erosion was often controlled.

An experimental study is currently underway on the Sacramento River utilizing a palisade technique, consisting of placing nylon webbing between sets of pilings perpendicular to an eroding bank, in order to reduce water velocities and trap sediments (Michny, 1987). The palisade technique minimizes bank disturbance and has been utilized primarily on large river systems.

The bank protection technique explored here combines a palisade-type system with a brush deflection system originating from the base of the bank. Bank protection was simultaneously combined with revegetation to accelerate restoration of natural habitat values and further encourage sedimentation and bank stability. Locally available biological materials were used and labor was provided primarily by community volunteers.

Study Area

The study area is on Lindo Channel, a segment of Big Chico Creek located in Chico, Butte County, California, at an elevation of 69 meters. Lindo Channel carries high water overflow from Big Chico Creek but is dry for six months in summer. Peak flows experienced in recent winters can reach 90 cubic meters per second.

The upper five kilometers of Lindo Channel in the urban area has experienced increasing amounts of runoff and a long history of gravel mining, degrading the streambed and destroying riparian vegetation. Soil compaction on the surrounding terraces, combined with lack of summer flows, have created conditions difficult for the natural reestablishment of bank vegetation. Bridge crossings, bike paths, and a freeway overpass have caused localized erosion along banks by deflecting and altering currents.

The site selected for restoration consists of an eroding, undercut bank 69 meters long and 3 meters high, located along an outside curve just downstream of the Highway 99E freeway overpass. The freeway buttresses and apron are thought to have contributed to erosion along the bank by forcing flows against it, and by slowing velocity which causes an extensive point bar to form opposite the erosion site.

Methods

A system was designed using brush deflectors anchored in a continuous series along the eroding bank and at strategic points just upstream. Trenches 1 meter deep and 0.6 meters wide were used to facilitate placing cuttings into the gravelly substrate and to provide a

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Botanical Consultant and Project Coordinator, Chico, California.

trough in which to anchor deflectors. Figure 1 shows the location of deflectors. Deflectors A and B were installed just upstream to direct currents away from the bank. A continuous deflector C was placed parallel to the bank to stabilize the toe. Deflector C was extended 11 meters upstream of the erosion site and curved away the main channel to prevent flows from getting behind the deflectors. The downstream end was extended 12 meters beyond the end of the bank to accommodate downstream migration of the cut. Deflector D was placed downstream and across the channel to reduce any erosion induced by the project.

A rope "dead man" system was placed in the bottom of the trenches to help hold the brush deflectors in place, anchored with metal t-bar fence posts and weighted with short lengths of rebar. Pieces of freshly cut tree trimmings in 3 meter lengths were wired butt end down to the rope with 12 gauge wire. Tree trimmings with a lot of branching to dissipate energy were most desirable.

Dormant cuttings of riparian plants 1.5 meters in length were placed between the anchored brush with two thirds of the cutting below the substrate and one third above. The trench was then backfilled.

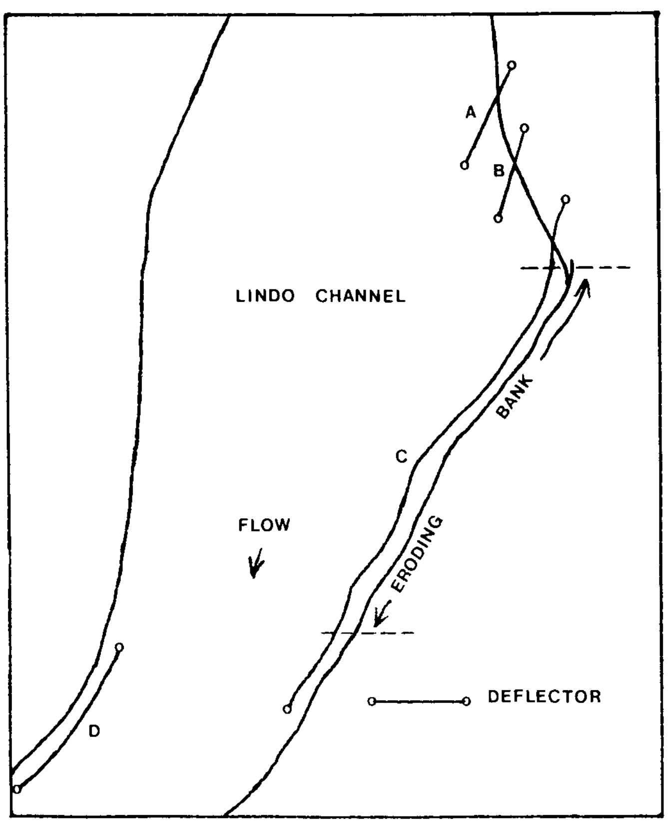

Figure 1 — Location of brush deflectors at Lindo Channel.

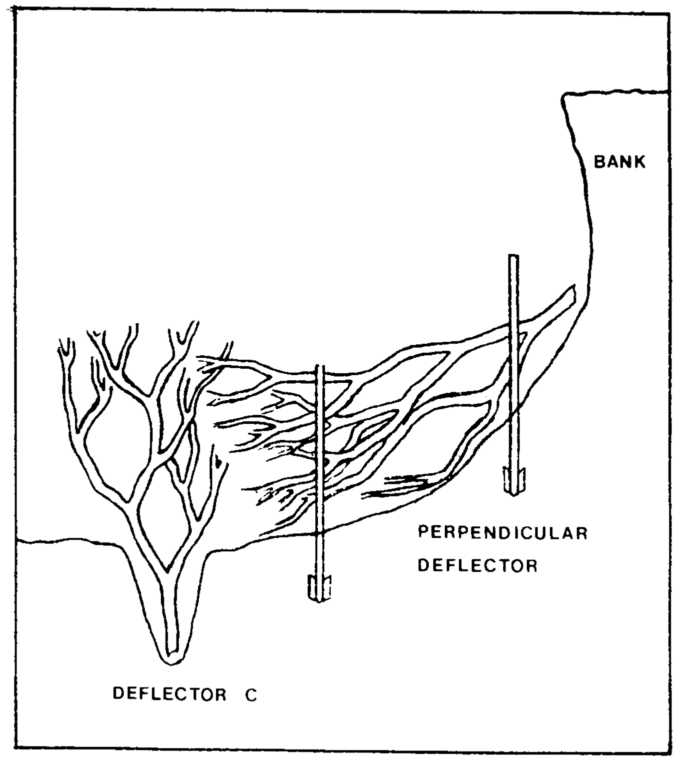

Figure 2 — Cross section of the eroding bank showing deflector C and a set of perpendicular deflectors.

Brush deflectors were also installed in a series perpendicular to the bank and deflector C. Figure 2 shows a cross section of the bank and deflector C with a set of perpendicular deflectors. Pairs of t-bar metal fenceposts 2 meters long were driven into the bank at 9 meter intervals. Tree trimmings were wired onto the upstream side of the fenceposts so that the branches extended out and down into the current. The finished height of the perpendicular deflectors was about 1.5 meters. Figure 2. Cross section of the eroding bank showing deflector C and a set of perpendicular deflectors.

Additional dormant cuttings were placed in the eroding bank over the next winter. Crow bars were used to make holes for the cuttings. The bar was worked down into the gravelly substrate in a circular, rocking motion. Working in teams, one member gradually pulled the crow bar out while another held the cutting and forced it downward along the side of the crow bar. The bar was then used to work the substrate around the cutting to make sure there were no air pockets.

Cuttings were taken from plants native to Lindo Channel and collected on site or nearby and placed at a variety of locations up and down the bank. The following plant species were used for cuttings: cottonwood (*Poplins fremontii*); willow (*Salix goodingii*) and (*S. laevigata*); and mule fat (*Baccharis viminea*). A drip line placed along the base of the bank was irrigated for 12 to 18 hours every 7 days during the dry season.

Installation was achieved over a 2 day period in October of 1986. Trenches required 5 hours of backhoe work. Labor required 204 person hours, contributed by community volunteers and members of the California Conservation Corp. Four truckloads of tree trimmings and cuttings were brought in, approximating 120 cubic meters of material.

To accommodate more capacity in the channel and to reduce the amount of water forced against the eroding bank, the instream edge of the point bar opposite the bank was shaved off with a bulldozer and the gravel pushed across the main channel and against the base of the brush deflectors. Four hours of bulldozer work moved approximately 180 cubic meters of gravel.

In preparation for the second winter, deflectors A and B and perpendicular deflectors were supplemented to maintain their effectiveness. One additional fencepost was added to each perpendicular deflector abutting the bank. Deflectors A and B were extended an additional 3 meters into the main channel and several fenceposts were added to receive brush. Fresh tree trimmings were wired to fenceposts along each deflector and additional cuttings were placed up and down the bank and subsequently irrigated during the dry season.

Two truckloads of tree trimmings containing approximately 60 cubic meters of material was used to augment the deflectors. Seventy person hours of labor were contributed by volunteers.

Results and Discussion

Two months after the initial October installation, the rainy season began. While overall rainfall for the winter was less than normal, several storms resulted in high flows for periods of 1 to 4 days, inundating the deflector system. The peak flow for the year reached approximately 78 cubic meters per second in March.

The brush deflectors substantially reduced the effects of moderate and peak flows against the eroding bank. Debris accumulated in the deflectors and increased their effectiveness. Large chunks of overhanging bank material which fell in were held in place at the base of the bank. Fine sediments built up behind the initial deflectors A and B, and at the lower end of deflector C where flows were at their slowest. About 0.3 meters of downcutting was observed along the middle third of deflector C.

Much of the brush along the middle section of deflector C disappeared gradually over the winter. This section experienced the most intense flows. In contrast, the perpendicular deflectors between deflector C and the bank were full of debris and appeared to be the more effective at protecting the bank than deflector C.

Loss of brush along deflector C was probably due to the location of the trench itself. The backhoe could not trench close enough to the base of the bank and consequently, deflector C was 1 to 2 meters further into the main channel than desired. Trench location also resulted in poor sprouting for the cuttings placed there, since those in the middle section of deflector C were inundated even during low flow conditions. In contrast, cuttings placed higher up on the bank along the upstream and downstream end of deflector C, and in deflectors A, B, and D rooted well and grew over 1 meter the next summer.

Based upon this experience it is recommended that trenching not be used along steep banks because of the difficulty in working close enough to the toe without causing bank collapse. Trenching appears to be successful when applied to areas that have a gentle slope and when large amounts of cuttings are needed.

The second year, rainfall was about 40 per cent of normal. Two early storms in December inundated the deflectors. Occasional storms in spring maintained low flows in the channel, but no further high flows occurred.

Examination of the streambed the following spring revealed some downcutting and scour at the end of deflector B which had been extended too far into the channel. Deflector B's terminal fence post washed out and the second one was bent. Otherwise, deflectors A and B and the perpendicular deflectors performed well. Cuttings sprouted and are thriving.

Fresh tree trimmings will need to be added to the deflectors annually until the vegetation is large enough to provide both deflection and bank stability. Adjustments in the deflectors may be necessary to increase or decrease deflection at key points. Irrigation must be carefully planned and monitored in climates like that of California to assure that the revegetation effort is successful.

It is important to note that the system described here has not yet been exposed to heavy winter flows. The mild winters to date may well have enhanced revegetation by providing time for plants to root. It remains to be demonstrated whether the riparian vegetation establishing along the bank will be able to provide long term protection.

Acknowledgments

I would like to thank the Chico community volunteers and members of Streaminders for contributing to planning, installation and maintenance of the project. This project was supported by a grant from the California Department of Water Resources, Urban Stream Restoration Program.

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REESTABLISHMENT OF NATIVE RIPARIAN SPECIES AT AN ALTERED HIGH ELEVATION SITE[1]

Franklin J. Chan and Raymond M. Wong[2]

Abstract: The failure of a 22-foot-diameter pipe caused an estimated water flow of 40,000 cfs for approximately one hour, which scoured and removed 1.75 million cubic yards of soil and vegetation from Lost Canyon. Mitigation for the damage caused by the pipe failure included re-establishing the lost vegetation. This paper describes the process of re-establishment including the riparian component. Co-operative planning; perseverance in plant acquisition; use of local sources of plants; use of a qualified contractor; and applying ecological principles in planting techniques and maintenance practices contributed to successful re-establishment.

Lost Canyon is a part of the Helms Pumped Storage Project located 50 miles east of Fresno, California at elevations of 6300 to 7800 feet. This hydro facility adds more than a million kilowatts of electric generation capacity to the Pacific Gas and Electric Company (PG&E) system. During the testing phase of the construction of the power plant in 1982, a 22-foot-diameter pipe failed at the Lost Canyon Crossing. The high-energy flow of water (40,000 cfs for approximately 1 hour) destroyed various types of native vegetation, including mountain meadow, montane chaparral, Jeffrey Pine, Lodgepole Pine, Red Fir and deciduous riparian vegetation (PG&E 1983a). It also removed 1.75 million cubic yards of soil from the canyon. Shortly after the pipe failure, PG&E established a task force to mitigate the damage caused by the pipe failure. A series of workshops with regulatory agencies was set up to prepare a mitigation plan (PG&E 1983b). Necessary work and studies that would help prevent further damage to the environment were initiated. Studies included water quality, slope stability and sedimentation, wildlife and fisheries, visual impacts and revegetation.

This paper reports on portions of the revegetation mitigation including the test and operational plantings. Riparian and other vegetation types are included to compare their performance in re-establishing themselves.

Of the vegetation lost due to the pipe failure, 20 percent was riparian vegetation. The proposed revegetation projected an increase of riparian vegetation from 20 to 30 percent because of the increased width of the canyon floor caused by the scouring, the construction of two stream checks, and the high wildlife value of the riparian vegetation. It was essential to conduct trial plantings at the earliest possible date to determine the feasibility and effectiveness of planting under the drastically altered conditions in Lost Canyon (PG&E 1984a). The test plantings were extremely valuable for formulating recommendations for the subsequent operational plantings. The operational planting consisted of planting 50,000 seedlings over a period of two years. The plant establishment rate required by the agencies was 400 to 500 woody plants per acre in plantable areas.

Test Planting

General Overview

A series of test plantings was conducted in 1983. The data covered the period of 1983 to 1985 after snowmelt. Because of the large volume of data, only selected material is presented. Test plantings were installed to evaluate species performance, range of environmental conditions, planting techniques and time of planting. Eleven planting areas/planting season combinations were evaluated. Two to eight species and two to four planting methods were planted in each planting area, resulting in the planting of 17 species in total (table 1).

Planting Methods

The planting methods used in the Species Trial represented 4 levels of planting intensity (see notes, table 1; Chan 1985) for a wide range of species in addition to 2 planting methods for establishing willows. The collar is a 5-inch diameter, 5 1/2-inch deep cylinder used to collect and concentrate precipitation into the root zone of the planted seedling. The collar is inserted into the planting hole, keeping the upper 1 1/2 inches above ground. The seedling is planted inside the collar at the natural grade. The screen is a 16-inch sheet of aluminum insect screen wrapped around the upper half of the collar and secured with tie wire to form a screen cylinder. The screen protects the seedling against deer, rodents and insects. It also provided shade to the seedling. The other two planting methods (Treatments V and VI) applied to a separate study regarding the establishment of willows and was tested in only one planting area. Treatment V was planting unrooted cuttings and Treatment VI was planting rooted cuttings.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Consulting Horticulturist and Senior Statistician, respectively, Pacific Gas and Electric Company, San Francisco, California

Table 1 – 1985 Lost Canyon revegetation project planting design.

Planting Area	Planting Season	Number of Species	Treatment Types*	Replications Per Species/Treatment	Total Plants
1	Spring	7	I-IV	10	280
1	Fall	7	I-IV	10	280
2	Fall	8	I-IV	10	320
3	Fall	6	I-IV	10	240
4	Fall	5	I-IV	10	200
5	Spring	8	I-IV	10	320
5	Summer	8	I-IV	10	320
5	Fall	8	I-IV	10	320
6	Spring	5	I-IV	10	200
7	Fall	6	I-IV	10	240
8	Fall	2	V-VI	50	200

*Treatments:
I = No collar, initial watering only
II = Collar, initial watering only
III = Collar, screen, initial watering only
IV = Collar, screen, scheduled watering

Results

Data were collected at the end of the first growing season and again after the second growing season after snow melt in 1985. Because there are too many results to present each separately, results will be presented graphically. An explanation of the graphic presentation is given in the example below for the comparison of survival for the seven species at planting area 2 (table 2).

The eight species are ranked from the highest survival rate to the lowest survival rate. The number of plants that survived is directly below the species letter. The total number of plants tested for each species (40) is identical and is shown to the right of the slash. Thus, 31 out of 40 plants of species H plants survived. In order of survival rate, from highest to lowest, the ranking was highest for species H, lowest for species G. The underlining of a group implies that there is no significant difference at the .05 level between members of that group. More than one group may be underlined in each analysis to show significant differences between groups and individuals. Thus, HCEDBF implies that species H, C, E, D, B and F statistically have about the same survival rate. However, if two species are not underlined, then these two species are significantly different at the .05 level. So, the survival rates for species C, E, D, B, F and A are statistically superior to species G.

The analyses for height and stem diameter are presented in a similar manner. The mean height or stem diameter growth is substituted for survival rates. The results of comparing stem diameter growth for the seven species at planting area 1 were tabulated (table 3).

Height and caliper width comparisons between species are made using all plants (dead and surviving). The mean height and caliper width given below the comparisons are only for those plants that survived.

Table 2 – Analysis 1: Most Successful Species - Planting Area 2

Survival	Best						Worst	
Rank (Species)[1]	H	C	E	D	B	F	A	G
Number Surviving	31	28	28	27	22	22	21	7 /40[2]

[1] The letter symbol for species in the results of the test plantings are:

A - *Salix,* LPM
B - *Salix,* HC
C - *Populus tremuloides*
D - *Populus trichocarpa*
E - *Pinus c. murrayana*
F - *Pinus jeffreyii*
G - *Chrysolepis sempervirens*
H - *Sambucus caerulea*
I - *Alnus incana*
J - *Pinus monticola*
K - *Sorbus scopulina*
L - *Abies concolor*
M - *Abies magnifica*

[2] Total number of plants for each species.

Table 3 – Analysis 1: Most Successful Specie Planting Area 1.

Stem diameter	Best						Worst
Rank (Species)	E	C	F	A	D	B	G
Mean (diameter)	6.4	4.5	4.5	4.6	3.8	5.1	3.8

Results were affected not only by site conditions, but by construction activities in the canyon including building stream flow checks, diversion channels, debris removal and hazardous tree removals. In spite of these disturbances, the results generally reflected the effectiveness of the plant species, plant methods and cultural practices tested.

As expected, survival was consistently higher the first year compared to the second year. What was not expected was the high overall survival in the first year. In six of the eight planting areas, all species tested in those areas had over 53 percent survival. In 32 of the 44 species/area cases, survival was over 80 percent. In 40 of the 44 cases, survival was over 70 percent. Disregarding planting areas, 13 of 17 species had over 70 percent survival (PG&E 1984b). In the other two planting areas, low survival was associated with the planting of unrooted cuttings of willows.

Good results in the first year were attributed to using adapted species for the various planting areas. Also contributing to the results were the performance of the revegetation contractor, initial watering of all plants, occurrence of some summer rain in August, and the relatively short time plants had been in the ground. However, some plants had grown at the site during most of the growing season and had withstood poor soil conditions and rather hot and dry conditions during the first year.

Mean height and caliper growth were determined for surviving plants regardless of planting areas (table 4). These data in the first year had limited significance but they were valuable for future evaluation of the test plantings.

In the second year regardless of the level of difficulty of the various planting areas, riparian species performed satisfactorily (tables 3 - 8).

In Lost Canyon, 50 percent or higher survival under the difficult conditions was considered good. In all five planting areas (tables 5 - 9), where riparian species were planted with other vegetation types, the majority of species that performed best were riparian species. In particular, Populus tremuloides was in the best performance group in all of the five planting areas, as well as the top performer in the streambank planting area which had only riparian species (table 10). Area 7 did not have any riparian species.

Comparing the four planting treatments tested, best results were related to the level of planting intensity. Overall, the more effort expended, the better the results (table 11). Under specific conditions, the most intensive method may not be the most cost-effective method because conditions may not warrant the additional effort or cost. For example, in favorable moist sites watering may not be necessary, or depredation may not be a problem. However, if the site is difficult, the most intensive method will likely provide the best chance of success.

Operational Planting

Overview

Operational plantings were initiated one year after the test plantings. Selection and propagation of plants were initiated during the same year as the trial planting. Because of the magnitude of the Lost Canyon revegetation planting, PG&E proposed that the planting be performed in two phases. The reason for this was to concentrate on planting stabilized areas first and to allow time for steeper slopes to stabilize. Extending the planting installation also helped relieve the plant acquisition difficulties associated with the short time frame.

The planting design for Lost Canyon was developed by physically marking 200 foot sections from the head of the canyon down to the end of the canyon at Wishon Lake. This sectioning was effective in designating species for specific conditions in a section and facilitating distribution of plants throughout the canyon. It also facilitated communications in reporting special problems and applying specific treatments to the correct areas. Because the canyon was 200 to 300 feet wide, sections were approximately one acre in size in most cases. Ninety sections were established.

Records were kept on plants in each section in regards to what was planted (PG&E 1987a; PG&E 1988) and what maintenance was provided. Much effort was made to establish a balance of vegetation types throughout the canyon and to match the species to conditions where they were best adapted. Color-coded flags were used to mark actual planting locations of individual plants. A qualified person was selected to mark locations in advance of the planting crew. The person not only had to be able to identify most favorable or promising locations for each species, but had to develop natural patterns and densities that were compatible with the surrounding area.

Planting Procedures

Specifications and drawings were prepared and the job was bid. Circuit Rider Productions of Windsor, California was the successful bidder. Different planting methods and cultural practices were specified for different planting conditions in order to achieve the most cost-effective results. Of the 50,000 seedlings planted, 22,093 were riparian species.

Table 4 - Total Mean Height Caliper and Survival of each Species regardless of Planting Area, Species Trial - Lost Canyon, Helms Project, first year.

Species	Mean Height (cm)	Mean Caliper (mm)	Pct of Survival (No. Plants)
Salix sp. (LPM) unrooted	0	0	0
Abies concolor	3.5	2.2	75.0 (90)
Pinus monticola	3.8	2.0	75.0 (90)
Abies magnifica	3.9	2.1	76.9 (123)
Pinus jeffreyii	8.9	3.3	92.5 (259)
Salix sp. (HC) rooted	9.7	2.4	88.6 (186)
Arctostaphylos patula	9.7	2.4	97.5 (39)
Sambucus caerulea	10.0	2.6	91.3 (73)
Sorbus scopulina	14.2	4.2	85.8 (103)
Ceanothus cordulatus	15.5	2.5	62.5 (25)
Populus trichocarpa	15.8	2.9	87.5 (210)
Salix sp. (LPM) rooted	17.2	2.8	83.2 (341)
Salix sp. (HC) unrooted	17.8	2.8	9.2 (12)
Alnus tenuifolia	20.4	4.6	55.0 (22)
Chrysolepis sempervirens	*22.7*	2.6	81.3 (130)
Populus tremuloides	26.6	3.4	99.2 (357)
Pinus C. murrayana	33.3	5.9	99.4 (358)

Table 5 - Statistical Analysis Lost Canyon Revegetation - 1985 Analysis 1: Most Successful Species - Planting Area 1 (Wildlife Area). Site conditions: Moderate but disturbance from construction activities.

Survival	Best					Worst		
Rank (Species)	C	E	F	D	A	B	G	
Number Surviving	37	36	29	27	26	16	15	/80
Height (cm)	Best						Worst	
Rank	C	E	A	D	F	B	G	
Mean	34.9	32.8	27.8	24.4	13.4	20.6	22.1	
Stem diameter (mm)	Best						Worst	
Rank	E	C	F	A	D	B	G	
Mean	6.4	4.5	4.5	4.6	3.8	5.1	3.8	

See key to species symbols in Table 2.

Conclusion - Species C, Populus tremuloides, and E, Pinus c. murrayana, are clearly the best in survival, height and stem diameter.

Table 6 - Statistical Analysis Lost Canyon Revegetation- 1985. Analysis 1: Most Successful Species - Planting Area 2 (wildlife area). Site conditions: moderate.

Survival	Best						Worst		
Rank (Species)	H	C	E	D	B	F	A	G	
Number Surviving	31	28	28	27	22	22	21	7	/40
Height (cm)	Best						Worst		
Rank	E	C	D	B	A	H	F	G	
Mean	34.	28.4	26.4	22.0	23.0	7.1	12.0	14.3	
Stem diameter (mm)	Best							Worst	
Rank	E	C	D	F	H	B	A	G	
Mean	7.0	4.6	3.9	4.9	3.1	3.7	3.4	3.3	

See key to species symbols in Table 2.

Conclusion - Species E, Pinus c. murrayana, is clearly superior in survival, height and stem diameter.

Table 7 - Statistical Analysis Lost Canyon Revegetation- 1985. Analysis 1: Most Successful Species - Planting Area 3 (wildlife area). Site conditions: moderate.

Survival	Best					Worst	
Rank (Species)	E	*C*	D	A	B	F	
Number Surviving	31	29	25	19	15	13	/40
Height (cm)	Best					Worst	
Rank	E	*C*	D	A	B	F	
Mean	38.6	37.0	24.1	32.1	23.1	11.5	
Stem diameter (mm)	Best					Worst	
Rank	E	*C*	D	A	B	F	
Mean	7.5	5.3	3.8	4.0	3.8	3.7	

See key to species symbols in Table 2.

Conclusion- Species E, Pinus c. murrayana, is superior for survival, height and stem diameter.

Table 8 - Statistical Analysis Lost Canyon Revegetation- 1985. Analysis 1: Most Successful Species Planting Area 4 (high bluffs). Site conditions: difficult.

Survival	Best				Worst	
Rank (Species)	E	A	B	C	D	
Number Surviving		11	9	9	4	/40
Height (cm)	Best				Worst	
Rank	E	A	C	B	D	
Mean	35.7	23.9	37.9	22.3	19.3	
Stem diameter (mm)					Worst	
Rank	E	A	C	B	D	
Mean	7.8	3.9	5.1	3.7	3.7	

See key to species symbols in Table 2.

Conclusion - Species E, Pinus c. murrayana; A Salix, LPM; and C, Populus tremuloides, are superior for survival, height and stem diameter.

Table 9 - Statistical Analysis - Lost Canyon Revegetation - 1985. Analysis 1: Most successful species - planting area 5 (spoil area). Site conditions: difficult.

Survival	Best							Worst	
Rank (Species)	C	A	F	E	M	K	J	L	
Number Surviving	60	49	47	38	29	27	26	21	/120
Height (cm)	Best							Worst	
Rank	C	E	A	F	A	K	J	L	
Mean	28.9	35.9	22.0	9.8	13.8	6.2	5.3	5.9	
Stem diameter (mm)	Best							Worst	
Rank	C	E	F	A	K	M	J	L	
Mean	4.2	7.0	4.1	3.8	4.7	2.0	2.5	2.1	

See key to species symbols in Table 2.

The heights for species E and F are similar statistically.
Conclusion - Species C, Populus tremuloides, is the best.

Table 10 - Statistical Analysis Lost Canyon Revegetation - 1985. Analysis 1: Most successful species - planting area 6 (streambank areas). Site conditions: favorable.

	Best				Worst	
Survival						
Rank (Species)	C	D	A	I	B	
Number Surviving	38	29	28	21	6	/40
Height (cm)	Best				Worst	
Rank	C	D	A	I	B	
Mean	34.3	35.0	33.4	32.9	21.8	
Stem diameter (mm)	Best				Worst	
Rank	C	A	I	D	B	
Mean	5.4	5.8	8.0	5.7	5.7	

See key to species symbols in Table 2.

Conclusion - Species C, Populus tremuloides, is the best.

Table 11 - Statistical Analysis Lost - Canyon Revegetation - 1985 . Analysis 6: Comparisons of treatments I, II, III, and IV. (all planting areas, except 8).

	Best			Worst	
Survival					
Rank (Treatment)	IV	III	II	I	/680
Number Surviving					
Height (cm)	Best			Worst	
Rank	IV	III	II	I	
Mean	24.4	24.1	22.9	24.3	
Stem diameter (mm)	Best			Worst	
Rank	IV	III	II	I	
Mean	4.6	4.6	4.6	4.8	

Conclusion - Collar, screen and supplemental watering (Treatment IV) always ranks among the best treatments for survival, height and stem diameter.

Table 12 - Statistical Analysis - Lost Canyon Revegetation - 1985. Analysis 5: Benefits of planting rooted cuttings (planting area 8).

	Species A			Species B		
Survival	Best	Worst		Best	Worst	
Rank (Treatment)	VI	V		VI	V	
Number Surviving	12	2	/50	34	26	/50
Height (cm)	Best	Worst		Best	Worst	
Rank	VI	V		VI	V	
Mean	21.8	11.0		51.7	26.6	
Stem diameter (mm)	Best	Worst		Best	Worst	
Rank	VI	V		VI	V	
Mean	3.8	2.3		5.2	3.7	

Conclusion - Planting rooted cuttings of Species A (Treatment VI) is vastly superior to planting unrooted cuttings (Treatment). V). Planting rooted cuttings (Treatment VI) of Species B offers no significant benefits over unrooted cuttings (Treatment V) of Species B.

Table 13 - Representative age, class, growth, and survival of species planted in sample sections.

Species	Section No.	Age Class	Aver. Height (cm)	Aver. Caliper (mm)	Percent Survival of Sample	
Alnus incana	32	3	52.0	13.0	70.0	(10)
	37	3	91.0	19.0	48.2	(56)
	44	3	59.0	17.0	75.8	(33)
	77	3	107.0	21.0	86.1	(36)
Corpus stolonifera	*37*	*3*	1	5.6	5.0	(20)
	37	1	7	4.1	30.0	(10)
	44	2	2	5.3	57.1	(14)
	48	3	3	6.4	38.5	(26)
Populus tremuloides	32	3	62.0	8.4	23.4	(64)
	44	3&2	55.0	8.6	69.5	(105)
	48	3	35.0	6.9	88.6	(44)
	77	3	67.0	10.0	66.7	(45)
Populus trichocarpa	*37*	*4*	49.0	10.0	NK	(22)
	44	2	43.0	11.0	NK	(19)
Salix spp.	32	3	53.0	11.0	53.7	(54)
	44	1	19.0	5.4	23.6	(110)
	48	1	12.0	3.6	32.5	(40)
	48	3	71.0	9.9	64.0	(50)

Results

Because of the vast and difficult terrain and the exceptionally high number of plants planted, it was not feasible to count every seedling in the canyon. A sampling method (PG&E 1987b) was used to determine the number of seedlings established. Of three statistical estimating procedures used, survival estimates ranged from 47,017 to 48,441 after three years from the initial operational planting. This figure included all sources of plants PG&E had planted including the test plantings and a supplemental planting of 5,270 plants.

The source of the plants inventoried were categorized by the type planting, year planted and whether the plant was derived from natural regeneration or aerial seeding (Lodgepole and Jeffrey Pines). It was sometimes difficult to pinpoint the source of a plant because of various reasons. However, for most species, it was fairly easy to distinguish planted individuals from those of natural regeneration. Many of the identifying flags and planting collars were still in place. Most of the plants inventoried were attributed to the revegetation effort (PG&E 1988). The total number of living plants regardless of origin was accurate and was used to fairly assess the fulfillment of the regulatory agencies' requirement for plant establishment.

Some results of the riparian vegetation plantings are provided (table 13). These results in many cases were comparable to the test planting.

Discussion

Selecting Adapted Species

For typical riparian conditions, it is efficient to plant willows or black cottonwood as soon as conditions are favorable in the Fall using cuttings planted directly at the site. Selecting local sources of cuttings and planting as soon as the source plants become senescent is recommended. If the site is marginal, i.e. the seasonal weather conditions predicted to be dry or time of planting is delayed into spring, rooted cuttings of local sources of species is recommended. Supplemental watering should be used if needed.

For difficult sites where it is desirable to establish riparian vegetation more considerations need to be given to the planting. Identifying site conditions in which the various types of riparian species are able to become established is best accomplished by establishing trial plantings early in the planting program or by installing limited size pilot planting. Testing a wide range of species in a wide range of conditions is desirable in large projects. Significant results should be evident in one year.

Even without understanding the internal mechanism of the plant's ability to become established, one can utilize the plant's response to acquire an indication of its future performance at disturbed sites. Indicators such as vigor, color of foliage, survival and growth rate at the site have more direct value than laboratory studies or studies performed at other sites. In addition, site conditions change with time as nature creates more favorable conditions for plants to develop. These subtle changes may take place over relatively longer periods of time but are difficult to study because of the lack of research continuity and the funding difficulty.

Quaking aspen, scouler's willow and to a lesser extent, red-stem dogwood have a wide range of adaptation. It seems these species are capable of becoming established in quite dry and rocky conditions at high elevations. Their peak performance may not be at these kind of sites, but growth is quite adequate. Reproduction by natural seeding may not be likely under these conditions but vegetative perpetuation is possible.

Plant Acquisition and Timing of Plant Propagation

In addition to selecting adapted plant species and using proper planting methods for specific site conditions, plant acquisition is also important, including plant propagation and timing. Planning and co-ordination is essential. Because of the 6 to 12 month lead time to acquire plants it may not be feasible to include plant acquisition as part of the planting contract nor may it even be desirable to do so. Plant acquisition is a specialized process requiring rigid guidelines but enough flexibility to acquire sufficient supplies of species. A planting contractor may have limitations. Specialized knowledge of plant propagation may be required. Plant acquisition is also time consuming; knowing current market conditions is necessary.

Maintenance

Minimal or no maintenance is desirable as the most effective means of establishing riparian vegetation. Plants that grow in balance with the natural existing environmental conditions are better able to survive and to continue perpetuating on their own. One is not able to determine the adaptiveness of the species used for the existing site conditions without applying this approach. The response of the species should be evident in the first growing season. If watering is used, it should be only enough to supplement the natural rainfall during periods of drought or if plantings are installed late in the season. However, it may be more cost-effective to install supplemental plants than to perform excessive maintenance. The results of the initial planting will allow one to make a determination as to the necessity of making a supplemental planting. If exceptional vigor is observed with certain individual plants or species compared to plants that failed or performed poorly, these plants should be propagated to expand the planting. It is also advisable to identify specific site conditions where positive results were consistent and emphasize planting such areas in later stages.

Conclusions

As a group, the riparian vegetation in Lost Canyon was versatile. Some species were most adapted to typical riparian conditions in which deep sandy soil was saturated in late winter-early spring and perennially moist at lower depth in the latter part of the growing season. Other species were able to extend their environment to drier conditions but still probably utilize moisture at lower depths, particularly in rocky soil. Some species were established in nearly solid rock with few fissures but had constant moisture from seepage.

The revegetation effort significantly accelerated and aided the healing process in Lost Canyon. However, the need for improvements in the state-of-the-art was evident. A better understanding of plant establishment in regards to nature's response to a catastrophic event is needed. Areas of research include inoculation of disturbed soil with mycorrhizae and other micro-organisms.

According to one scientific investigator, replanting a native ecosystem cannot be realized if a component as critical as mycorrhizal symbiosis is not included in the replanting process (St. John, 1984). This did not appear to be true from the data collected at Lost Canyon as well as some other revegetation projects. Artificial inoculation of a severely disturbed soil may not be obligatory although it is likely to be beneficial to establish native woody plants. Also, fertilization seems to aid rather than inhibit plant establishment. The optimal amount appears to vary with species. The lowest levels that can achieve a healthy growth response is recommended.

An understanding of natural processes needs to be more clearly defined, including re-establishment of soil organisms in relation to host plants, assimilation of minerals and organic matter and how to apply new technological information into practical horticultural procedures. We need to be able to better identify a plant's range of adaptation and to understand how to establish a balance between the plant and the existing environmental conditions. Riparian vegetation appears to be established in Lost Canyon and normal continual development appears promising five years after the initial planting.

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WATERSHED RESTORATION IN THE NORTHERN SIERRA NEVADA: A BIOTECHNICAL APPROACH[1]

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Abstract: A cooperative erosion control project was initiated in 1985 for the North Fork Feather River watershed in California's northern Sierra Nevada due to widespread accelerated erosion. Resulting sedimentation problems have impacted fish, wildlife and livestock resources, and have created operational concerns for hydroelectric facilities located downstream. In response, concerned groups met to develop a restoration plan. A Memorandum of Agreement was signed and a Coordinated Resources Management Planning Committee was formed to facilitate the planning and implementation process. The watershed restoration program was initiated with a small demonstration project that was implemented in Red Clover Creek. The objective was to demonstrate structural and nonstructural methods that reduce erosion, restore riparian vegetation, and improve habitat for fish and wildlife, and to develop a planning process for future projects. A 4-year monitoring pro-gram was initiated to provide data for a cost and benefit analysis. The planning process, improvement measures, and some preliminary monitoring results are presented.

In recent years there has been a growing interest among professionals, politicians and the public in improving watershed conditions in California. This is in response to the critical need for additional high quality water to foster urban growth, agricultural expansion, industrial, recreational, and energy-producing uses in the state. This trend is reflected in the growing importance of cumulative effects assessment, legislation contained in Section 208 of the Federal Water Pollution Control Act, and the amended Clean Water Act of 1987. California is presently developing a nonpoint source pollution control plan, which includes both toxics and sediment, in response to this legislation (State Water Resources Control Board 1988). In addition, the State Water Resources Control Board has required an assessment and monitoring study to determine the adequacy of current Best Management Practices (BMP's) contained in Forest Practice Rules for protection of water quality (State Water Resources Control Board 1987). These institutional signals may be indicative of the changing political climate regarding water quality control at both the federal and state level.

Since degraded riparian areas can be major contributors of sediment to streamflow, much of the growing interest in improving water quality has focused on restoration and management of streamside zones. Increased demand for recreational resources, aesthetics and good water quality, and the recognition of widespread degradation have provided the impetus to develop and implement techniques to repair degraded riparian habitats. A wide variety of techniques are available which are documented in manuals, symposia proceedings, and research papers.

Institutional incentives for riparian restoration lag far behind available technology. The manner in which upstream managers and downstream users interact in the restoration process has not been reconciled. The responsibility for implementing restoration measures has largely been left to landowners, making spot treatment of major watershed problems a common remedy. Site specific projects can create additional watershed problems, and in some cases, lead to project failure due to inadequate consideration of physical and biological factors from the watershed perspective. The ability of one landowner or organization to gather the needed preproject information and to bear the responsibility of implementation alone is unrealistic and infeasible.

Restoration at the watershed level is complex and seemingly impossible due to discontinuous land ownerships, the difficulty in assessing causes and solutions, and the great expense in stabilizing degraded sites. It can be accomplished, however, through extra effort and organization. Coordination of parties most likely to benefit through the planning and implementation process seems to spawn the most successful projects. This paper summarizes the process used to implement such a riparian enhancement project in California.

Background

The North Fork Feather River (NFFR) watershed is located on the west slope of the northern Sierra Nevada. It drains 5,058 square kilometers of variable terrain (Langridge 1984), and has long been recognized for its recreational and aesthetic value. This watershed is an

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important component of California's vast water distribution network, produces a significant amount of hydroelectric power, and provides extensive fishing, hunting, grazing, timber, mining, and aesthetic values. Most of the timbered areas are managed and administered by the Plumas National Forest, while the large alluvial valleys are predominantly privately owned.

Land use by man is largely responsible for the accelerated erosion conditions apparent in this watershed today. Extensive mining, grazing, timber harvesting, pioneer settlements, and burning and cultivation of meadows has reduced vegetation cover, leaving uplands and streambanks barren and vulnerable to erosional processes. This has resulted in a network of hydrologically unstable channels due to increased overland flow and sediment discharge.

Increased sedimentation and poor water quality have produced problems for landowners, managers, and resource users. Livestock producers have less forage production to support cattle on floodplains due to lowered water tables associated with downcutting stream channels. Recreationists find fish populations are reduced due to lack of overhanging vegetation, poor water quality and warm water temperatures. Inadequate cover of riparian vegetation has reduced nesting and rearing habitat for waterfowl and other wildlife species. Hydroelectric producers must contend with increased sedimentation in reservoirs which creates operational and environmental concerns. These effects are symptoms of the degraded state of this watershed.

Planning

Coordinated Resource Management Planning(CRMP)

A cooperative, interagency effort was started in 1985 in response to the accelerated erosion prevalent in the watershed. Fourteen federal, state, and local agencies, and private sector groups met and later signed a Memorandum of Agreement (MOA). This document outlined the commitments of each group in developing and implementing a watershed erosion control plan. It became evident that a process was needed to coordinate the interactions and contributions of participating groups, and to streamline bureaucratic constraints. Therefore, the MOA participants elected to use the CRMP process to facilitate planning at the local level. Plumas Corporation, a non-profit economic development organization, was appointed the project coordinator.

The CRMP process is often used to solve complex resource management problems that involve multiple landowners and special interest groups extending over large geographic areas (Anderson and Baum 1987). This approach integrates the needs of participants into an action plan. Since decisions are made by consensus, conflicts are minimized. Contributions of participants are leveraged to provide benefits at an affordable cost. It is also widely used by public land management agencies which enhances project credibility, and may provide additional funding opportunities.

Such a planning process can be used effectively to address riparian problems from a watershed or "big picture" perspective. Success, however, depends upon completion of a thorough pre-project survey to determine geomorphological, hydrologic and biologic characteristics of the area, in addition to historical and current land uses.

River Basin Study

A River Basin Study (RBS) is being conducted by the USDA Soil Conservation Service (SCS) to evaluate and prioritize sources of erosion in the watershed, and to identity cost effective restoration measures. Results will be used to develop a restoration plan which identifies critical areas, and as a means to secure additional project support. The local CRMP committee is responsible for guiding the RBS so that high priority areas of concern are emphasized accordingly. A draft report has been submitted and is presently in the review process (USDA Soil Conservation Service 1988).

Demonstration Project

The CRMP committee decided to implement a small demonstration project in the headwaters of the watershed as a first step in developing a regional erosion control plan. The project was designed to test and evaluate the effects of several erosion control techniques on streambank stability, sediment reduction, and the recovery of riparian vegetation. In addition, the project would provide an opportunity to establish a workable planning process for future cooperative projects.

Site Description

Potential sites for the demonstration project were surveyed by an interdisciplinary field team and a 1.5 kilometer stretch of Red Clover Creek was selected. It is located 40 kilometers east of Quincy, California, on the eastside of the Sierra Nevada crest. The creek flows through Red Clover Valley which is a highly erodible alluvial valley at an elevation of 1,676 meters. It drains about 250 square kilometers of terrain and contributes large amounts of sediment to the East Branch North Fork Feather River (EBNFFR) system (Mitchell 1986), which is the focus of the study. The valley is privately owned and is surrounded by lands administered by the Plumas National Forest.

The climate is relatively dry and valley soils are poor due to a history of wind and water erosion. The vegetation is composed predominantly of undesirable shrubs and grasses such as sagebrush, rabbitbrush, and cheatgrass. Sparse willows line old stream channels and many native herbaceous perennials have been replaced by less desirable weedy species due to the impact of land use and lowering of the water table. The actively eroding stream channel is 15-18 meters wide and has vertical cut banks 2-4 meters in height. Vegetation cover and mix of species have significantly declined since the turn of the century due to loss of floodplain and streambank vegetation, limited ground water storage, and variable precipitation (Lindquist and Filmer 1988, Mitchell 1986).

Stabilization Measures

An improvement plan was developed for the demonstration site by technical members of the CRMP committee. The objective was to provide a realistic plan for treating the riparian system, which includes the channel, streambanks and uplands. Practical and cost-effective techniques were selected from a variety of options, based on materials and expertise available, cost, and aesthetic values. A biotechnical approach, which includes use of both engineered (structural) and biological (nonstructural) methods, was used (Gray and Leiser 1982). Methods selected are described in the following sections.

Structural Improvements

Check Dams—Four loose rock check dams were designed to reduce both the channel gradient and downcutting of the streambed. They were built at points determined by the channel gradient and location of bedrock anchor points. Each dam raises the water level about 1 meter which forms a pond on the upstream side of each dam. The ponds reduce the velocity of the flow, which decreases the erosional energy of the water and causes deposition of suspended sediments. Over time the streambed elevation will rise as deposition continues, and streambank erosion will be reduced as riparian vegetation becomes established. The recharge of the water table will enhance the production of vegetation in the floodplain.

Revetment—Pine revetment was installed to demonstrate an economical approach to stabilizing streambanks in place of more expensive rock riprap. A 30 meter section of the channel was lined with pine tree tops, that were inverted, overlapped and cabled into the top and toe of the bank. The structure traps sediment, prevents further bank erosion, and enables vegetation to become established along the cut banks. This rounds and narrows vertical banks, and over a period of time the structure is totally concealed. This method has been used with success in Oregon (Sheeter and Claire 1981) and in Modoc County with juniper, but pine was used exper-imentally in this case due to the absence of significant amounts of juniper in this area.

Nonstructural Improvements

Revegetation—A revegetation plan was implemented to accelerate streambank stabilization. The following treatment variables were compared: survival rates of four hardwood species including coyote willow (*Salix exigua*), mountain alder (*Alnus tenuifolia*), black cottonwood (*Populus trichocarpa*), and quaking aspen (*Populus tremuloides*); two plant forms (unrooted stakes vs. rooted liners); and two planting seasons (fall vs. spring). Treatments were composed of various combinations of these variables based on availability of materials, species native to the valley and planting feasibility (Lindquist and Filmer 1988)

Fencing and Land Management—5 kilometers of exclosure fencing were installed around the project, creating a 26-hectare riparian pasture. The fence was designed to control livestock and vehicular access, and to protect monitoring equipment. The fencing will be used to develop a rotational grazing system to control forage use on eroding uplands and in the riparian zone. Identification of improved land management practices is a vital component of riparian restoration.

Monitoring Program and Preliminary Results

A 4-year monitoring program was developed to annually evaluate the erosion control measures used and to assess costs and benefits. It is not intended to be a comprehensive evaluation due to budget and time constraints, but it includes variables that are of interest to CRMP members. The cost evaluation portion of the analysis will include labor, monitoring and maintenance expenses derived from implementation of the project. Preliminary results are provided below in some cases, and the others are expected to be available in 1989.

Channel Cross Sections

The effects of improvement measures on channel configuration, streambed elevation and sediment entrapment are being evaluated with cross sections of the channel. Permanent transects have been established every 16 meters along the creek in the study area and in control sites. The data will be used to evaluate the effectiveness of these measures in accelerating stream recovery.

Revegetation Success

Survival rates of planted liners and stakes were identified after the first growing season for both fall and spring plantings. These values were used to compare which species, season of planting and form of plant responded best to conditions in the demonstration area. This information was then correlated with the proximity of each planting area to either stream or water table moisture zone (Lindquist and Filmer 1988).

Preliminary results indicate that willow stakes can be planted in either fall or spring with similar rates of success, whereas liners respond best to spring planting. The location of plantings in relation to available soil moisture seems to be a major factor determining first year survival (Lindquist and Filmer 1988).

Water Table Recharge

The effect of improvement measures on the shallow water table is being monitored with 24 piezometers (wells). They are located on transects crossing the demonstration area and in downstream control areas, and extend from the streambank to points 160 meters into the floodplain (Patzkowski 1987). Piezometer data will be used to create monthly groundwater contour maps, and to determine the influence of the project on the shallow water table near the stream and in the adjacent floodplain (Gilbert and Sagraves 1987). These data will be correlated over time with changes in floodplain vegetation composition and cover.

Preliminary data indicate that a difference in groundwater gradient and direction of flow is evident between control and test wells. Control areas exhibit a relatively sharp gradient with flow directed toward the stream course, indicating the meadow is draining. In the vicinity of the ponds, however, the groundwater gradient has been significantly reduced and flow tends to mound around the check dam ponds at certain times of the year (Gilbert and Sagraves 1987). Therefore, depressions and low areas far from the channel have experienced a dramatic increase in forage production due to the increase in water table elevation.

Floodplain Vegetation Response

Permanent vegetation transects have been established in conjunction with piezometers to collect species composition and cover data. This information will be used to establish trends in the response of vegetation to shallow water table levels over time. A database is being developed to correlate these two effects. Increased vegetation cover and diversity benefits wildlife and livestock, and protects soils and streambanks from erosional processes.

Fisheries Response

The response of fisheries to improvement measures is being monitored by electroshocking techniques (Longanecker 1988). Sampling stations within the study area and a control location 3 kilometers downstream have been identified. Pre-project data identified very few fish in either the control or the demonstration area. Post-project data collected in 1986 indicate a dramatic increase in fish within the study area, while numbers remain low in the control. Data from 1987 seem to confound the analysis since fish numbers in both sites are similar. This is in response to accelerated fishing pressure in the ponds within the study area, and the building of dams by beaver in the control site downstream, which simulates the study treatments.

Photo-Monitoring

Permanent photo-monitoring stations have been established along the channel in the demonstration area. They will be used to pictorially document the effect of the project on changes in channel alignment and establishment of riparian vegetation.

Conclusions

Planning

Restoration of riparian zones using a watershed-wide approach requires coordination of groups most likely to benefit and a pooling of resources to be successful. Prohibitively high expenses associated with large scale projects, and the legal complexities when many land owners are involved, make coordinated planning the most realistic approach. Planning processes such as CRMP are valuable in organizing and facilitating such projects, and can also create additional funding opportunities.

Restoration projects should not be attempted until enough background and inventory information is collected. Obtaining a "big picture" perspective during the planning process that includes pertinent physical, biological, and historical information will greatly increase the chances for project success. Monetary losses and potential environmental consequences of project failure are also avoided.

Demonstration Project

Though only preliminary results are available, much improvement can already be visually detected. Reduced water velocity has resulted in sediment deposition behind the check dams and along the banks, which has encouraged the reestablishment of riparian vegetation. The raised water table has increased forage production in the floodplain, and water backed up by the dams has enhanced fish and waterfowl habitat. Control of livestock grazing within the riparian pasture has stimulated production and vigor of poor condition perennial grasses and forbs. Monitoring data collected will be used to validate these observations, and to develop a cost and benefit evaluation of the project.

A vast array of techniques are available for restoring degraded riparian zones. Taking the time to develop a sound, realistic plan, and to select appropriate methods will minimize project costs and provide the best opportunity for success. Engineered structures are appropriate in certain situations but they are expensive and should be replaced by or used in conjunction with nonstructural methods when possible. In some instances, merely changing current land management practices can provide desirable results without any additional measures (Elmore and Beschta 1987). The ability of vegetation to stabilize a degraded site should not be overlooked or underestimated in restoration planning.

Finally, all improvement measures will require maintenance whether they are sophisticated structures or simply fencing and planting. This is especially important the first few years after implementation. To ensure project longevity, anticipated maintenance requirements should be included in the planning process when tasks are delegated to participating groups.

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REVEGETATION OF RIPARIAN TREES AND SHRUBS ON ALLUVIAL SOILS ALONG THE UPPER SACRAMENTO RIVER, 1987-1988[1]

Steven P. Chainey, F. Jordan Lang, and Skip Mills[2]

Abstract : Two sites on the Sacramento River near Red Bluff and Colusa, California were planted with seven native tree species plus valley elderberry (a shrub) in an effort to mitigate for the loss of woody riparian vegetation from bank protection construction projects in the area. The state-owned environmental easements on terraces on the river side of the levees had been planted unsuccessfully once before, following failure of native species to regenerate naturally. The new (1987-88) effort includes experimental plantings that are considered to represent state-of- the-art techniques. These are designed to protect the plants and promote survival and growth but require minimal maintenance activity. Fifteen different types of container stock as well as live cuttings of some species have been planted in a variety of situations, including deep- augered, backfilled holes. All plants were fertilized and protected from herbivory and insect damage. The 3-year monitoring program is yielding data on survival/mortality, growth rate, and plant vigor.

Native riparian tree and shrub species were planted in the winter of 1987-1988 at two sites along the banks of the upper Sacramento River near Red Bluff and Colusa, California. The purpose of these plantings was to mitigate for the loss of woody riparian vegetation caused by construction of riprap bank protection at the sites in 1982 and 1984. The revegetated areas are on state-owned "environmental easements" on high floodplains adjacent to the riprap. The U.S. Army Corps of Engineers (COE) Sacramento District sponsored the artificial revegetation project because natural revegetation had not occurred at either site and a previous attempt in 1985 to replant the Red Bluff site had suffered 100 percent mortality.

A second objective of this project is to perform a practical field test of planting techniques for riparian revegetation. Test results will be determined over a 3-year monitoring period through the winter of 1990-1991. Experimental treatments include various sizes, ages and container types of the planting stock used; augered planting holes to two different depths; and soil amendments. Monitoring will also attempt to detect the effects of different soil textures, measured depth to the water table during the growing season, plant species adaptability to various microsite characteristics, and the effects of herbivory or insects on plant vigor and survival.

The eight native riparian species planted are boxelder (*Acer negundo*), buckeye (*Aesculus californica*), white alder (*Alnus rhombifolia*), valley elderberry (*Sambucus mexicana*), oregon ash (*Fraxinus latifolia*), sycamore (*Plalanus racemosa),* Fremont cottonwood (*Populus fremontii)* and valley oak (*Quercus lobata*).

Soils at the Colusa site are primarily alluvial fine sandy barns with a low to moderate amount of organic matter. The site previously supported a dense riparian forest and is adjacent to a remnant stand of mature riparian trees and understory.

Conditions at the Red Bluff site are less favorable for plant establishment. The planting areas were recently graded to alluvial subsoil during reconstruction of adjacent private levees. Half the site's soils are coarse sandy loams, with the remainder in cobbly or gravelly exposed subsoil.

Planting Methods

Planting Hole Preparation

Planting holes were augered to two different depths. The purpose of the deeper holes was to penetrate through impermeable layers of subsoil and to eliminate stratification of alluvial deposits that may hinder deep root penetration to the water table.

Twenty percent of the planting holes, randomly assigned, were augered 3 meters (10 feet) deep. To overcome the torque resistance of the cobbly subsoil, a six-wheel-drive well-drilling rig with a 33-cm- (13-inch-) diameter bit was necessary. The average cost per 3-meter- (10-foot-) deep hole was $15, including equipment transport, set-up, and two operators.

The remaining 800 planting holes were augered 0.6-meter- (2-feet-) deep using a tractor-mounted 26-cm- (10-inch-) diameter bit. With good vehicle access, the average cost per 0.6-meter- (2-foot-) deep hole was

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approximately $2 including transport, handling, and one driver/operator.

Before backfilling, all angered holes were flooded with water pumped from the river and allowed to percolate for 24 to 48 hours. This preirrigation of planting holes was essential because of two consecutive winters of low rainfall. Even the 3-meter- (10-foot-) deep holes, including holes near the river banks, had bone-dry soil at the bottom. The normal summer water level in the Sacramento River averages about 3.0-4.5 meters (10-15 feet) below the planted terrace at Red Bluff and 8.5 meters (25 feet) at Colusa. Low rainfall prevented a sustained rise of the river stage adequate to saturate the soil below the planted terraces.

The 3-meter- (10-foot-) deep holes were initially backfilled and tamped to a depth of 0.6 meter (2 feet). All holes, both the backfilled 3-meter- (10-foot-) deep holes and the 0.6-meter- (2-foot-) deep holes, then received a 24-month slow-release fertilizer tablet (17-7-12) at the 45- to 60-cm (18- to 24-inch) depth. Most holes were then backfilled with a mix of soil augered from the holes and Columbia-series topsoil imported from orchards adjacent to the planting sites. Some holes at the Colusa site received no soil amendment for comparison of results.

To encourage horizontal root expansion, planting-hole soil should be similar in texture and composition to the existing soil surrounding the planting hole (Harris 1983). River terrace soils at both sites were typically droughty sandy loams or cobbly loams with an undeveloped soil profile. Therefore the imported topsoil amendment was considered essential to improve the fertility and, more importantly, the water-holding capacity of the soil immediately under the plantings.

After the holes were backfilled, low berms were mounded to create approximately 1-meter- (3-foot-) diameter watering basins around the holes. All planting holes were preirrigated a second time to fully soak the backfill material.

Selection of Plant Species

The eight tree and shrub species planted were stipulated in the COE revegetation contract based on COE surveys of average species composition at similar sites with undisturbed riparian forest. All are native Sacramento Valley riparian species.

In general, plants were randomly assigned to locations within the planting areas, regardless of species or microsite characteristics. Exceptions to this rule were made for extremes of microsite that seemed particularly inappropriate for certain species. For example, alder and ash were only planted close to the river bank. On very shallow cobbly soils only elderberry or buckeye, particularly drought-tolerant species, were planted. Shady sites adjacent to tall forest stands were planted with mostly alders, boxelder, buckeye, and oak.

Planting Stock Acquisition

The short lead time for the contract precluded custom growing of specialized revegetation plant materials. Based on availability, nursery reputation, and quality and age of nursery stock, planting stock was acquired in various container types and sizes: tree bands; 0.5-, 1-, and 5-gallon cans; leach tubes; styrofoam cups; and bare-root stock. An attempt was made to include two or more types of container stock for each species to compare results.

Plant Protection Kits

Figure 1 illustrates the plant protection kits installed around all plants except 5-gallon elderberries. The screen mesh prevents damage from deer, rabbits, rodents, and leaf-chewing insects. The screen also shades the young plant and accumulates moisture at night from dew or fog.

The plastic collar anchors the screen and serves as a barrier to horizontal extension of weed roots. It also discourages gopher damage and promotes deep vertical rooting by the seedling. The plastic will disintegrate before stem girdling an occur, but the anchor wire around the collar must be removed in 2-3 years to prevent girdling, depending on species growth rate.

The 0.9-meter- (3-foot-) square weed cloth is an effective alternative to frequent hand weeding and also conserves soil moisture. The woven plastic fabric is permeable to rainwater but prevents virtually all weed seed germination. Plastic barriers less than 0.9 meter (3 feet) in diameter are not effective because weeds next to the barrier can easily root laterally under the barrier and into the planting hole. To prevent barrier loss in the wind, the corners must be anchored with long metal staples or large rocks.

Winter Planting

All plants were installed during the period from December 1987 to February 1988. Except for severe rain storms, planting proceeded regardless of weather. Planting crews included local residents and experienced revegetation personnel. To streamline the planting process, all holes were marked ahead of time with color-coded surveyors flags for each species and each container type to be used. Upon completion of planting, a detailed planting layout was prepared, indicating species, plant size and type, container types, soil texture, hole depth, and location for every plant.

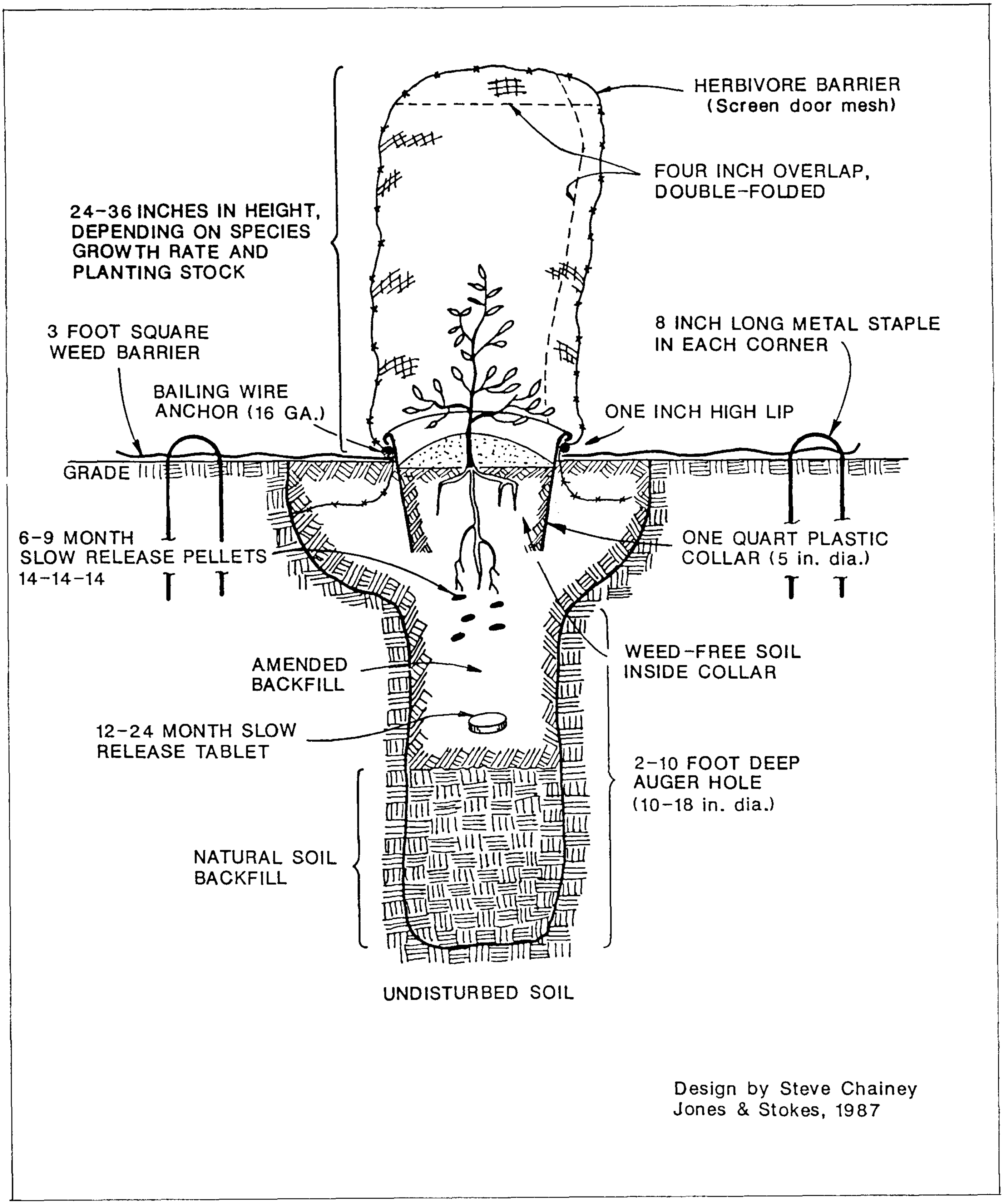

Figure 1—Conceptual sketch of plant protection kit (Section view not to scale).

Irrigation, Maintenance, and Monitoring

Performance Standards

The revegetation contract requires a 3-year maintenance and monitoring period. Contract performance standards require 90 percent survival at the end of the first year (i.e., by February 1989) and 75 percent survival at the end of the second year (i.e., by February 1990). Methods of irrigation and maintenance are at the contractor's discretion. To ensure satisfaction of the survival standards, 10 percent more plants were planted than were actually required in the contract.

Irrigation and Maintenance

Both the Red Bluff and Colusa sites are subjected to trespass for river-related recreational use. Because of the high risk of tampering and vandalism, repeat spot watering is used rather than installation of a surface-drip or overhead irrigation system.

Irrigation water is applied every 7-10 days in the driest months using a 757-liter (200-gallon) tractor-mounted tank with hand-held spray wand. Depending on plant size and soil water-holding capacity, 4-11 liters (1-3 gallons) are applied at each watering event. Irrigation began in mid-April 1988 and will continue through October. In August 1988, irrigation water was supplemented with a liquid nitrogen fertilizer.

As the plants grow vertically, the screen mesh is opened at the top. The mesh tube continues to shade the lower stem and prevent rodent girdling of stem tissue. Weeds inside the plastic collar are removed by hand. Maintenance visits occur every 2 weeks.

Monitoring

Starting height and vigor of the plants installed were recorded in February 1988. Beginning May 1, all plants were monitored every 2 weeks by the same observer at both sites. Periodic observations of each plant included the following parameters:

Parameter	Condition or Unit
Vigor	Excellent, good, fair, poor, dead
Height	Cm (inch)
Width (i.e., diameter of canopy)	Cm (inch)

Vigor is an overall qualitative observation based on leaf turgor, stem caliper, leaf color, foliage density, and leaf size. Vigor is rated relatively within a given species group.

Depth to water table was measured periodically in four 3-meter-(10-foot-) deep pipe wells at each of the two sites. The pipe is a 10-cm- (4-inch-) diameter perforated drain pipe. A dipstick measures the standing water table at various times of the year. Maximum high water table in winter also indicates the depth to the moist soil zone in the spring (in the absence of competing vegetation). This past winter of 1987-88, the river water level never was high enough to raise the water table within 3 meters (10 feet) of the soil surface at either planting site. This condition is highly atypical and stressful to native phreatophytes.

Other incidental observations of plants include herbivory damage, insect infestation, drought stress, frost burn, poor planting stock, summer drought dormancy (buckeye and elderberry), winter dormancy, and vandalism.

First Year Results

Results are reported here from monitoring through July 1988 (Table 1). Monitoring will continue into the fall until plants are fully senescent.

Colusa Results

Overall plant survival at the Colusa site was 91 percent by July 1988. Nearly half the deaths were sycamore tubelings, many of which were severely damaged by unusual late frosts in early spring. This is the only species noticeably damaged by frost burn. The protective screens appear to have served as frost barriers for most species. Surviving sycamore plants experienced significant net growth in height (average = 25 cm, maximum = 90 cm) and good vigor.

First-year growth patterns were distinctly different among the species. Alder, boxelder, buckeye and elderberry experienced over half their total height growth before mid-May, when ash was just breaking bud. Cottonwood, oak, and sycamore showed steady growth in June and July and continued canopy growth into early September. Rooted oak acorns developed shoots with buds in April and first leaves in May.

Buckeye and elderberry seedlings went into early drought dormancy in July, a pattern similar to other plants of these species in the wild growing nearby. Elderberry developed new shoots and leaves as early as February, when all other species were still winter dormant.

Table 1-Propagule survival in flood and overhead sprinkler irrigated areas.*

	Number Planted		Growth (cm) by May 19		Growth (cm) May to July 19		Height (cm) On July 19		Vigor* July 19		First Year Mortality		Percent Mortality	
Species/Container	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff	Colusa	Red Bluff
Alder/Tree bands	24	14	30.0	6.9	17.5	1.8	78.2	44.5	2.6	0.4	2	11	8	79
Ash/Bare root	35	36	7.4	4.3	14.2	1.8	38.4	25.4	3.0	1.3	3	16	9	44
Boxelder/1 gallon	53	31	32.0	30.7	14.2	6.6	87.4	73.4	2.9	1.9	4	4	7	13
Buckeye/Tree bands	26	22	14.2	3.8	2.8	3.8	30.0	29.2	2.0	1.3	3	9	12	41
Cottonwood/Tree bands	48	70	42.4	21.1	32.3	13.5	87.4	48.0	3.0	1.2	5	36	10	51
Cottonwood/1 gallon	38	—	33.8	0.0	41.1	0.0	115.6	0.0	3.3	—	1	—	3	—
Cottonwood/Tubes	—	15	0.0	18.0	0.0	7.1	0.0	35.3	—	0.7	—	9	—	1
Elderberry/5 gallon	121	85	50.3	47.0	10.4	9.1	113.8	112.8	1.9	1.3	0	15	0	18
Elderberry/1 gallon	43	23	70.6	49.3	11.9	8.6	90.7	70.1	2.3	0.9	0	13	0	56
Elderberry/Tubes	53	29	66.3	39.4	19.8	4.3	89.4	53.8	2.3	0.8	0	12	0	41
Valley oak/Tree bands	—	11	—	12.2	0.0	3.6	0.0	47.0	—	2.1	—	2	—	18
Valley oak/1/2 gallon	23	24	9.1	5.3	7.4	2.0	19.6	17.3	3.0	2.7	2	0	9	0
Valley oak/Bare root	52	28	10.9	13.5	7.6	10.9	25.7	30.7	3.1	3.5	11	0	21	0
Sycamore/Tubes	37	26	8.6	4.6	20.1	3.0	40.4	17.8	2.5	0	14	26	38	100
Sycamore/Cups	30	33	12.7	4.6	12.2	1.5	42.4	21.6	2.5	0	7	26	23	85
Totals	583	447									52	179	9	40

*Vigor: 4= excellent, 3=good, 2=fair, 0 dead.

The most unexpected growth responses were for boxelder, elderberry tubelings, and oaks from rooted acorns. By May 19, boxelder growth rivaled that of cottonwood. Height growth by elderberry tubelings equaled or exceeded that by 5-gallon elderberry plants. Elderberry tubelings were about 2 years younger than the 5-gallon plants. Some plants from tubelings had nearly as much total canopy volume as the 5-gallon elderberry by July 1988.

Although average height of sprouted acorns in July was less than 22 cm (9 inches), numerous individuals were 46-75 cm (18-30 inches) in height by July 19, with excellent vigor. Current-year oak acorns with taproots planted in February were considerably larger and more vigorous than oaks in 0.5-gallon containers from last year's acorn crop.

The most serious herbivory at the Colusa site is from gophers (often fatal) and deer (rarely fatal). The screens effectively prevented rabbit and rodent girdling of young stems as well as caterpillar and grasshopper defoliation.

Red Bluff Results

A heat wave in June 1988 was a severe problem at the Red Bluff site. On one day the temperature reached 118oF with 20-mph winds. On that day, nearby crops and orchard trees were losing turgor even as they were being irrigated. By July 1988, seedling mortality on this site approached 40 percent. Drought stress was the overwhelming cause of death for all species of newly planted seedlings. Browse and vandalism were minimal. No gophers are present in the cobbly soils.

Mortality varied greatly by species. Only two of 63 oaks (all taprooted acorn stock) have died and oak vigor remains in the good range. Also, 90 percent of the boxelders and 80 percent of the elderberry have survived. Many plants appearing to have died by July are resprouting in September. On the other end of the spectrum, nearly all of the alders and sycamores died in the heat wave. Half the ash, buckeye, and cottonwood also died.

Growth responses of boxelder, elderberry, and valley oak were good at Red Bluff and similar to the pattern at Colusa. For the surviving plants at Red Bluff, height growth was typically 25-50 percent of the average values at Colusa.

To satisfy the contract performance standards, approximately 150-200 new plants will be installed during winter 1988-89 to compensate for first-year losses. Overall stand vigor and turgor at the Red Bluff site has improved in August since plants were irrigated with a fertilizer supplement.

Discussion

For elderberry, the similar growth performance by 5-gallon seedlings and small tubelings is an important finding. Considerably less time and expense is required to handle and plant small tubelings, compared to 5-gallon containers.

Similarly for valley oaks, rooted acorns can be handled more cost effectively (and contract-grown on shorter order) than larger oak seedings in 0.5- or 1-gallon containers. Bare root sprouted acorns also have an undisturbed tap root 15- to 30-cm (6- to 12-inches) long at the time of planting in early February. The superior root:shoot ratio of taprooted acorns is a major advantage in drought avoidance and therefore survival.

Frost damage to sycamore seedlings can be avoided in the future by purchasing cold-hardened stock from nurseries in colder climate zones. Buckeye direct seeded in the field may have better growth and survival than using nursery-grown stock in containers because of the exceptional taproot growth of this species. This species, like oaks, becomes pot-bound well before significant shoot elongation has occurred. Direct-seeded buckeye has shown a high rate of germination and survival in several previous revegetation efforts (Chan 1985).

The quality of nursery planting stock is a good predictor of first-year survival and growth. A preponderance of mortalities and plants of low vigor observed in May and July had been previously recorded as inferior plants at the start in February. The quality and source of planting stock should be the last area of budget trimming for revegetation contracts.

The mesh screens and the weed barriers used were highly effective at preventing herbivory and reducing weed competition. The protection kits have withstood extremely high winds and gopher burrowing activity. It appears that the screens also protected young plants from frost burn last spring. Using weed barriers also cut maintenance costs measurably and enhanced plant vigor and survival by reducing competition with weeds.

Spot watering at the Colusa site has been cost effective and adequate for plant growth and survival (based on a 7- to 10-day repeat cycle). At the more droughty Red Bluff site, more frequent watering events or a drip irrigation system may have averted the high mortalities during the heat wave. Another consideration to overcome low soil water-holding-capacity is to use deep pole-planted stock for species known to root adventitiously (cottonwood, willow). One- or 2-year-old bare root stock may also be effective for some species (alder, sycamore) by providing a higher root:shoot ratio.

Species should be thoughtfully matched to microsites for which they are known to be adapted and not planted in arbitrary mixes in random locations. Adequate lead time (9 months minimum prior to planting time in early winter or early spring for bare root and cuttings) should be provided in revegetation contracts to collect seed or cuttings to grow high quality nursery stock. Custom wholesale nurseries specializing in revegetation container stock (tree bands, tubes, and bare root with a high root:shoot ratio) will match age and container type to the revegetation techniques required for each site.

Acknowledgements

This revegetation project is supported by the U. S. Army Corps of Engineers (Sacramento District), Contract No. DACW05-88-C-0015.

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COYOTE CREEK (SANTA CLARA COUNTY) PILOT REVEGETATION PROJECT[1]

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Abstract: The Santa Clara Valley Water District, located in Northern California, is currently evaluating a pilot riparian revegetation project on a 1.6 ha (4 ac) site adjacent to Coyote Creek in the south San Francisco Bay Area. Specific techniques used during the design, site preparation and installation of 3640 plants (including seed planting locations) are described. This paper reports on the analysis of 1 year's data, comparing the survival of various types of plant materials for each of the 15 native plant species installed. Plant survival is evaluated for portions of the site irrigated by overhead sprinklers versus flood irrigation. Weed control techniques and plant protection measures are also discussed.

The Santa Clara Valley Water District and the U.S. Army Corps of Engineers are in the process of designing and constructing flood control facilities on the lower portion of Coyote Creek. This project will involve the construction of earthen high flow bypass channels and earthen levees along a 9.6 km (6.0 mi) stretch of the creek. Mitigation measures proposed to compensate for the removal of approximately 15 percent of the existing riparian trees in the project area include the creation of 13.0 ha (32.5 ac) of new riparian habitat on the flood plain within the project levees.

Goals and Objectives

The Coyote Creek Pilot Revegetation Project has been designed to accomplish the dual goals of 1) creating 1.6 ha (4 ac) of flood plain riparian forest habitat as partial mitigation for flood control project impacts, and 2) serving as a test site for determining the most effective, efficient and economical means of re-establishing riparian vegetation on the additional 11.4 ha (28.5 ac) of required mitigation habitat.

Fifteen species of native riparian trees and shrubs were installed on the site in the winter of 1986-87 and are being monitored yearly in order to 1) determine the most successful or other suitable alternative types of plant material (propagules) for each species; 2) determine the most cost-effective means of establishing each plant species; 3) test the relative success in achieving plant establishment through various irrigation options; 4) identify the best management practices for controlling the growth of weeds; and 5) test rabbit and rodent control measures.

Project Location and Site Conditions

The pilot revegetation project is located on fallow agricultural land in north San Jose (due west of the City of Milpitas and east of Alviso). It is north of Highway 237 and south of Dixon Landing Road (see figure 1). The revegetation site is adjacent to the existing cottonwood-dominated riparian forest bordering the banks of lower Coyote Creek. Upon completion of the flood control project this revegetation site will lie within the flood control levees and will be bounded by the creek to the east and a high flow bypass channel to the west (see figure 2).

The climate of the Santa Clara Valley at the south end of the San Francisco Bay is a Mediterranean type with wet winters and dry summers. The project area is typical of the valley floor climatologically with 35.6 cm (14 in) average annual rainfall. During the 1987-88 year 25.3 cm (10 in) of precipitation was recorded at the site.

The ground water level at the revegetation site has been monitored by the Coyote Creek Riparian Station (CCRS) since January 1987. Water levels are being recorded semimonthly by 15 piezometers. The lowest ground water reading was a depth of 2.67 m (105 in) on March 30, 1988 and April 15, 1988. The highest level recorded was a depth of 1.35 m (53 in) on May 8, 1987.

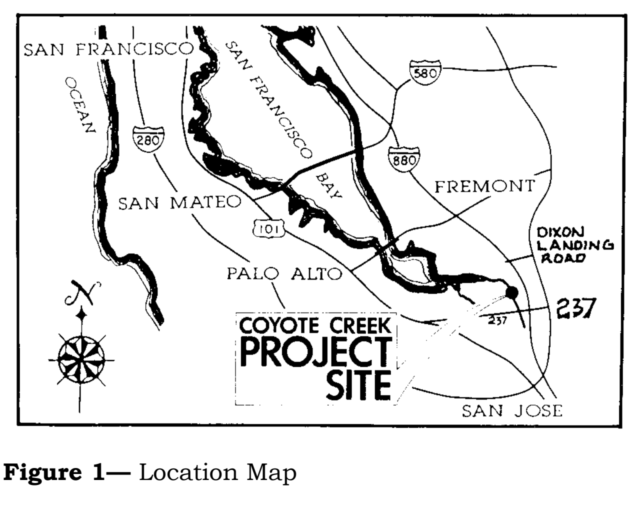

Figure 1— Location Map

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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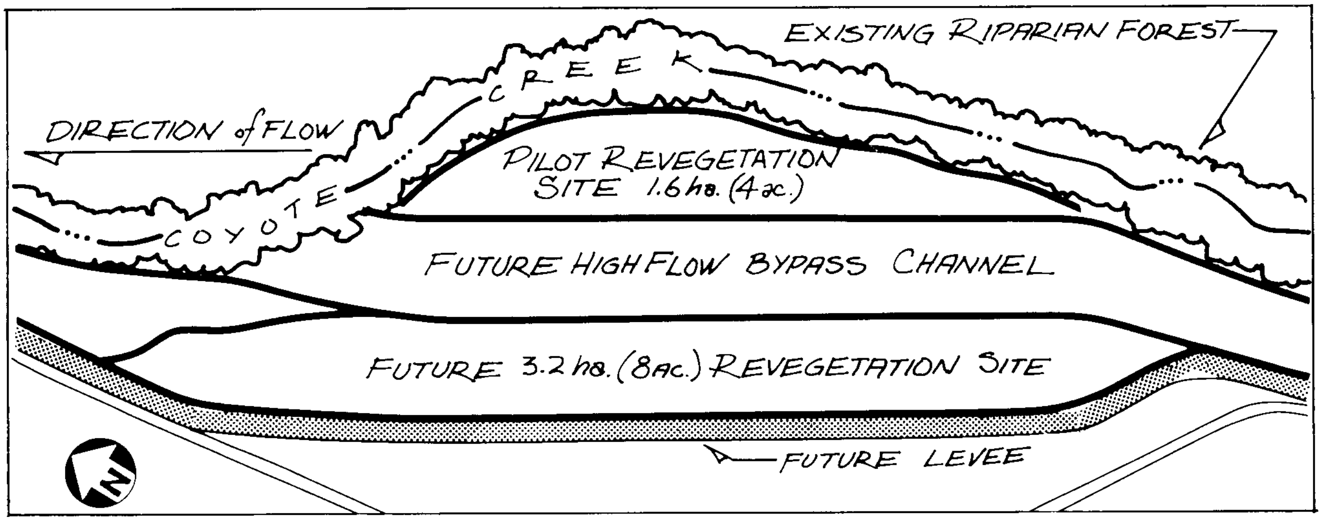

Figure 2– Site Plan

During the months of May, June and July the ground water level is at its highest. This is due to the ponding of water (for agricultural purposes) in the lower portion of Coyote Creek adjacent to the revegetation site. A flashboard dam, located a short distance downstream of the revegetation site, is usually installed in April and removed in November of each year.

The soil at the site is a fertile sandy loam with variable amounts of sand and silt. It is well drained and has an occasional clay lens at about 1.2 m (47.2 in).

Methods

The following tabulation presents the propagules that are being tested for each plant species:

Scientific Name	Common Name	Propagule
Acer negundo spp. *californicum*	California box elder	c,s,g
Alnus rhombifolia	White alder	g,t,l
Fraxinus latifolia	Oregon ash	b,g
Juglans hindsii	California black walnut	s,g
Platanus racemosa	Western sycamore	g
Populus fremontii	Fremont cottonwood	pc,c,l
Quercus agrifolia	Coast live oak	s,g
Quercus lobata	Valley oak	s,g,p
Salix laevigata	Red willow	c,l,g
Salix lasiandra	Yellow willow	c,l,g
Sambucus mexicana	Blue elderberry	l,c,s
Umbellularia californica	California bay	s,g
Artemisia douglasiana	Mugwort	l
Rosa californica	California rose	l,s
Rubus vitifolius	California blackberry	i

Key: b=bare root, c=cutting, g=1-gallon container, l=leach tube, p=4" pot, pc=pole cutting, s=seed, t=transplant

For each plant species one type of plant material was selected as the preferred propagule (listed first). The preferred propagule was the one considered to be highly likely to succeed and at the same time the most economical to install and maintain. Preference was given to planting more of the preferred propagules than the alternates.

Planting Design and Layout

The revegetation site was divided into two major areas for the purpose of testing flood versus overhead sprinkler irrigation. It was intended that, to the extent possible, the northern area (Area A), and the southern area (Area B), would be similar in design. The use of symetrical and evenly spaced "test plots" was purposely avoided in order to achieve the desired result of a naturally appearing riparian community.

The site was divided into two planting zones; Zone 1 extending westward from Coyote Creek for a distance of 45.5 m (150 ft). and Zone 2 covering the remainder of the site west of Zone 1. This zonation was an attempt to incorporate the plant species' differences in moisture requirements into the design. Zone 1 plant species are typical of a mid-level flood plain terrace while the Zone 2 plant list represents the plant assemblage which might be expected on an upper-level flood plain terrace. Most of the plant species planted in Zone 1 currently occur along lower Coyote Creek. Selection of the Zone 2 list was based upon analysis of the floristic composition along other streams in the region.

Design considerations included planting those tree species which naturally occur together in associations to produce groves. Certain other tree species were either planted only as individuals (e.g. coast live oak), or in single species groves (cottonwood, willow, alder and walnut) which is their more common pattern of occurrence. The shrub and groundcover species were planted either within, adjacent to, or connecting the groves of trees.

The groves composed of one tree species were planted only in Zone 1. Groves consisting of more than one tree species varied in their composition depending upon the planting zone. The following are the plant associations and the percent composition of each of the trees and shrubs planted in mixed species groves.

Plant spacing and planting density varied according to the species. Generally, plants were installed on 1.8-2.4 m (6-8 ft) centers. This close spacing will compensate for dieback and was also employed to provide enough of each propagule.

Site Preparation

The revegetation site was an abandoned orchard covered with tall, dense weeds. It was cleared in the fall shortly before planting. A track-laying tractor with a blade, a grader, and a backhoe with a box scraper (provided by the San Jose Department of Water Pollutions Control) were used to clear the weeds. A ridger behind a tractor was used to create the levees for the flood irrigation cells.

A wire mesh fence, 91 cm (3 ft) above and 76 cm (2.5 ft) below ground, was installed along the western boundary of the project site to restrict rabbit, rodent and human access. Invasive non-native plant species, including giant reed (*Arundo donax*) and tree tobacco (*Nicotiana glauca*), were removed followed by application of glyphosate (Roundup) where Sprouting occurred. Gophers and rabbits were trapped and removed from the site prior to plant installation.

Plant Association	Zone 1 (1st 45.5 m)	Zone 2 (>45.5 m)
Sycamore Assoc.	60 pct. Sycamore 5 pct. Ash 10 pct. Elderberry 20 pct. Box elder 5 pct. Bay	70 pct. Sycamore 20 pct. Elderberry 10 pct. Bay
Box elder Assoc.	50 pct. Box elder 20 pct. Elderberry 15 pct. Ash 15 pct. Bay	60 pct. Box elder 30 pct. Elderberry 10 pct. Bay
Valley oak Assoc.		70 pct. Valley oak 10 pct. Black walnut 5 pct. Ash 10 pct. Elderberry 5 pct. Willow

Plant Installation

Three-meter (10-ft) long pole cuttings were taken from nearby Fremont cottonwoods. Poles were no larger than 4.4 cm (1 3/4 in) in diameter with the branches and succulent tops pruned off. The poles were inserted into augered 1.8 m (6 ft) deep, 20 cm (8 in) diameter, holes which were then back-filled with "tamped-in" native soil.

Cuttings (approximately 1.2 m long) of cottonwood, box elder and willow were also obtained nearby. The slant-cut ends were dipped in rooting hormone just prior to installation. Transplants of white alder were taken from the gravel bar of a nearby creek, transported to the site and planted in native soil.

Leach tube super cells (3.8 cm [1-1/2 in] by 20 cm [8 in] plastic tubes) sometimes referred to as tubelings or liners, 1 gallon size container stock and 4-inch pots were installed directly into the native soil.

Most of the plants and cuttings, with the exception of the large pole cuttings, were individually protected with plastic photo-degradable forest tree protectors 12 cm (5 in) in diameter and 61 cm (24 in) tall to prevent browsing and girdling by rabbits or rodents. Additionally, each planting hole received a slow release fertilizer tablet.

Seeds of box elder, live oak, valley oak, walnut, bay and rose were direct seeded into protective collars (1 quart size cottage cheese containers with the bottoms removed) with 46 cm (18 in) tall aluminum insect screen cylinders attached (Chan and others 1977). A sterile soil medium was used in the top 8 cm (3 in) of the collars to reduce weed germination. Black walnut, coast live oak, valley oak and bay were planted with 3 seeds per planting location. Approximately 10 of the smaller seeds were planted within each collar.

Irrigation

Water is pumped from Coyote Creek with a gasoline pump into a 10 cm (4 in) mainline. Four manifold valves which serve 7.6 cm (3 in) aluminum irrigation pipe branch off the mainline for the sprinkler section, and are removed to feed the flood section cells. There are also two non-irrigated control areas. Irrigation during the first year was on a 1 to 2 week schedule during the spring and early summer, or as needed, and tapered off to every 3 to 4 weeks in the fall.

Weed Control

A variety of weed control measures and types of equipment are being tested for effectiveness and cost. Both fabric and bark mulch were used around some of the plantings. A combination of mowing, tilling, and hoeing has been used to control weed growth between the plantings. Roundup was also used in certain areas.

Results and Discussion

One year of maintenance, and analysis of monitoring data collected in the fall of 1987, have allowed us to make some preliminary observations about certain aspects of the project. The present analysis evaluates 1318 propagules irrigated by flooding and 2107 propagules irrigated by overhead sprinklers and excludes 215 propagules installed outside of these areas.

First Year Survival

Permanent grid lines running east-west across the revegetation site were established at 12 m (40 ft) intervals. This made it possible to relocate each plant without employing a rigid structure for the layout of the planting trials. During the first three years after installation, each plant will be inspected and evaluated in mid-fall as to survival, height, spread, vigor and type of any damage.

A comparison of survival (after one growing season) of all plant materials in Area A (flood irrigation) versus Area B (overhead sprinkler irrigation) shows that there were generally similar levels of survival. In the flood irrigation area, 73.1 percent survived, compared to 75.8 percent survival in the sprinkler irrigation area (table 1).

Certain propagules had a higher rate of survival under one irrigation method than under the other. California black walnut seed, cuttings of blue elderberry, and seed of California bay, had much greater survival in the sprinkler irrigated area. The cuttings and leach tube plants of Fremont cottonwood, 1 gallon and cuttings of willow, and leach tubes of mugwort all were clearly more successful in the flood irrigated area. One gallon coast live oak were also more successful in the flood irrigated area; however, because of the small sample size of this propagule, this difference may not be significant.

To evaluate survival among different propagules of each species, the data were combined for both irrigation techniques. Box elder seed and 1 gallon plants had a clearly greater survival rate than cuttings. White alder transplant survival was high compared with other propagules of this species. Oregon ash had a similar rate of survival for both bare root and gallon size plants. Seeds of California black walnut had a survival rate of about 20 percent less than 1 gallon material. Pole cuttings of Fremont cottonwood had the highest level of survival of the three types of propagules tested for this species. Because of the low numbers of 1 gallon plants of coast live oak, a determination of the significance of the disparity in survival between these and direct seeded propagules is not possible. For the same reason, the 100 percent survival of 4-inch pots of valley oak may not be significant when compared with the survival rates of the seed and 1 gallon material for this species. However, 1 gallon valley oak were clearly more successful than seeds. All willow propagules had a high level of survival. Blue elderberry leach tubes were much more successful than seeds and cuttings. One gallon plants of California bay and leach tubes of California rose had much greater survival than seed of these species. Although it was recorded that there was no survival of California rose seed when the trial plantings were monitored in the fall of 1987, field personnel have since noted germination of rose seeds in several of the collars in the spring of 1988.

Depth To Groundwater

Water ponded in Coyote Creek by the agricultural dam and the subsequent rise in the ground water level during the summer is an unusual situation that could have adverse or beneficial effects on the survival and growth of the plantings at the revegetation site. Excavations of the root systems of certain tree species indicate that their roots have already reached saturated soil. If this is indicative of root development in general, the watering regime could be discontinued without significant loss of trees.

Weed Control

Abundant weed growth has resulted from the summer irrigation making weed control a formidable task. The weed problem may have been reduced by better site preparation such as discing or tilling several times during the growing season to exhaust latent seed in the soil, using pre-emergent herbicide, removing the top 30 to 40 centimeters of soil, and/or sowing a low growing herbaceous ground cover mix to out-compete the weeds.

The redwood bark mulch was somewhat effective in reducing weed growth and also made the pulling of weeds easier. However, numerous weeds grew through the mulch. The fabric mulch was ineffective as it covered too small an area and was anchored with soil which supported weed establishment. Flood irrigation deposited additional soil on top of the fabric mulch promoting the establishment of weeds whose roots then penetrated the fabric. A larger sized fabric mulch secured with wire staples would have been more effective.

A Bachtold High Weed Mower has proven to be the most effective weed control device for the site. The scythe is the next most useful weeding tool, especially for use in the flood irrigated cells where the ground is uneven and the cell ridges impede the mower.

April and May applications of Roundup resulted in initial dieback of the weeds. However, as a result of summer irrigation and a large seed bank in the soil, the weeds returned. Late summer applications of Roundup did not suppress the weeds on the site, probably due to the lateness of the application with respect to the growing cycle of the plants.

Table 1-Propagule survival in flood and overhead sprinkler irrigated areas.*

Species	Propagule	Area A (flood) Number Planted	Area A (flood) Number(Pct) Surviving		Area B (sprinkler) Number Planted	Area B (sprinkler) Number(Pct) Surviving		Total Number Planted	Total Number(Pct) Surviving	
Acer negundo	Cutting	47	16	(34.0)	81	23	(28.4)	128	39	(30.5)
	Seed	26	23	(88.5)	8	7	(87.5)	34	30	(88.2)
	1 gallon	36	29	(80.6)	45	38	(84.4)	81	67	(82.7)
Alnus rhombifolia	Leach tube	-	-		21	13	(61.9)	21	13	(61.9)
	Transplant	-	-		14	13	(92.9)	14	13	(92.9)
	1 gallon	22	16	(72.7)	58	38	(65.5)	80	54	(67.5)
Fraxinus latifolia	Bare root	25	24	(96.0)	46	40	(87.0)	71	64	(90.1)
	1 gallon	16	16	(100.0)	32	26	(81.3)	48	42	(87.5)
Juglans hindsii	Seed	39	10	(25.6)	62	36	(58.0)	101	46	(45.5)
	1 gallon	5	4	(80.0)	18	11	(61.1)	23	15	(65.2)
Platanus racemosa	1 gallon	337	324	(96.1)	429	375	(87.4)	766	699	(91.2)
Populus fremontii	Pole cutting	65	56	(86.2)	485	435	(89.7)	550	491	(89.3)
	Cutting	42	24	(57.1)	24	10	(41.7)	66	34	(51.5)
	Leach tube	6	1	(16.7)	17	0	(0)	23	1	(4.3)
Quercus agrifolia	Seed	150	57	(38.0)	12	4	(33.3)	162	61	(37.7)
	1 gallon	9	8	(88.9)	10	3	(30.0)	19	11	(57.9)
Quercus lobata	Seed	72	50	(69.4)	133	98	(73.7)	205	148	(72.2)
	4-inch pots	6	6	(100.0)	-	-		6	6	(100.0)
	1 gallon	133	123	(92.5)	202	187	(92.5)	335	310	(92.5)
Salix sp.	Cutting	49	45	(93.1)	79	54	(68.4)	128	99	(77.3)
	Leach tube	-	-		2	2	(100.0)	2	2	(100.0)
	1 gallon	31	29	(93.5)	63	41	(65.1)	94	70	(74.5)
Sambucus mexicana	Cutting	31	8	(25.8)	44	16	(36.9)	75	24	(32.0)
	Seed	29	1	(3.4)	21	0	(0)	50	1	(2.0)
	Leach tube	67	49	(73.1)	94	74	(78.7)	161	123	(76.4)
Umbellularia californica	Seed	12	0	(0)	21	5	(23.8)	33	5	(15.2)
	1 gallon	30	29	(96.7)	41	37	(90.2)	71	66	(92.9)
Artemisia douglasiana	Leach tube	13	10	(76.9)	8	3	(37.5)	21	13	(61.9)
Rubus vitifolius	Leach tube	6	0	(0)	9	2	(22.2)	15	2	(13.3)
Rosa californica	Seed	-	-		17	0	(0)	17	0	(0)
	Leach tube	14	6	(64.3)	11	7	(63.6)	25	13	(52.0)
TOTAL		1318	964	(73.1)	2107	1598	(75.8)	3425	2562	(74.8)

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* Data for seed propagules refer to the number of seeded locations.

Irrigation

The economic and horticultural feasibility of flood and overhead sprinkler irrigation are being tested because direct individual irrigation methods (drip, bubbler, truck) have been tested and quantified in previous studies. Perhaps agricultural methods will prove to be less expensive.

Filling flood cells with water was laborious due to breaks in levees, abandoned subsurface drains from the old orchard, and irregularities in topography and flood cell design. Some species in the overhead sprinkler irrigation area developed leaf mildew.

Initial growth in the flood irrigation area subjectively appeared to be more rapid than in the sprinkler section. Most of the cottonwood pole cuttings were 3.6-4.6 m (12-15 ft) tall at the end of one growing season. We will be analyzing the data on growth rates of the trees after we collect another year's data.

Ongoing Monitoring

Changes in the vegetation at the site are being monitored in conjunction with a wildlife monitoring program being conducted by Harvey & Stanley Associates and CCRS. A systematic vegetation sampling program is being employed to document semiannual changes in canopy height, canopy cover, foliage density and diversity at different heights within the canopy and herbaceous cover.

The plantings at the revegetation site will be monitored annually for 2 more years. Survival and growth data will be evaluated at the end of the 3 year monitoring program. Figures 3-9 show some examples of plant growth as of August/September of 1988.

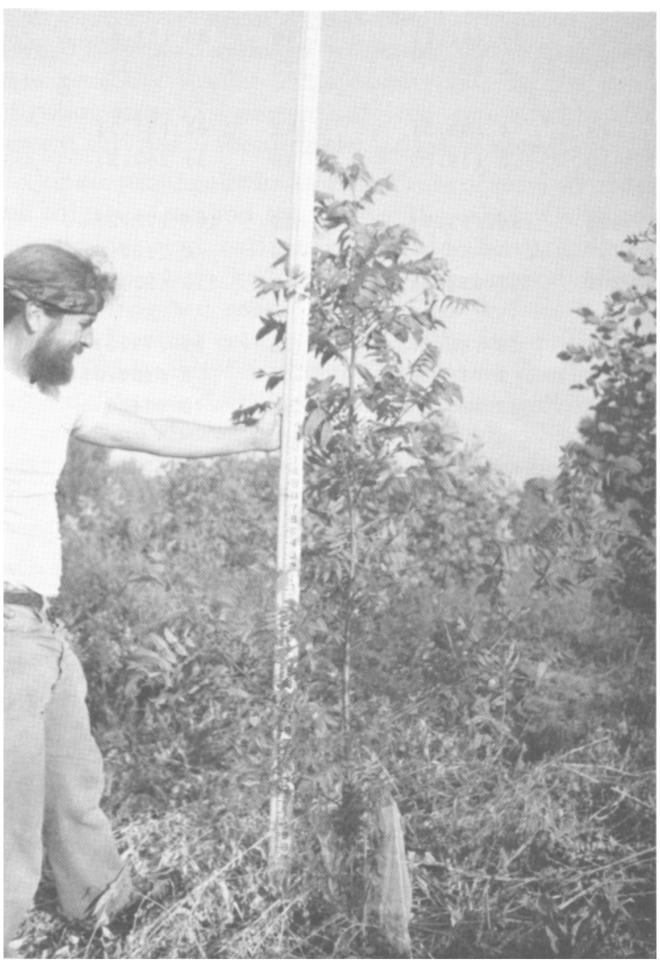

Figure 3– California Black Walnut from seed, 19 months after installation (2.0 m [6.8 ft], flood irrigation).

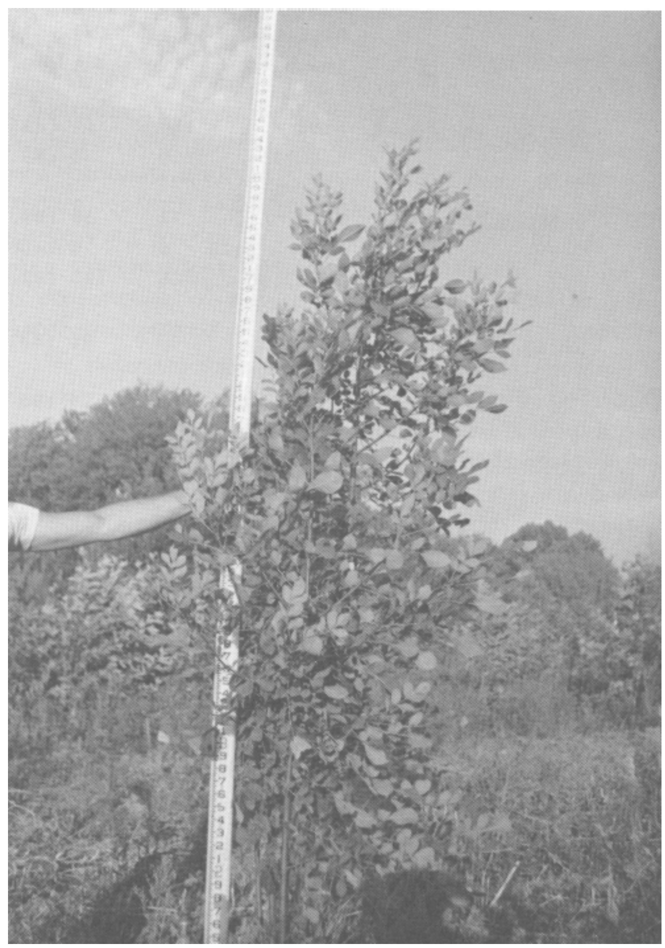

Figure 4– Flowering Ash from 1 gallon stock, 19 months after installation (2.6 m [8.5 ft], flood irrigation).

Figure 5- Western Sycamore from 1 gallon stock, 19 months after installation (3.3 m [11 ft], flood irrigation).

Figure 6- Valley Oak from 1 gallon stock, 19 months after installation (2.2 m [7.3 ft], flood irrigation).

Figure 7- Blue Elderberry from 1 gallon stock, 19 months after installation (flood irrigation, note fruit).

Figure 8- Western Sycamore and Blue Elderberry from 1 gallon stock, 19 months after installation (3.2 m [10.8 ft], overhead sprinkler irrigation).

Figure 9- Fremont Cottonwood pole cuttings, 19 months after installation (7.1 m [23.5 ft], overhead sprinkler irrigation).

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REVEGETATION ALONG COYOTE CREEK (SANTA CLARA COUNTY) AT TWO FREEWAY BRIDGES[1]

Veda L. Lewis and Keith A. Robinson[2]

In 1985, construction was completed on a new California Route 101 freeway segment San Jose and Morgan Hill, Santa Clara County. In order to mitigate the impacts to two acres of riparian habitat, on-site replacement planting was installed at two bridge sites.

Coyote Creek is one of the county's few remaining streams which supports remnant stands of mature riparian forest. It drains a watershed of over 200 square miles. Upstream, water levels are controlled by releases from Anderson Reservoir. Dominant plant species along the creek in the project area are as follows: Fremont cottonwood (*Populus fremontii*), valley willow (*Salix hindsiana*), red willow (*S. laevigata*), and coast live oak (*Quercus agrifolia*). A relatively sparse understory is dominated by California blackberry (*Rubus vitifolius*) and coyote bush (*Baccharis pilularis* ssp. *consanguinea*).

Plant materials were installed on June 31 and July 1, 1987. Planting holes were augered 18 inches wide and 3 feet deep and were backfilled with 1 cubic foot of nitrified redwood compost, 20:10:5 fertilizer tablets and native soil. Three inches of wood chip mulch were spread within the plant basins. Shrubs were planted along the middle to upper sections of the streambank. Trees, except willow, were planted along the upper slope. Specifications required hand weeding within the riparian zone, but a nonselective, postemergent contact herbicide (Diquat) was used on two occasions. Due to funding restrictions no materials were used to discourage wildlife browsing or to provide shade.

Results

Rhamnus californica showed excellent survival under a variety of planting conditions. At Site One *Gaultheria* was destroyed by wild pigs in October of 1987. The pigs uprooted the plants to get to fertilizer tablets within the backfill material. *Gaultheria shallon* in full sun did not perform well. *Populus* losses were due to scouring.

Discussion

Some of the shrub losses may be related to summer planting; however, inconsistent watering, poor soil structure, and inadequate shading may be responsible for the varied results.

Rhamnus appeared to be best suited to the various site conditions. High mortality rates of *Ribes* immediately following planting (Tables 1 and 2) may have resulted from poor quality specimens or mishandling during planting. High mortality rates between July and December of 1987 were probably due to less than optimum shading and a lack of available water within the root ball. Losses of *Gaultheria shallon* appeared due to exposure and animal damage.

Replacement plantings were done in May of 1988 in order to replace the large loss of *Ribes* which occurred in 1987. Insufficient information is available to determine the reason for the relatively poor survival of *Salix* cuttings over the first month after planting. However, dehydration during planting may have been the major factor. The few *Rubus* specimens surviving after one month were in full to partial shade.

Funding restrictions do not provide for ongoing maintenance. With the current drought conditions, this will undoubtedly be a critical period for the small plants which may not be fully established.

As of September 14, 1988 only *Gaultheria shallon* specimens planted in full shade were alive. This was due to the lack of supplemental irrigation after June 1988.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Biologist and Landscape Architect, respectively, Caltrans District 4, San Francisco, California.

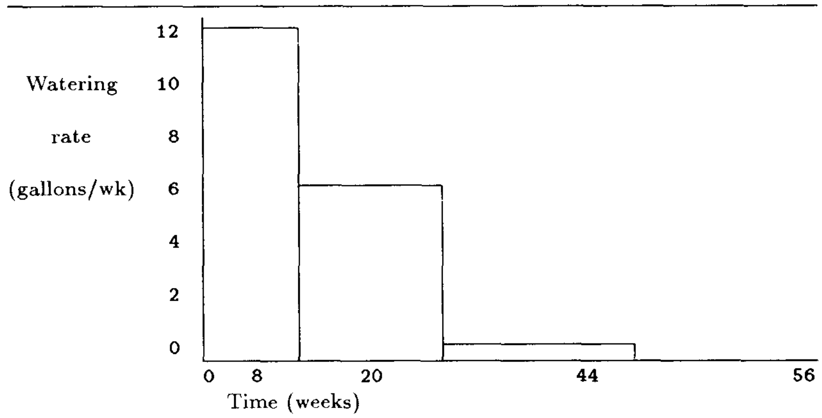

Figure 1 - Watering Schedule

Table 1 - Plant List

Species	No. of specimens Site 1	Site 2	Size Size	Total no. specimens	Density Ft. on Ctr.
Rhamnus californica	104	118	1 gal	222	10
Ribes sanguineum	520	301	1 gal	821	5
Gaultheria shallon	221	183	1 gal	404	6
Heteromeles arbutifolia	89	55	1 gal	144	12
Quercus agrifolia	42	12	5 gal	54	20
Populus fremontii	50	21	1 gal	71	—
Platanus racemosa	12	5	5 gal	17	—
Aesculus californica	5	5	5 gal	10	—
Salix hindsiana[1]	—	—	—	—	2V
Rebus vitifolius[1]	—	—	—	—	2V

[1] Cuttings planted May 1988.
[2] Plantings were made in previously dug holes at varying densities.

Table 2 - Percent survival at Site 1 (S1) and Site 2 (S2)

Species	July 87 S1	July 87 S2	Dec. 87 S1	Dec. 87 S2	Mar. 88 S1	Mar. 88 S2	June 88 S1	June 88 S2	Sept. 88 S1	Sept. 88 S2
Rhamnus californica	100	100	98	100	98	99	97	98	95	97
Ribes sanguineum	85	98	5	24	3	15	3	15	3	15
Gaultheria shallon	[1]x	[1]x	80	65	64	63	62	61	*	*
Heteromeles arbutifolia	100	100	95	93	78	78	78	78	78	78
Quercus agrifolia	100	100	100	100	98	100	98	100	98	100
Populus fremontii	100	100	100	100	100	50	100	50	100	50
Platanus racemosa	100	100	100	100	100	100	100	100	98	100
Aesculus californica	100	100	100	100	100	100	100	100	100	100
Salix hindsiana[2]	n	n	n	n	n	n	32	29	*	*
Rebus vitifolius[2]	n	n	n	n	n	n	12	31	*	*

[1] x = no data available.
[2] Cuttings installed in May 1988.
n = No data since cuttings installed in May 1988.
* Roots system may be functioning; mortality cannot be determined.

THE CRESCENT BYPASS: A RIPARIAN RESTORATION PROJECT ON THE KINGS RIVER (FRESNO COUNTY)[1]

Jonathan A. Oldham and Bradley E. Valentine[2]

Abstract: The Kings River Conservation District planted over 1200 plants of 19 riparian species in the first of two phases of a riparian revegetation project in the San Joaquin Valley. To date, tree survival rates vary from 17 to 96 percent among species, with an overall rate of 62 percent. Shrub survival averages 57 percent and ranges from 23 to 73 percent. Factors affecting plant survival include soil quality, irrigation technique, climate, topography, weed competition, gopher and beaver depredation, vandalism, maintenance practices, and budget constraints.

The 1982-83 Kings River water year run-off, at 261 percent of average, ranked as the wettest year on record. In April 1983, the capacity of the North Fork to carry floodwater to the San Joaquin River was exceeded and floodwaters were diverted to Tulare Lake. Overall, 800,000 acre-feet of water was delivered to the basin, inundating 83,000 acres of productive agricultural land (KRWA 1984). To reduce up to 3 years of lost crop production, the Tulare Lake Reclamation District No. 749 (TLRD) decided to pump floodwaters from the Lake. Four pumping stations reversed flows through the South Fork to the North Fork of the Kings River through the Crescent Bypass, a 9.6 km man-made channel connecting the South Fork with the North Fork, and into the San Joaquin River. To accomplish flow reversal, channels and levees were enlarged and cleared. Many portions of the South Fork and a 4.8 km section of the Crescent Bypass were dredged and cleared of most vegetation.

In August 1984, a restoration agreement between the TLRD and the California Department of Fish and Game (CDFG) directed restoration of the impacted waterways. Much of TLRD's channel work benefited the Kings River Conservation District's (KRCD) flood channel maintenance program. Therefore, in April 1985, the KRCD assumed responsibility from the TLRD to mitigate those losses along the Crescent Bypass.

This paper reports on the first of two phases of a riparian revegetation project in the central San Joaquin Valley. Few riparian restoration projects in the San Joaquin Valley have been reported. We present methods, techniques, problems, and results for the practical field restorationist. This is Research Report No. 88-10 of the Kings River Conservation District's Environmental Division.

Project Site

The Crescent Bypass is approximately 56 km south of Fresno, near the towns of Riverdale and Lemoore in Kings County, California. Rainfall averages near 17.8 cm and falls during the winter months. Temperatures exceed 38°C during the summer and occasionally drop below 0°C in the winter (USDA 1986).

The bypass was constructed in the 1920's to bypass floodwaters around a constricted reach of the South Fork and then into Tulare Lake. The 40 m wide channel runs principally north-south, the left bank facing northwest and the drier right bank facing southeast. The levee slopes are steep and vary from 2 to 10 m wide. The channel is uniform and water depth is normally 0.6-0.9 m deep. Over the years, dense riparian vegetation including willow, cottonwood, oak, elderberry, buttonbush, blackberry, cattails and tules established themselves in the channel and along the banks, as determined from aerial photographs and remnant vegetation. After dredging and installation of the pump-back stations in 1983, only weeds, a few willow trees, and one cottonwood tree remained. Since the bypass no longer carries extreme flood flows, stringent channel and levee maintenance regulations (The Reclamation Board 1981) are eased. Numerous agricultural drains discharge into the bypass, some with an electrical conductivity (EC) of 25 mmhos/cm. Electrical conductivity of water in the bypass averages 2.4 mmhos/cm.

Soil EC along the right bank averages 7.2 mmhos/cm, (range of 3.9-10.8 mmhos/cm). Left bank soils average 1.7 (range of 0.6- 2.1 mmhos/cm). SAR values (Sodium Absorption Ratio, a measure of soil sodicity) in soils along the right bank average 10.7 meq/l (range of 4.9-15.1 meq/l), while left bank values range from 2.6 to 7.0 meq/l and average 5.0 meq/1. Soils vary along the bypass from sandy loams at the north end to heavy, poorly drained, clay barns at the south end. Values of soil pH range from 6.8 to 8.0.

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[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Staff Biologist and Environmental Division Chief, respectively, Kings River Conservation District, Fresno, Calif.

Methods

In fall 1985, a pilot project was conducted to determine the conditions influencing plant growth and survival. Four species of shrubs (275 cuttings and 118 containers) were planted at 0.16-km intervals along both the left and right banks (viewed downstream), 0.6 to 4.6 m above the water table. Four species of trees (52 containerized plants) were planted only in select sites along the levee (due to levee maintenance requirements), and in a 0.2 ha impacted site at the north end of the bypass, known as Ron's Park. Only 16 plants were watered throughout the summer due to manpower limitations. Plants were irrigated with buckets using water from the bypass, the quantity determined by the size of the berm around each plant, [generally, 19 to 38 L (5 to 10 gal)].

In January 1987, the first phase of the project was implemented, but constrained by a limited budget. The Site Revegetation Plan called for vegetation to be established every 183 m along the 4.8 km section of the bypass. Twenty-three shrubs and trees were planted in each of 28 plots, with 14 plots per bank. Each plot was 12-30 m long and 366 m apart. A total of 641 shrubs and 144 trees was planted in the plots, select areas along the bypass, and Ron's Park. Container stock was mostly 1 gal and a few 5 gal pots, except for the POTR & POFR trees which were 15 gal containers (table 1). RUUR and CEOC were planted as 25-38 cm cuttings taken from new and old growth stems.

Most were pencil size to 1.3 cm diameter; however, some of the CEOC cuttings were as thick as 4 cm. Cuttings were dipped in IBA (indole-3- butyric acid) rooting powder before planting in a rebar-augered hole. Plants were placed in two or three offset rows, with different species of vines, shrubs, and trees mixed to create structural and species variations. Increased plant diversity helps define species tolerant to environmental conditions and (rodent) depredation (ILR 1979). Plants were installed on the lower portions of the levee to avoid drag-grading during levee maintenance. Berms were constructed around each plant and the weeds tilled within each basin. All plants were irrigated weekly from June through October with good quality water from a nearby well.

About 50 large and small POFR and tree willow (SASP) cuttings were planted irregularly along the northern 1/3 of the bypass. The large pole cuttings (12.5 cm by 213 cm) were sunk into holes angered to the water table. Smaller cuttings (1.3 -5 cm by 91-152 cm) were simply pushed into the soil near the water table.

Table 1 —Trees and shrubs planted along the Crescent Bypass in Phase I.

			Number of Plants Ron's Park Plots	& Select Areas
Trees		Acronym		
Box Elder	*Acer negundo*	ACNE	6	11
White Alder	*Alnus rhombifolia*	ALRH	7	16
Oregon Ash	*Fraxinus latifolia*	FRLA	5	16
Black Walnut	*Juglans hindsii*	JUSI	2	7
Sycamore	*Plantanus racemosa*	PLRA	4	12
Fremont Cottonwood	*Populus fremontii*	POFR	7	20
Black Cottonwood	*Populus trichocarpa*	POTR	3	7
Valley Oak	*Quercus lobata*	QULO	4	17
		Total	38	106
Shrubs				
Wild Clematis	*Clematis lasiantha*	CLLA	4	0
Golden Current	*Ribes aureum*	RIAU	56	3
California Rose	*Rosa californica*	ROCA	63	1
Woody Rose	*Rosa woodsii*	ROAO	79	0
Elderberry	*Sambucus mexicana*	SAME	131	0
Snowberry	*Symphoricarpos rivularis*	SYRI	108	2
Wild Grape	*Vitus californicus*	VICA	26	0
Buttonbush[1]	*Cephalanthus occidentalis*	CEOC	88	7
Wild Blackberry[1]	*Rubus ursinus*	RUUR	63	10
		Total	618	23

[1] Planted as cuttings.

After initial losses, one inch mesh chicken wire three feet high, was placed around the base of most trees for beaver protection. Some of the wire was loosely placed around trees and some was placed close to the trunk, depending on the species, number of lateral branches, and tree size.

Baskets made of 1.3 cm wire mesh screen were installed around plants in one plot to test their effectiveness against gophers. They were twice as big as the plant container and buried with the top of the screen above the ground surface.

All trees and both ends of each plot were marked with fenceposts, protecting plants from drag-grading. The location of each plant was mapped and survival data (number surviving : number planted) was recorded monthly. Infrequent observations of the large pole cuttings were made throughout the season.

Results and Discussion

Pilot Project

Survival for the pilot study after one growing season was low. Only 11.5 percent of the trees and 4.2 percent of the potted shrubs survived for a total of 12 out of 170 container plants. No cuttings survived. Most of the mortality resulted from plants and plot markers being dragged off the levee by the Channels and Levees (C&L) maintenance crew. Additionally, several trees were justifiably removed during an emergency flood control operation. By the time irrigation began, only 16 plants remained. Even then, the irrigation water taken from the bypass was toxic to the young plants, containing EC's over 3500 mmhos/cm (unknown at the time). Insufficient manpower, conflicting time commitments, and budget constraints at the start of the project added to poor survival.

Phase I: Shrub survival

Phase I survival rates were substantially higher than those of the pilot planting. The survival rate for the shrub container stock was 57 percent after one growing season. Most plants (71 percent) died between the time of planting and July, while only 29 percent died over the summer (fig. 1). (Although irrigation started the beginning of June, survival data was not recorded until July.) We expected a higher mortality during the hot summer period. The shrub cuttings failed again despite increased care and maintenance. The short length of the cuttings combined with a lack of adequate water are likely causes. Because of the low survival of the cuttings, they are excluded from the survival rate calculations. Consequently, plant numbers between plots are inconsistent, ranging from 7 to 24 and averaging 17.5 plants per plot. Although the plants are still equally distributed along the length of the bypass, plots with few plants contribute to the large variation of interplot survival rates.

Stresses experienced prior to planting might explain some of the early mortality. Despite our efforts, non-acclimated and poor quality nursery stock was obtained from non-local nurseries shortly before planting. Furthermore, temperatures dropped below freezing for several nights before planting, freezing the potting soil, leaves, and buds of many plants.

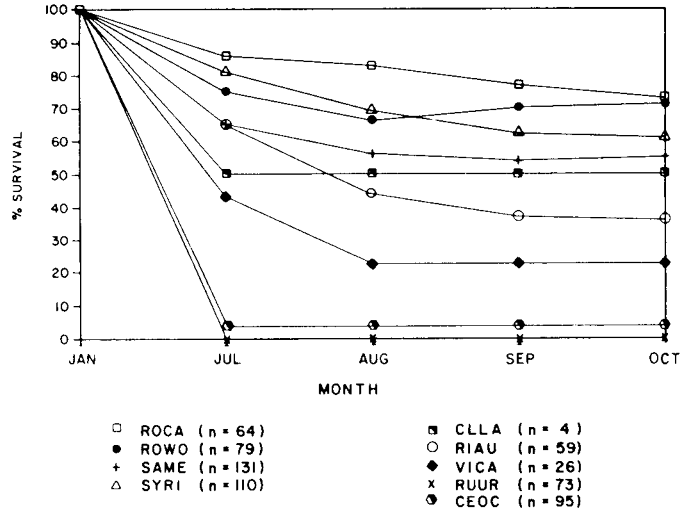

Figure 1— Shrub survival from time of planting to end of first growing season.

Soils exceeding 2 mmhos/cm are considered saline and can adversely affect plant growth. Soils with EC values between 8 and 12, classified as highly to very highly saline, can reduce plant growth 30 to 50 percent (Dargan et al. 1982). Soil tests showed EC's of 8.7 and 10.8 mmhos/cm in two of 4 soil tests along the right bank. The average survival rate for the right bank was 52 percent, while the left bank averaged 62 percent (fig. 2).

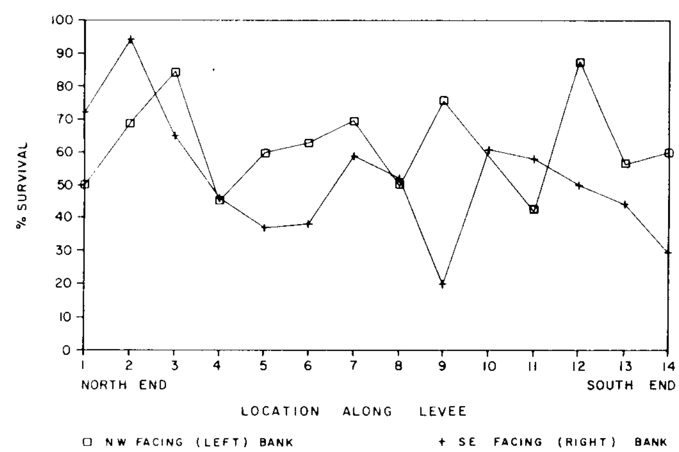

Figure 2— Shrub survival for each bank after first growing season.

The sandy loams at the north end differ from the silt barns and clay barns at the southern end. Although not reflected in the survival data, plant productivity is directly affected. In general, plants along the northern section of the bypass are much larger and healthier than those of the southern section. The transition is greatest between plots 4 and 9 on the right bank, and between 10 and 14 on the left. Fine textured particles of the clay loams inhibit development of mycorrhizae and are more limiting than soil fertility problems (Kozlowski 1987; Kramer 1987; Jorgensen 1988). Shrinking and swelling from electrostatic, osmotic, and hydrostatic pressures inhibit root formation and penetration, water uptake, and physiological plant processes. Furthermore, Frenkel and Meiri (1985a) state that a high sodium content (SAR greater than 5 meq/l) is deleterious to the physical properties of soils, resulting in a low infiltration rate of water, low permeability of the soil to water and gases, and poor structural quality of the media. High sodium content is also toxic to plants and will create physiological drought conditions (Dargan and others 1982; Emerson 1984; Frenkel and Meiri 1985a).

Aspect affects survival as well. The southeast exposure of the right bank increases evapotranspiration. As a result, salts accumulate in the root zone. In order to maintain a favorable salt and water balance in the root zone, thorough leaching is required (Frenkel and Meiri 1985b; Meiri 1984). Deep watering also enables root penetration through the soil profile to adequate available moisture near the water table, since upward capillary water movement is low for most soils (Helliwell 1986). Self-sustaining plants are the end result. Even though unfavorable salt conditions will always be present, the size of the watering basins, the amount of water applied, and the physical and environmental conditions associated with the site combine to directly affect plant growth and survival.

Although evapotranspiration is reduced on the cooler northwest facing left bank, other factors affected survival almost to the same extent. Public access to the left bank impacted several plots considerably. Most noticeable in plots 4, 5, and 6, plants were pulled up, trampled, and burned. Berms were destroyed and stakes broken or pulled out. Unauthorized use of levee roads, fence destruction, and various negative impacts from ATV (All Terrain Vehicle) enthusiasts are common, not only on the bypass, but along much of the river system. We feel posting more signs or increasing public relations would be ineffective and time consuming, as did Goldner (1981) who experienced similar problems.

Left bank plant survival was also influenced by the irrigation crew. The C&L maintenance staff was assigned irrigation responsibilities for the left bank, while Environmental Staff members irrigated the right bank. The objectives for involving the C&L staff were two fold: to provide needed manpower, and to increase their awareness so that they would avoid our plots during their levee maintenance activities. Both objectives were met but to a limited extent. The C&L staff's relatively lower enthusiasm was evidenced by poor irrigation, weed control, and berm maintenance despite repeated reminders of their importance.

Site specific problems affected many plots individually. Plot 4 on the left bank contained compacted soils and asphalt from an old bridge demolished during channel excavation. As mentioned, plots 4, 5, and 6 were impacted by fishermen. Plot 9 on the right bank had the highest EC's (10.7), worst sodicity (SAR=15.1), and a high clay content, resulting in a survival rate of 20 percent.

Finally, many plants were lost to gophers and rodents which chewed off either root systems or plant stems. Damage was worse in the clay soils where tunnel systems remain intact. There was no difference between the plot with gopher baskets and the rest of the plots. However, observations during the early stages of Phase 2 indicate that much of the early plant loss has been to gopher depredation.

Phase I: Tree Survival

Survival of containerized tree species was 62 percent. Of the mortalities, 83 percent died before July (fig. 3). Similarly, Anderson and others (1984) found that the majority of young POFR saplings on the Lower Colorado River died between November and July. POFRs and POTRs along the bypass survived better than other tree species. Beaver depredation was the only cause of their mortality. The beavers accessed trees by pulling down loose fitting screens. This prompted us to resize the remaining screens. Fortunately, some of the stumps resprouted, resulting in increased mid-summer survival (fig. 3). With the exception of initial leaf burn on a POTR tree near a drain, the high salts and poor soil conditions have apparently not affected the cottonwoods. Once the roots reach the water table, growth and productivity is tremendous. Incidental observations of the POFR and SASP pole cuttings indicated similar growth with 2 to 3 ft branches by mid-summer. Similar results from Colorado were reported by Miller and Pope (1984). Unfortunately, most of our tree cuttings (unscreened) were depredated by beavers.

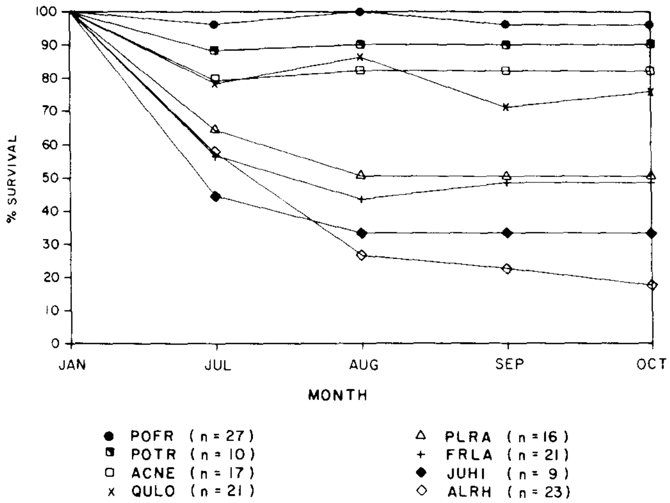

Figure 3– Tree survival from time of planting to end of first growing season.

ALRH and JUHI had the poorest survival rates. ALRH mortality is primarily attributed to the poor site conditions, most plants never recovering from transplant shock, beaver depredation, and in many cases, lack of adequate water. When planted in or very close to the water table, they did well. Soil condition was important to JUHI. They survived only in the sandy loams at the north end. Beavers did not damage JUHI or any other species not mentioned.

Further comparisons of the effects of site and soil conditions on survival within and among tree species is not attempted due to the low number of trees planted, inconsistent placement along the length of the channel, site specific differences, and beaver depredation.

Conclusions

Every planting year tends to become a pilot project because so much is learned from the previous year's effort. After the small "pilot planting", Phase I was the largest planting to date with the most learned. Benefitting from that, Phase II survival as of July 1988 was around 80 or 90 percent for both trees and shrubs. The kind of soluble salts, the soil texture, environmental conditions, and the nature of the plants are the most important factors determining plant growth. By developing the methods and techniques to more closely match the conditions of our revegetation site, we are increasing plant survival as well as our knowledge of restoration management. This benefits other restorationists, wildlife, and the diminishing riparian habitats of our environment.

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A RESTORATION DESIGN FOR LEAST BELL'S VIREO HABITAT IN SAN DIEGO COUNTY[1]

Kathryn J. Baird, and John P. Rieger[2]

*Abstract: This paper describes the procedure for developing a specific habitat restoration model. Results of a detailed Least Bell's Vireo (*Vireo bellii pusillus*) habitat study on the Sweetwater River drainage, San Diego County California, generated the baseline vegetative and habitat data used. Mean percent cover, density, abundance, species composition, and expected mortality rates of vegetation were used to determine the specifications for the restoration design. Mapped nesting plots were used to determine the arrangement of the planting components.*

Restoration has become a common practice in mitigating for the loss of sensitive habitats in Southern California. Yet literature review reveals a paucity of empirical information on the fundamentals of revegetation. Nor can we collectively predict how successful revegetation in California will be (Odion and others 1988). Evaluating revegetation projects has often been difficult and confusing for both the implementing parties and the reviewing agencies involved.

This paper focuses on the development of a detailed habitat model employing quantitative information based on the current biological understanding of the target species, Least Bell's Vireo (*Vireo bellii pusillus*). Baseline studies and statistical analyses will allow for more consistency of projects, improved standards for evaluating restoration projects, and, hopefully, a greater understanding of the habitat being restored.

Model Development

The first step in designing any restoration project is to succinctly define the project's goals and constraints. The construction of State Route 76 requires 7 acres of successful mitigation before construction of 76 can begin. Success is defined as either a vireo pair nesting on site or no statistically significant differences between parameters on the mitigation site and those in the functioning Least Bell's Vireo habitat (Hendricks and Rieger 1989). The California Department of Transportation management aspires to begin construction in the third year, placing a two year time frame on the development of the mitigation site! The goal of this project is thus two-fold: one, to establish occupied Least Bell's Vireo (riparian) habitat within two years time and, two, to establish a habitat capable of long term growth and regeneration.

Once the goals have been established it is possible to design a sampling scheme for the collection of data to be used as the basis for the restoration design. A well-designed baseline study is a prerequisite to a successful plan (Bramlet 1988). The baseline study for this project included habitat analysis on 10 vireo nesting sites on the Sweetwater River drainage in San Diego County, California, contained in a larger vireo habitat study (Hendricks and Rieger this proceeding). The sampling method employed and the parameters chosen are dependent upon the project's goals and the habitat being studied. The following parameters were evaluated in this study: species composition and abundance, density, frequency, diversity, percent cover, plant height, and linear edge.

Determination of Model Specifications

Consultation with the U.S. Fish and Wildlife Service determined that 5.2 acres of the 7 acre mitigation site would be designated as nesting quality habitat with the remaining 1.8 acres to be foraging habitat. This model focuses on the 5.2-acre nesting type habitat.

Since this model is intended to create a habitat rather than simply revegetate an area, physical community structure as well as species composition is important. Plants were grouped according to their growth form: tree, shrub, or herb. Areas not covered by a canopy or an herbaceous layer (i.e. bare ground) were designated as open areas. Open areas occur fairly consistently throughout vireo habitat so were incorporated into the model. The area of each category was calculated according to equation 1 (Q1), with results presented in table 1.

Q1. Percent cover for category x Total nesting area = Total area per growth form.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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Table 1 — Mean percent cover values and area allocation for each category.

Plant type	% Cover	Area (acres)	Area (hectares)
Trees	46.7	2.45	0.99
Shrubs	32.9	1.72	0.70
Herbs	7.8	0.41	0.17
Open	12.6	0.66	0.27

Density, diversity, frequency, and average shrub and tree heights were calculated from the original data base collected at each of the nest sites. Frequency, linear edge, and diversity values were not directly used to generate the revegetation model. However, frequency values are indicative of plant distribution patterns and diversity of species per unit area. Therefore, both parameters were used as a simple test on the final model. Density values were determined for each vegetation type (table 2).

Table 2 — Mean density values per plant growth form.

Growth form	No./ft^2	No./ac	No./ha
Tree	0.023	1000	2470
Shrubs	0.091	3966	9800
Herbs	0.060	2655	6560

A partial species list was developed from the field data. Several highly invasive species were removed from the field list with the idea that they would establish readily without artificial seeding(*). The quantity of each species required was determined using equation 2 (Q2), with results presented in table 3. The method of calculating seed poundage to approximate the composition observed is described in Schaff (1988).

Q2. (Density of plant form/acre) x (Abundance of species) = Number of individuals per acre.

To obtain vireo nesting habitat following two growth seasons, mature as well as young growth is required. Measured tree heights were converted into height categories, and percent composition calculated for each species (fig.1). This pattern of height distribution and the anticipated growth rates of riparian trees were used to determine the percentage of tree sizes planted. At 4-feet/year (Rieger 1988), seedlings should be in the critical 9 to 15 foot range in two growth seasons. However, planted seedlings will not be able to attain the more mature size and form within this time. For this reason it is necessary to transplant mature trees and *Baccharis glutinosa* shrubs to the site, using a technique previously conducted by Caltrans (Rieger 1988).

The incorporation of expected mortality rates into the model is an effort to eliminate the need for replanting, a difficult task for a large contracting agency and a potentially major disturbance to the habitat. Mortality values used in this design were estimates based on observations of previous riparian restoration sites, since documented values were unavailable. Post-planting maintenance should reduce the estimated mortality rates. Original seedling quantities were increased by the mortality percentage to obtain the adjusted planting quantities (tables 4, 5).

Time constraints on this project eliminated the incorporation of natural recruitment into the model. For projects with greater time flexibility the adjusted planting number can be reduced by the expected natural recruitment rate.

To determine the appropriate spacing for the trees and shrubs, the total number of square feet per acre available for each species was derived from equation 3 (Q3).

Q3. (Percent cover of plant form) x (Species abundance) X (43560 sqft/acre) = Species area in square ft./acre.

This value divided by the adjusted quantity of plants, yields the average area allocated per plant. The square root of this value is the average distance between each plant. To achieve fuller growth on the larger trees the 15 gallons seedlings will be planted at 6 foot intervals, the 5 gallon at 4 foot intervals and the 1 gallons at 3 foot intervals. Transplant trees will be planted independently of the other seedlings at 14.5 foot intervals from themselves. The smaller seedlings will be planted around the mature trees leaving a 5 foot clearance. Species are planted in small monotypic patches within the overall design, with similar size plants clumped together, approximating the field conditions.

Table 3 - Species list and quantities required per acre of mitigation.

Species	% abundance	# per unit area: acre	# per unit area: hectare
Trees			
Salix lasiolepis	40.0	400	988
S. gooddingii	36.3	363	897
S. hindsiana	11.3	113	279
S. laevigata	10.2	102	252
Populus fremontii	1.3	13	32
Platanus racemosa	0.7	7	17
	Total	1000	2471
Shrubs			
Baccharis glutinosa	92.0	3650	9019
Isocoma veneta	4.6	180	445
Artemisia palmeri	3.4	130	321
	Total	3960	9785
Herbs			
Ambrosia psilostachya	33.2	882	2179
Artemisia douglasiana	13.0	345	852
Anemopis californica	29.1	773	1910
Pluchea purperescens	1.9	52	128
*Heliotropium curvassavicum**	2.7	72	178
*Heterotheca grandiflora**	7.2	67	166
Urtica holosericea	9.7	258	638
Galium sp.	2.5	67	166
	Total	2516	6217

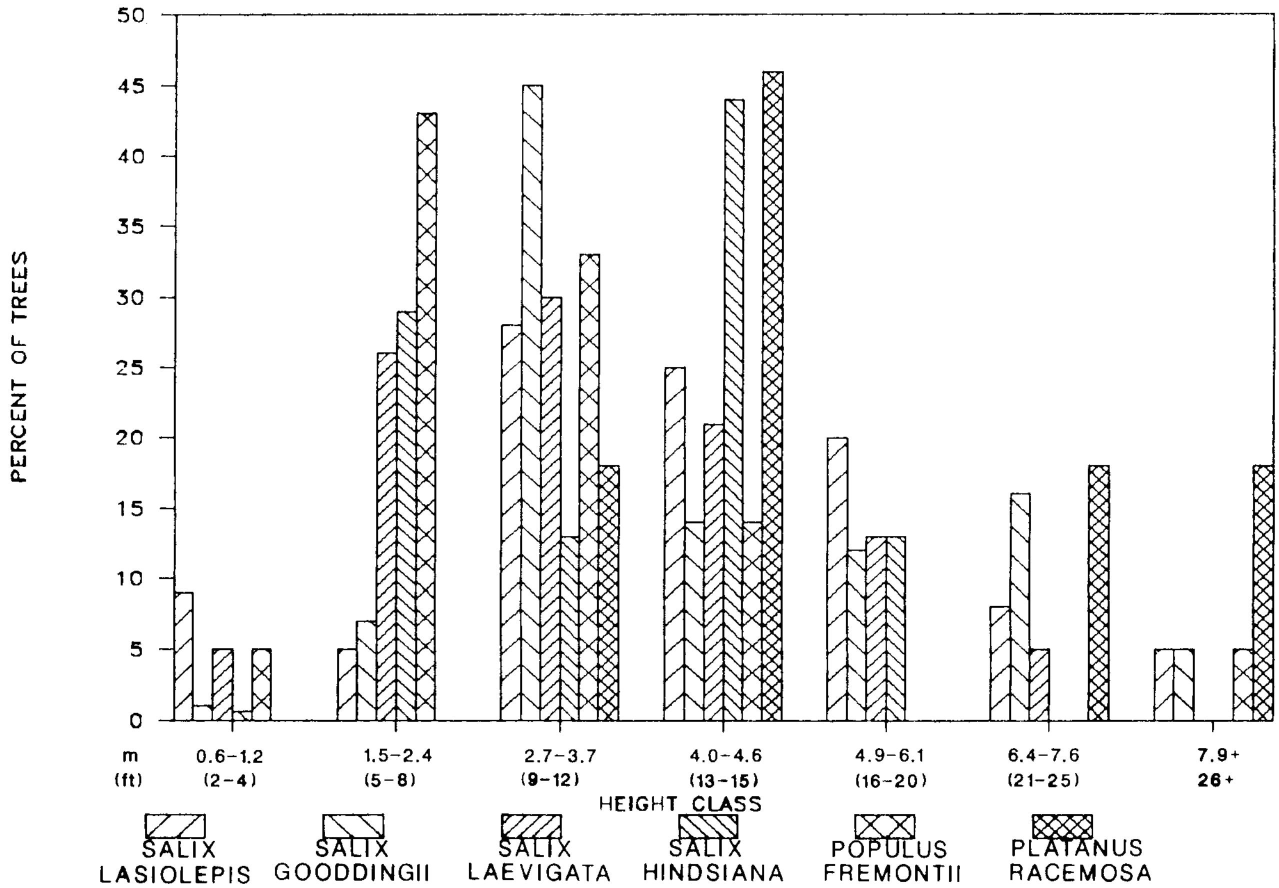

Figure 1- Height class distribution of riparian trees in Least Bell's Vireo habitat.

Table 4 - Tree specifications per acre of mitigation.

Tree ht.(ft)	Planting size	% trees	# trees	% mort.	Adjusted # trees	Planting dist.(ft)	Area (ft^2)
S. lasiolepis (47% tree cover) (40% species cover) (43560 ft^2/acre) =8190 ft^2 planted in S. lasiolepis.							
1-2	1 gal	30	120	25	150	3	1350
3-4	5 gal	40	160	10	176	4	2816
4-5	15 gal	20	80	5	84	6	3024
15+	transplant	10	40	1	40	14.5	1000
Total		100	400		450		8190
S. laevigata (47 pct trees) (10.2 pct sp) (43560 ft^2/acre) = 2047 ft^2							
1-2	1 g	30	31	25	39	3	351
3-4	5 g	40	41	10	45	4	720
4-5	15 g	20	20	5	21	6	756
15+	transplant	10	10	1	10	14.5	250
Total			102		115		2077
S. hindsiana (.47 pct trees) (.11 pct sp) (43560 ft^2/acre)= 2312 ft^2							
1-2	1 g	30	34	25	43	3	387
3-4	5 g	40	45	10	50	4	800
4-5	15 g	20	23	5	24	6	864
15+	transplant	10	11	1	11	14.5	275
Total			113		128		2326
S. gooddingii (.47 pct trees) (.36 pct sp) (43560 ft^2/acre)= 7432 ft^2							
1-2	1 g	20	73	25	91	3	819
3-4	5 g	30	109	10	120	4	1920
4-5	15 g	40	145	5	152	5	3800
15+	transplant	10	36	1	36	14.5	900
Total			363		399		7439

Table 5 — Shrub specifications per acre of mitigation.

B. glutinosa (32.9 % shrub)(92 % sp)(43560 ft/acre) = 13184.74 ft2

Planting size	Plants per clump	% shrubs	No. shrubs	% mort	Adj no. shrubs	Planting dist. (ft.)
1 gal	1	20	548	25	639	2
	2	50	1370	25	1712	2
	3	30	821	25	1026	2
	Total	75 %	2739			
2 gal	1	50	427	10	470	3
	2	50	427	10	470	3
	Total	23 %	854			
transplant		2	57	0	57	15

Baccharis glutinosa will be planted in clumps of 1, 2 and 3 seedlings per one gallon container and in clumps of 1 and 2 per container in the 2 gallon size. All 1 gallon size *B. glutinosa* containers will be planted a 2 foot intervals and the 2 gallons at 3 foot intervals. All 48 *Platanus racemosa* and 130 *Populus fremontii* will be planted as 5 gallon container plants and will be scattered throughout the site.

Designing the Layout

Following the calculations of plant specifications, the question becomes: What type of planting arrangement best matches Least Bells Vireo habitat? Habitat maps had been delineated from each of the nesting plots. Four successful nest sites were chosen as models. These four maps were joined together connecting similar areas forming a primary layout design. Areas (percent cover) of trees, shrubs, herbs and open space and linear edge were measured and checked against calculated values. Small adjustments were made yielding a mosaic nesting area design which can be repeated, fitting edges together to accommodate any size restoration area (fig. 2). The layout design was reviewed by several biologists familiar with the Least Bells Vireo.

To increase the amount of edge habitat, and intersperse foraging area into the design, the nesting habitat was divided into five irregular blocks each surrounded by foraging area. The foraging area consists of young *Salix gooddingii, Baccharis glutinosa,* open area and a few scattered *Populus fremontii* as requested by U.S. Fish and Wildlife Service. Figure 2 shows a portion of the design.

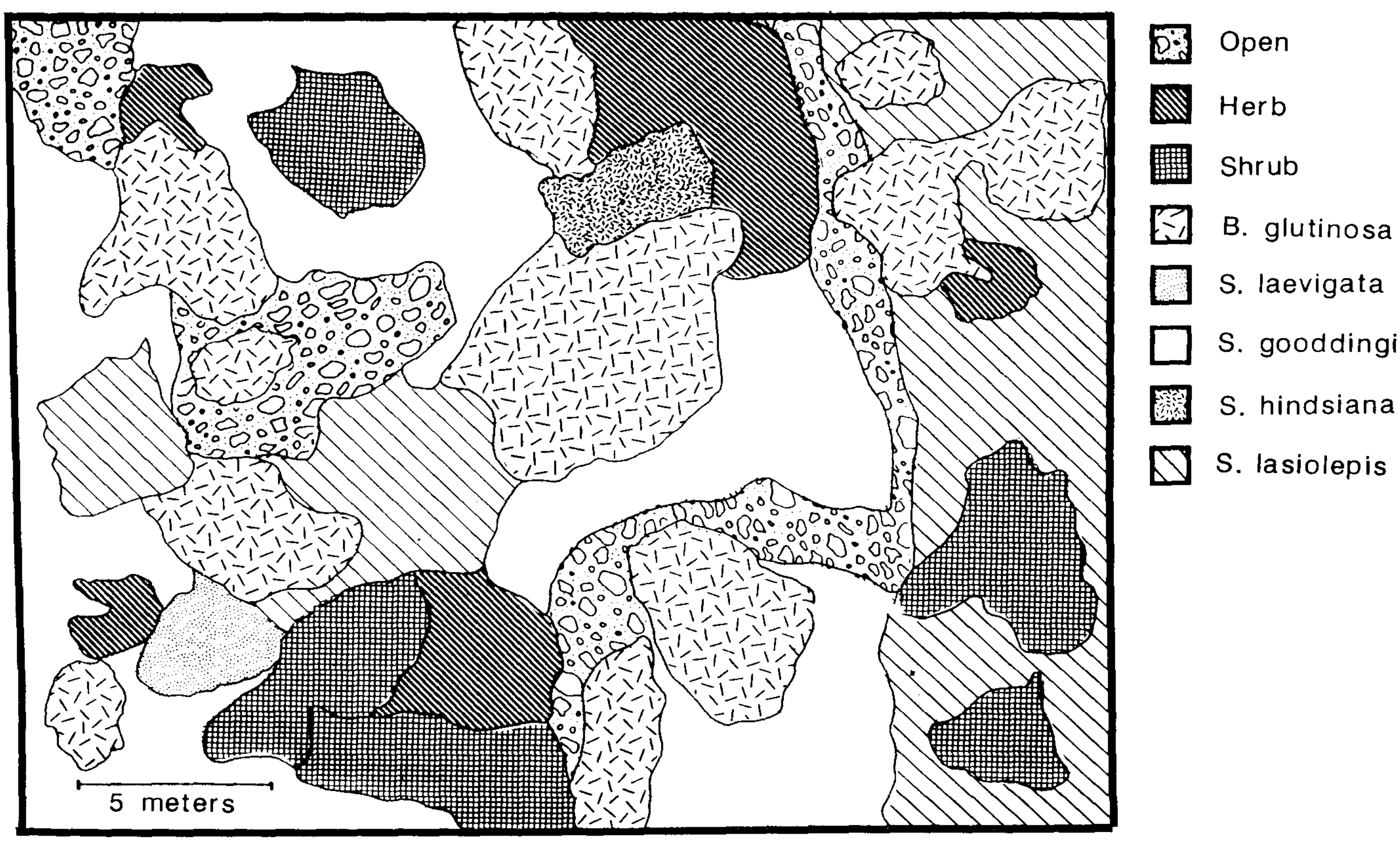

Figure 2— Primary design illustrating the mosaic pattern of growth forms and vegetation.

Leaf litter and deadfall have proven to be an important component in riparian systems, yet 5 year old restoration sites lack sufficient accumulation of either. To rectify this, deadfall and leaf litter will be distributed throughout the site.

Competition from exotic or native weedy species is a major problem in the establishment of most restoration projects. No soil fertilizers will be applied since they are known to suppress the development of mycorrhizal fungi (Hayman 1983), and may favor exotic or non-mycorrhizal weedy species over native species (St. John 1987). The effects of mycorrhizal inoculation on riparian seedling survivorship, growth rate and competitive ability is currently being tested.

The probability of a successful revegetation effort is maximized when conditions that promote the establishment of the desired vegetation are provided (Odion and others 1988). Therefore, the mitigation site should match the hydrology and physiography of a natural riparian area as closely as possible. The surface elevation of a riparian restoration site should be no more than to 2 to 4 feet above the normal water table. This allows the vegetation more accessibility to the water table, as many of the riparian species have evolved shallow spreading root systems rather than deep penetrating systems. Although auguring down to the water table in ungraded sites works well for the initial plants (Anderson and Ohmart 1985), the increased elevation may have a negative influence on natural replacement. Species composition may be altered by the selection for drier habitat species. A lower surface elevation may permit natural flooding, a key component in maintaining an earlt to mid-successional riparian community (Granholm and others 1988).

The microtopography of riparian floodplains consists of ridges and swales. This variation in elevation and surface features leads to considerable differences in drainage conditions (Strahan 1984). In response, the grading plan calls for several larger channels with smaller finger-like projections to traverse the seven acre mitigation site. The actual surface will be left in a roughened condition to provide an increase in microtopography.

Conclusions

The method and extent of data collection used to describe the Least Bell's Vireo nesting habitat was easily transformed into a quantitative description of Vireo habitat. This approach yields a design which approximates the natural situation more closely than other methods. The design process presented in this paper can be applied to most habitats or species. It was not designed as a cookbook procedure, but as a general procedure or process for the creation of a restoration design. Depending upon the specific goals and constraints, the process can be modified to fit the requirements of most projects. Documentation of mortality and recruitment rates of riparian species would strengthen the model. Having specific criteria, based upon the current understanding of the biology of the target species or habitat, should allow for more consistency and improve standards for evaluating restoration projects helping to eliminate the confusion among project designers and reviewing agencies.

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CREATING HABITAT FOR THE YELLOW-BILLED CUCKOO (*COCCYZUS AMERICANA*) [1]

Bertin W. Anderson and Stephen A. Laymon [2]

*Abstract: Yellow-billed Cuckoo numbers have decreased alarmingly in recent decades. This is associated with demise of their riparian habitats. Study of habitat along the lower Colorado River and along the South Fork Kern River led to the conclusion that they require dense habitats dominated by cottonwood (*Populus fremontii*) and willow (*Salix *spp.). They nest predominantly in willow and forage primarily in cottonwood trees on insects and tree frogs. On the basis of this information habitat designs were made and revegetation efforts were undertaken to create habitat for this bird species. Factors that decrease planned rapid development of these habitats have included salinity, competition from weeds and damage by local wildlife and, more recently, cattle browsing.*

The Yellow-billed Cuckoo has been declining alarmingly in numbers in recent decades (Laymon 1980, Laymon and Anderson 1988, Laymon and Halterman 1985, 1987, Hunter and others 1987). This decline in numbers is associated with decline in their riparian woodland habitats. Precise data concerning their habitat requirements was determined along the Colorado River from 1976-1983 (Anderson and Ohmart 1984, Rosenberg 1980, Hunter and others 1987) and along the South Fork Kern River from 1985 to present (Laymon and Halterman 1985, 1987). On the basis of data from these studies revegetation projects were designed. Implementation began in 1979 on the Colorado River and in 1986 and 1987 on the Nature Conservancy's Kern River Preserve. The purpose here is to summarize features of cuckoo habitat requirements and to discuss progress in the revegetation effort. We pay particular attention to factors that detract from the objective of creating rather precise habitats as quickly as possible. We also make a prognosis on the likelihood of success in enhancing cuckoo populations on the Kern and Colorado Rivers. Some features detracting from success of a revegetation project are discussed in another paper (Anderson, this symposium). That paper compliments this one, therefore someone seeking a more detailed picture of revegetation problems and methods should will want to consider them collectively.

Methods

Revegetation Schemes

Revegetation schemes were based on cuckoo habitat requirements that have been determined from the work cited above. This work is from the area from the Colorado River westward across much of southern California. The research showed that cuckoos nest and forage in vegetatively dense stands (more than 150 trees per hectare) of cottonwood and willow. Foliage at all levels was greater than in other habitats on the Colorado River. They seem to select willows–often overhanging water–for nesting and cottonwood for foraging. Nests were placed 6-8 meters off the ground in dense foliage. Foraging typically occurred in areas with a greater overall foliage density than where nesting occurs. Average tree height was 10-15 meters.

Revegetation designs should include patches of willows, surrounded by cottonwoods. Planting densities should be high enough that as the community develops final foliage densities will be great enough to satisfy cuckoo needs. Since cuckoo numbers are so low, it is urgent that revegetation methods be used that maximize growth rates. The habitat should be diverse enough to promote foliage development in the understory as well as in the canopy.

Previous work (Anderson and Ohmart 1984) suggested that there would be complete canopy closure in three or four years after planting on the Colorado River where the growing season is over 200 days long. Cuckoos nested on the site beginning the third year after planting. On this site trees were planted at densities of 250 trees per ha. Natural factors, including patches of saline soil, will ensure development of horizontal and vertical foliage diversity.

Site selection must be made carefully (Anderson In press). Not only should it be strategically located so as to enhance the existing habitat, it must have soil and salinity level that will be conducive to rapid growth.

Even if site quality is high several features can reduce success. Among these are (1) inadequate planting stock,

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(2) competition from weeds and (3) browsing on saplings by deer or cattle.

Experimental Design for Propagation of Stock

In learning how to develop appropriate stock we have worked with many variables. Three of the most important include (1) use of rooting hormone to stimulate initiation of roots, (2) determining what constitutes a satisfactory sapling for planting, and (3) determining the potential of pole cuttings planted directly in the field.

We prepare cuttings by obtaining pieces of limbs about 38 centimeters long from local genetic stock less than about 15 years old. Cuttings are placed in 4-liter pots filled with equal amounts of sandy soil, peat moss, and perlite or vermiculate. In winter, cuttings are placed in greenhouses constructed from PVC pipe and visquine. To test the effect of rooting hormone we brushed rooting hormone (indolbutyric acid) on the cuttings before placing them into pots. A total of 1312 cottonwood and 560 willow cuttings were treated in this way. As controls an additional 50 cuttings were not treated with hormone. This work was done at The Nature Conservancy's Kern River Preserve, Weldon, California.

Anecdotal evidence suggested that saplings less than about 40 centimeters tall after developing in 4-liter pots for 8-12 weeks do less well after planting than those taller than this. To test this we monitored 125 trees randomly planted on a 10 hectare site on the Kern River Preserve that were 40 centimeters or taller at planting. An additional 152 randomly distributed trees were less than 40 centimeters at planting.

To test pole cuttings we placed 50 unrooted poles about 1 meter long directly into planting holes. On the Kern River sites, that water table is about 1.2 meters from the surface. These trees were randomly distributed and were treated with rooting hormone. Planting was in May 1986. In April, 1987 an additional 30 poles were planted on another site. Growth of these was compared with growth of cuttings.

Experimental Design to Determine Effects of Competition

Competition from trees was evaluated for cottonwood/willow trees planted along the Colorado River in 1979 and along the Rio Grande in 1986. For this work we defined a tree as being in competition if weeds were growing in the irrigation "bowl" in which it was planted. Competitors were either present or absent; no intermediate categories were recognized. Along the Colorado we had a sample of 195 trees with competitors absent and 64 where they were present. Along the Rio Grande we monitored 51 trees where competitors were absent and 16 for which competitors were present. Tillage was identical for both groups and soil and salinity levels were tightly controlled. This work included both cottonwood and willow trees. Since there were no significant differences ($P>0.05$) in variables monitored between the two species, we here combine results for the two species.

Experimental Design for Evaluating Efforts to Overcome Impacts from Browsing

The effects of browsing on sapling cottonwood/willow is discussed by Anderson (1989). In this paper our main objective is to evaluate the effort to reduce damage done by browsing. About 4500 trees planted in 1987 on the Kern River Preserve were browsed by cattle during winter, 1988. Since browsing apparently does serious damage to cottonwood/willow trees (Anderson 1988c) the decision was made to attempt to overcome this damage by irrigating the damaged trees and by providing them with fertilizer for an additional season. For comparison we used 147 two-year old cottonwood that were not browsed. These trees, however, were on another site located about 0.5 kilometer from the site that was browsed, thus comparative data must be viewed with some caution. None of the trees on the browsed site went unscathed. In addition, we monitored 87 cottonwood trees that treated during the second year and 84 trees that received no irrigation or fertilizer after browsing. Both sets of trees were randomly distributed across the site.

In all cases measurements were made weekly. Space precludes presenting all of this data so we present primarily data from the beginning and end of each growing season. Height refers to the distance from the ground to the tip of the tallest upstretched leaf. Growth is the difference in height between time A and time B. For the method of calculating foliage volume, see Anderson (In press).

Results and Discussion

Propagation Methods

Use of Rooting Hormone

After 8-10 weeks 85 percent of 560 willow cuttings treated with indolbutyric acid had developed into plants adequate for 1planting. Among 1312 cottonwood 56 percent had developed satisfactorily. Among 50 untreated trees 40 percent of cottonwood/willow trees (no difference betweens species) developed satisfactorily. These results are statistically significant (X2 5.02, 1 D.F., $P<0.05$), thus indicating that cuttings should be treated with rooting hormone to insure a more even and vigorous development of propagules. The significance of the results becomes apparent when comparing the needs of a project when rooting hormone is used and when it isn't. For example, if 5000 satisfactory cuttings are desired in a ration of 1 willow: 4 cottonwood, 7143 cottonwood and 1177 willow cuttings should be started. Without using hormone 12500 cuttings, 50 percent more, should be started.

Stature of Cuttings at Planting

In selecting trees for planting, those that are verdant and healthy looking should be selected. Beyond that cuttings that are 8-10 weeks old and are 40 centimeters or taller are more vigorous growers after planting than those less than this height (Table 1). Saplings less than this height at planting showed 36 percent less foliage volume after one growing season.

Table 1 - Growth (centimeters) over one growing season of cuttings started in 1 gallon pots and unrooted poles planted directly in the field.

Category at planting	Number of trees	Total growth (1SD)	Foliage volume (m^3)	Deviation from controls%
Controls>40 cm	125	143.3(15)	1.01	-
<40 cm	152	119.5(14)	0.65	-35.6
Unrooted poles	29	99.0(22)	0.42	-58.0

This cutoff point was actually discovered by trial and error; by observing growth rates of groups of decreasing size at planting until a size was found below which growth was reduced. The results presented here are the first test of that determination. It has since been repeated with a similar outcome in 1987 (Anderson 1988a).

Failure to use rooting hormone could lead to poor development and subsequent planting of unsatisfactory saplings with disappointing results. Reduced growth and stunting not only slows the development of cuckoo habitat but casts doubt on whether a site planted with poor saplings will ever develop into quality habitat. Growth during the second season indicates that trees less than 40 centimeters at planting lose even more ground relative to controls (Anderson 1988b). The smaller trees at planting showed only 22 percent of the foliage volume of controls. If about 25 percent of the site is planted with saplings less than 40 centimeters tall, it could result in 20 percent less foliage volume at the end of two years than if all sapling would have been 40 centimeters. Other data indicate that saplings over 66 centimeters are less vigorous than those 40-65 centimeters (Anderson 1987).

Pole Plantings

Among 50 pole cuttings planted in May 1987, 37 (74 percent) died by the end of the first season. By the end of the third 38 (76 percent). Mean height was 213 centimeters for those alive after three seasons; controls were 330 centimeters (2 S.E. = 27 cm). Growth of this set of pole plantings was inferior to that of potted cuttings. Planting in May, however, might have been too late in the season for best performance. This experiment was repeated the following year with an additional 30 poles planted in April.

In the second experiment survival was much improved, with only 1 (3 percent) dead by the end of the first growing season. Foliage volume was 58 percent less than for controls (Table 1).

Planting unrooted poles seems undesirable. They are, of course, easier to plant, but obtaining several thousand one meter-long poles could decimate local populations of young trees. Furthermore, if 30-40 percent fail to develop satisfactorily, as with cuttings (see above), an unsatisfactory site could result.

Competition from Weeds

Results indicate that competition from weeds, in our area primarily grasses of a variety of species, salt cedar (*Tamarix chinensis*), and arrowweed (*Tessaria sericea*), can be devastating. Losses after two growing seasons on the Colorado River reached 94 percent for foliage volume relative to control trees. On the Rio Grande losses were 87 percent (Table 2). Saplings encountering a competitive environment apparently rarely recover from the impact. After 10 seasons (Colorado River), 64 percent had died. Among those with no competition 13 percent had died. Weed control seems important.

Table 2 - Effects of competition from weeds for two-year old trees planted on a revegetation site along the Rio Grande near Presidio, Texas and along the lower Colorado River, near Blythe, California. Soil was sandy and salinity low.

River Location	Competitive Environment	Num. of trees	Dead Trees No.	Dead Trees %	Height (m)	2SE	Foliage Volume	(2SE)
Colo. R.	Absent	195	3	1.5	5.8	0.4	36.0	-
Colo. R.	Present	64	16	25.0	2.3	0.6	4.2	-
Rio Grande	Absent	51	0	0.0	3.8	0.2	14.4	0.7
Rio Grande	Present	16	0	0.0	2.0	0.4	1.9	1.8

Assuming that competition will result in foliage volume losses of 80 percent, uncontrolled competition on 25 percent of a site will result in a total loss of 20 percent in foliage volume for that site.

Efforts to Overcome Impacts of Browsing

At the end of one growing season browsed trees showed a reduction in foliage volume of about 26 percent (Table 3). Anderson (1988c) provided data indicating that second year losses increased to 46 percent. We hoped that by irrigating for another season and by applying fertilizer we could help browsed trees recover from the impact. By mid-August of the second growing season trees that were treated had 19 percent less foliage volume than expected of same-aged trees that had not been browsed. From previous work we predicted a 46 percent loss at this age in browsed trees, the observed loss was 35 percent. This could be due to slightly higher salinity conditions on the site with the trees serving as controls. Importantly, extensive loss was predicted and extensive loss was observed, even if precision was somewhat off.

Table 3- Impact of browsing by cattle on cottonwood trees on the Kern River Preserve over a two year period. S.D. = one standard deviation. Treated trees were provided with irrigation and fertilizer during the second year.

		Average						
Year	Category	N	Height (m)	S.D.	Growth (m)	S.D.	Foliage vol. (m^3)	S.D.
1	Not Browsed	147	1.4	.29	1.12	.29	.80	.50
1	Browsed	46	1.3	.26	1.06	.28	.59	.32
2	Not Browsed	141	2.6	.69	2.06	1.13	6.25	.73
2	Browsed							
	treated	87	2.4	.73	1.91	.76	5.05	3.73
	untreated	84	2.2	.60	1.73	1.10	3.93	2.90

The treated trees had 54 percent greater foliage volume than untreated trees, suggesting that our treatment during the second season had a significant beneficial effect. There remains some doubt, however, since cottonwood and willow trees treated for a second season on a site on the Colorado River showed similar improvement, but the treatment seemed to only postpone detrimental impacts until the third and subsequent years (Anderson and Ohmart 1982). Possibly browsed trees will yet falter. It may be premature to say that any sapling damaged in some way (browsing, competition, salinity effects) during the initial year of growth is likely to never recover, but as data accumulate this possibility looms more likely.

If browsing, whether by wild or domesticated animals, occurs on 25 percent of the site and average loss in foliage volume of browsed trees is 40 percent, there would be an overall loss of 10 percent on the site. Browsing by deer at this intensity is not unusual in our area. Incursion by domestic stock, as shown above, can cause damage far beyond this level.

Cuckoo Response to Revegetation

On the Colorado River, where growth of cottonwood and willow trees averaged three meters per year, cuckoos foraged on the site in the second year (1980). One pair nested on the site in 1981 and three pairs nested in 1982 and 1983. Thus it is possible to quickly develop habitat that cuckoos will accept. Unfortunately, annual growth on Kern River sites, because of a shorter growing season, is less-about 2 meters. Cuckoos neither foraged nor nested on a Kern River site during the third growing season. On that site foliage volume approached a level suggesting the cuckoo use might not be far off. But subtleties not apparent by mere measurement of foliage volume (e.g. branch configuration) may require yet further development. The point is that cuckoo habitat cannot be created overnight. The species' populations are low and their need for more habitat is urgent, but, in truth more habitat will not be forthcoming quickly. That cuckoos used the revegetation site on the Colorado River so soon after implementation provides stimulus to proceed with revegetation projects, but this undertaking should be done with the utmost care.

In this paper we indicate the vulnerability of revegetation projects to losses from inappropriate action at the propagation stage or as a result of planting low quality saplings. Thereafter competition from weeds can lead to additional losses. Even light browsing by deer detracts further from the probability of achieving the desired outcome. Anderson (1988) has shown that inappropriate tillage will add to these losses as can inadequately monitored irrigation. In desert riparian areas salinity levels must be carefully considered. No matter how careful site selection is there is likely to be some places on the site where salinity level will exceed levels at which cottonwood/willow trees will be maximally productive. Careless site selection can be disastrous to the project. Small, seemingly insignificant losses tolerated in one phase can quickly become disasters if similar disregard is multiplied across the nine factors mentioned above. In addition other factors affect vigor (soil type, use of fertilizers, factor interactions) that have not been discussed but that are nonetheless real. Serious effort to create habitat for cuckoos must take these realities into consideration.

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INITIAL DEVELOPMENT OF RIPARIAN AND MARSH VEGETATION ON DREDGED-MATERIAL ISLANDS IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA, CALIFORNIA[1]

A. Sidney England, Mark K. Sogge, and Roy A. Woodward[2]

Abstract: Natural vegetation establishment and development were monitored for 3 1/2 years on a new, dredged-material island located within the breached levees at Donlon Island in the Sacramento-San Joaquin River Delta. Vegetation measurements and maps prepared annually indicate that marsh and riparian vegetation types have developed rapidly. Topographic data for the island has been overlaid with vegetation data, and the results can be used to select elevations when designing future levees, dredged-material deposition areas, and fish and wildlife habitat enhancements.

In 1987, the U.S. Army Corps of Engineers and Port of Stockton completed a project to widen and deepen the Stockton Deep Water Ship Channel. A portion of the dredged-material was deposited in open water using sediment diffusers to control material placement. This recently developed technique was used to create small, exposed islands at two sites in the Sacramento-San Joaquin River Delta. The primary objective for creating these dredged-material islands was to provide wildlife and fisheries habitats. In 1987, we began a monitoring study sponsored by the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service. The study was designed to document vegetation establishment, to relate the results to island elevation and configuration, and to develop design guidelines that could be used by interested parties throughout the Delta to develop marsh and riparian woodland vegetation.

This paper presents our findings through the first 3 1/2 years of vegetation establishment on Donlon Island. Construction of the second site, Venice Cut Island, was completed 18 months after Donlon Island, and vegetation establishment there is considerably behind. Therefore, data for Venice Cut Island are not presented.

Study Area

Donlon Island is located in extreme southwestern Sacramento County approximately 3 km northeast of Antioch at Mile 7 on the San Joaquin River. The island is roughly triangular and is bounded by abandoned levees that have been breached at several locations.

Prior to modification, the interior of Donlon Island was primarily open water with small scattered clumps of California bulrush (*Scirpus californicus*). The encircling levees were fringed with California bulrush and in a few locations supported a narrow band of riparian vegetation dominated by Fremont cottonwood (*Populus fremontii*) and willows (*Salix* sp.).

The nine small dredged-material islands constructed at Donlon Island in January 1985 ranged in size from 0.7 to 5.3 hectares. We collected data only on the largest of these.

Methods

Standard surveying equipment was used to establish a permanent sampling grid on the study island in March 1987. Topographic surveys using the grid as a reference frame were conducted in April 1987 and April 1988. Measurements of surveyed points were converted to elevations relative to mean water level (MWL) based on measurements collected hourly at Antioch by the California Department of Water Resources.

Vegetation maps were prepared in spring and fall 1987 and spring and summer 1988. Vegetation types were identified visually by gross differences in vegetation structure and plant species composition. Location and extent of each vegetation type were measured relative to the permanent sampling grid.

Quantitative vegetation measurements were collected in June 1988. Sampling was stratified by vegetation type; 24 points were sampled in each of the common types and 5 points in uncommon types. At each sample point, a 1.0 by 1.0 meter sampling frame was placed randomly. All plant species present in the frame were identified and the percent cover estimated.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Environmental Resource Planners, Sacramento District, U.S. Army Corps of Engineers, Sacramento, CA.

Results and Discussion

Deposition of dredged-material created a roughly circular island of bare sand with scattered stands of California bulrush along the edges. Natural colonization occurred rapidly and resulted in the formation of a relatively distinct zonal vegetation (fig. 1). In 1988, we identified seven vegetation types. Physical characteristics of the two most important species in each vegetation type are presented in table 1.

Old Tales (OTU) is vegetation dominated by California bulrush and cattail (*Typha angustifolia* and *T. latifolia*) and was present before the dredged-material island was created. This vegetation is found at the lowest elevations (fig. 1). New Tules (NTU) supports the same species and is becoming established immediately above Old Tules (fig. 1). The extent of both vegetation types has increased over time (table 2).

Dense Wet Herbaceous (DWII) is a vegetation type composed primarily of annuals, biennials, and herbaceous perennials and found at intermediate elevations (fig. 1). The greatest number of species were recorded in this type, and no single species was dominant (table 1). Sparse Wet Herbaceous (SWII) is an uncommon vegetation type (table 2) that is a transition zone between dry upland sites and lower more moist sites. The area of Dense Wet Herbaceous has remained relatively constant over time (table 2), but the location of the zone has shifted as the lower fringes of Sparse Wet Herbaceous and Sparse Dry Herbaceous have developed into Dense Wet Herbaceous.

Sparse Dry Herbaceous (SDH) occurs at the highest elevations on the island (fig. 1). The ground is relatively barren and dry, and most plant species are annuals. This vegetation is the only type that is above the highest high tides. The extent of this Sparse Dry Herbaceous is decreasing as the lower fringes are being colonized by willows.

Willow Thickets (WIL) are found at intermediate elevations in the same elevation zone as Dense and Sparse Wet Herbaceous and the lower edge of Sparse Dry Herbaceous (fig. 1). The extent of this vegetation is increasing (table 2) as willows, Fremont cottonwood, and white alder (Alnus rhombifolia) invade adjacent vegetation types. Young individuals of these species already are present at the upper edges of the Old and New Tules and relatively high in the Sparse Dry Herbaceous zone (fig. 2). Our data suggest that if these tree seedlings survive and grow, willow thickets will become the dominant vegetation type on the island.

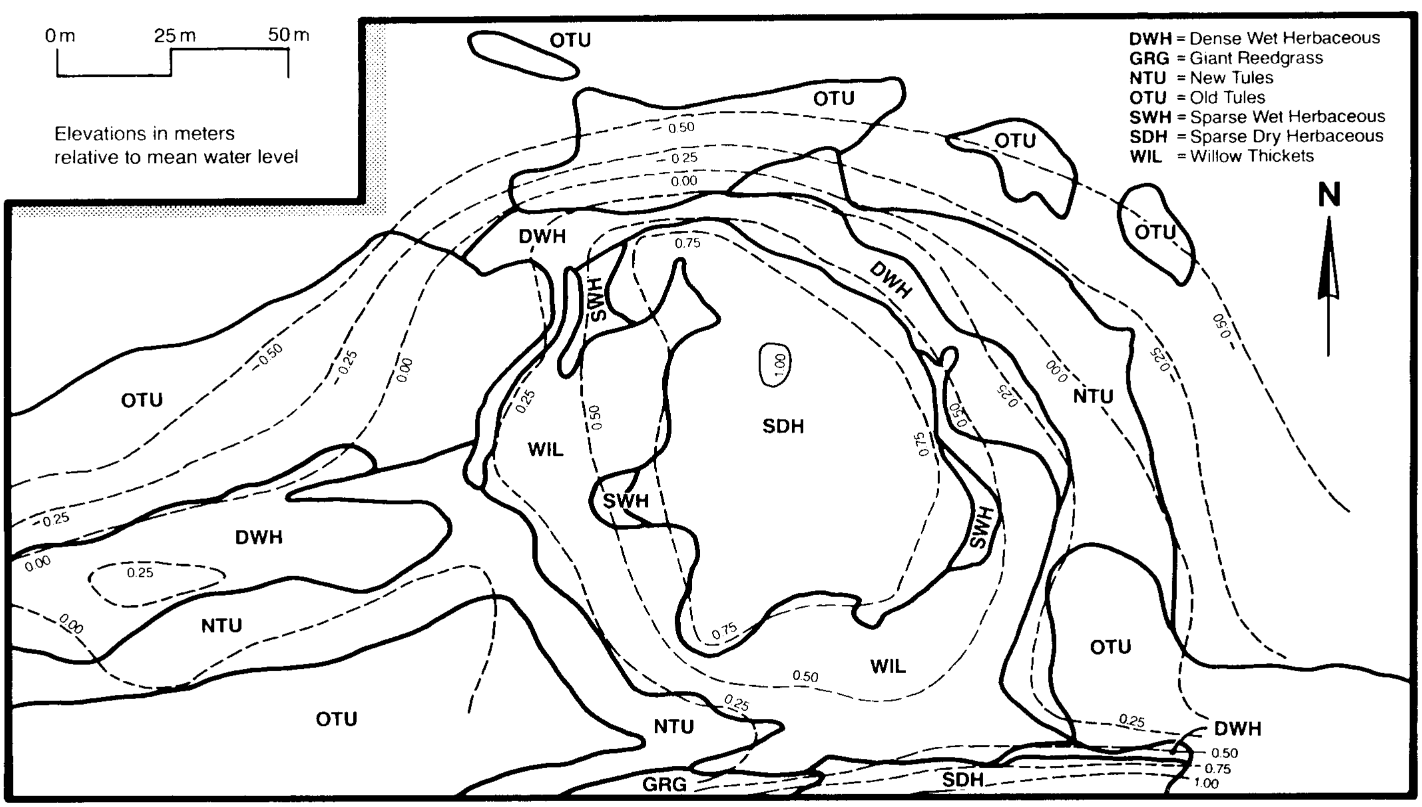

Figure 1– Topography and vegetation map of study site at Donlon Island in June 1988.

Table 1 - Percent average cover (AVGCOV), percent frequency of occurrence (FREQ),and importance values (IV) for two most important species found in each vegetation type on Donlon Island in late June 1988.

Vegetation Type[1] /Plant species	Avg. Cov. %	(±SE)	Freq[2] %	IV[3]
Old Tules (N=24)[4]				
California bulrush (*Scirpus californicus*)	68.3	(±5.4)	100.0	126.7
Cattail (*Typha* sp.)	9.1	(±2.7)	66.7	49.2
New Tules (N=24)				
California bulrush (*Scirpus californicus*)	29.1	(±6.6)	91.7	56.1
Cattail *(Typha sp.)*	20.1	(±3.9)	87.5	45.1
Dense Wet Herbaceous (N=24)				
Ladysthumb smartweed (*Polygonum persicaria*)	19.3	(±4.5)	79.2	24.0
Devil's beggartick (*Bidens frondosa*)	9.0	(±4.0)	62.5	13.7
Sparse Wet Herbaceous (N=5)				
Cudweed (*Gnaphalium luteo album*)	37.0	(±13.3)	100.0	55.0
Water bentgrass (*Agrostis semiverticillata*)	23.8	(±13.2)	80.0	37.4
Sparse Dry Herbaceous (N=24)				
Cudweed (*Gnaphalium luteo album*)	8.4	(±1.3)	91.7	44.6
Sticky willow herb (*Epilobium watsonii*)	4.5	(±0.7)	87.5	30.1
Willow Thicket (N=24)				
Willow (*Salix* sp.)	48.5	(±5.0)	95.8	45.6
Davy's centaury (*Centaurium davyi*)	13.0	(±3.3)	62.5	15.7
Giant Reed Grass (N=5)				
Giant reed (*Arundo donax*)	65.0	(±9.9)	100.0	61.3

[1] Vegetation types described in text.

[2] Frequency = percentage of sample quadrats (1 m 2) with species present.

[3] Importance value=(relative frequency + relative cover)*100%; maximum IV=200

[4] N = number of quadrats sampled in each vegetation type.

Table 2 -Temporal development of vegetation types on Donlon Island.

Date	OTU	NTU	DWH	SWH	SDH	WIL	GRG	Total
	Vegetation Type[1] (hectares)							
Winter 1985	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Spring 1987	1.0	0.4	0.3	0.3	0.7	0.4	0.0	3.1
Fall 1987	1.2	0.6	0.5	0.1	0.6	0.4	0.0	3.4
Spring 1988	1.3	0.6	0.5	<0.1	0.6	0.5	<0.1	3.5
Summer 1988	1.4	0.6	0.5	<0.1	0.5	0.6	<0.1	3.6

[1] Vegetation types described in text.

Giant Reed Grass (GRG) has established a small foothold at one site (fig. 1). This noxious weed has invaded from the adjoining levee and may be spreading (table 2).

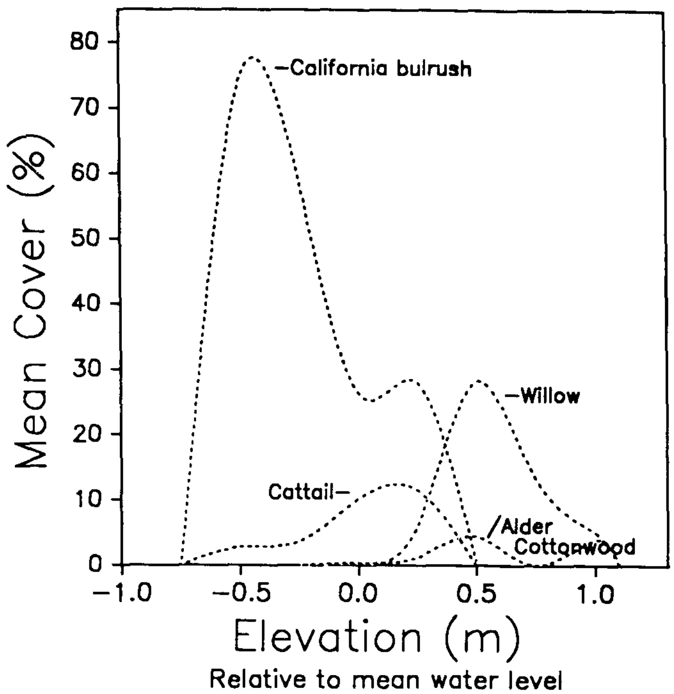

Figure 2- Distribution of perennial marsh and riparian woodland plant species on Donlon Island in June 1988, three and one half years after creation of the island.

Conclusions

Riparian and marsh vegetation is developing rapidly on the study site at Donlon Island. Our data suggest that the island may eventually consist of a band of tules and cattails from approximately -0.25 meters below to 0.50 meters above MWL. Riparian vegetation dominated by several tree species may develop from approximately 0.25 meters above MWL to at least near the top of the island (1.10 meters above MWL). These data are too early in the establishment process to determine the understory that may eventually be present under the riparian trees. However, at this early stage of development it is evident that valuable wildlife habitat has been created where none previously existed.

AIR-EARTH INTERFACE MODEL FOR RESTORING RIPARIAN HABITATS[1]

Robert M. Dixon[2]

The Santa Cruz River originates in the Patagonia Mountains in south-eastern Arizona, flowing south for about 24 km into the Mexican State of Sonora before curving to the west and then proceeding northwest hack into United States at the twin border cities of Nogales. From the border it courses north to Tucson and then northwest to the Gila Indian Reservation where it merges into the Gila River for a total distance of about 290 km.

The riparian system of concern in this paper is that portion of the watershed above Cortaro, Arizona (16 km northwest of Tucson). This part of the watershed has a total area of 9073 km^2 and includes the densely populated Tucson area along with the retirement community of Green Valley to the south.

This riparian system has been severely degraded by human activities during the past century. Severe overgrazing has eliminated most of the perennial grass communities, thereby denuding much of the watershed. Lacking protective vegetative cover, severe erosion has deeply gullied the watershed to accelerate runoff to the river channel. Over pumping of the aquifers (which once fed the Santa Cruz River) for agricultural and municipal purposes has lowered the historically shallow water tables to current depths of more than a hundred meters.

Now high-intensity long-duration rainfall runs off (instead of infiltrating) the Santa Cruz watershed, building into devastating and very costly floods as occurred in the Tucson area in October 1983. The response of the City of Tucson and Pima County to the flooding has been to straighten the river channel and smooth the floodplain wherever possible. The sidewalls of the river channel and floodplain are then stabilized with soil cement. However, this approach to flood control merely accelerates water flow, thereby causing severe cutting of the channel bottom and floodplain with resulting severe flooding and silting downstream where the channel and floodplain have not been straightened, smoothed and stabilized. Vegetative restoration of the Santa Cruz watershed is the only long term solution to this malfunction of the hydrologic cycle which is both ecologically and economically sound.

This poster paper outlines a new strategy for vegetative restoration of the Santa Cruz riparian system. The strategy has been successfully tested in both upland and lowland areas and is more cost effective than conventional alternatives when used in the arid Southwest.

The new strategy called the Air-Earth Interface (AEI) Model involves four interrelated and interacting AEI processes—*desertification, infiltration, imprintation* and *revegetation*—each of which will be briefly outlined on the following pages.

Desertification

Definitions

Generally, desertification is a land degradation process, triggered by human disturbances, which increases the aridity of the microclimate to which plants are exposed. Specifically, desertification denudes, smooths, and seals the air-earth interface to inhibit infiltration and revegetation processes.

Causes

Some causes of land desertification are:

1. Overgrazing of grasslands, shrublands, savannas, forests and associated riparian areas.
2. Overplowing of croplands usually for the production of annual plant species grown in a monoculture.
3. Overlogging of woodlands and forests for the production of lumber and paper pulp.
4. Industrialization involving the construction of pipelines, powerlines, well fields (oil and water), mining facilities, powerplants, factories refineries, warehouses, railways, and highways.
5. Mining, primarily pit and strip operations.
6. Urbanization involving the installation of utilities and the construction of streets, parking lots, housing, shopping centers, hotels and convention centers, and schools and playgrounds.
7. Flood control to mitigate the watershed effects of the preceding disturbances by straightening, smoothing, stabilizing, diking and diverting natural water courses to protect low-lying urban and industrial developments.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California

[2] Chairman, The Imprinting Foundation, Tucson, Arizona.

Problems

Some problems caused by desertification are:

1. Accelerated water runoff, soil erosion, flash flooding, and sedimentation, all of which are caused by reduced rainwater infiltration.
2. Reduced soil moisture, reduced groundwater recharge (falling water table), and reduced spring, stream and river flow, again caused by reduced infiltration.
3. Increased aridity of microclimate with corresponding deterioration in the habitats for plants and animals caused by a combination of low infiltration and high soil erosion.
4. Increased land denudation and decreased land productivity, also caused by low infiltration and high soil erosion.
5. Severe wind erosion, low visibility, and intense air pollution.

Two Examples

Figure 1. — Desertified upland watershed in the hot desert region of the Southwestern United States, caused by a century of severe overgrazing of Sonoran Desert shrubland. Both wind and rainwater from intense summer thunderstorms sweep freely across this smooth barren surface stripping away topsoil which took millennia to form.

Figure 2. — Floodplain erosion, caused by upland watershed desertification, exemplifies the twin hazards of desertification—upland droughts and lowland floods.

Infiltration

Definitions

Generally, infiltration is a process in which water moves vertically downward through the soil surface into the soil below to recharge soilwater and subsequently groundwater. Specifically, the process exchanges rainwater and soil air across the air-earth interface (AEI). Infiltration is rapid across a rough, open AEI and slow across a smooth, closed AEI.

Vegetation

Soil surfaces covered with vegetation, which are naturally rough and open, infiltrate water about 10 times faster than the smooth, sealed surfaces of desertified land. This means that a vegetated surface infiltrates most, if not all, of the rainfall on-site, whereas the barren desertified surface sheds most of it to erode and flood land lying down-slope.

Erosion

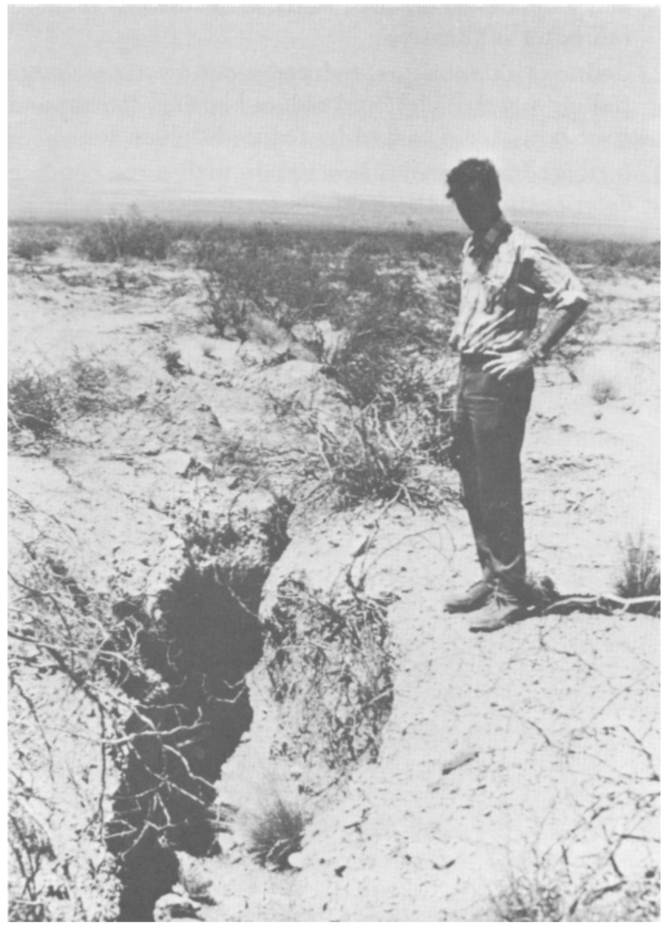

Figure 3. – Rainwater erosion of topsoil caused by severe overgrazing. Accelerated soil erosion is caused by accelerated rainwater runoff, in turn, caused by decelerated infiltration in response to desertification. This chain of cause-and-effect processes becomes a vicious circle that perpetuates itself in the fragile ecosystems of the southwestern United States, long after the original disturbance (such as overgrazing) has been removed.

Imprintation

Definitions

Generally, imprintation is a mechanical process in which angular teeth are forced into the soil surface to form funnel-shaped indentations, where seeds germinate and seedlings establish with a minimal amount of rainfall. Specifically, it is a process that roughens and opens a smooth, closed air-earth interface to accelerate infiltration, revegetation, and reversal of desertification.

Two Examples

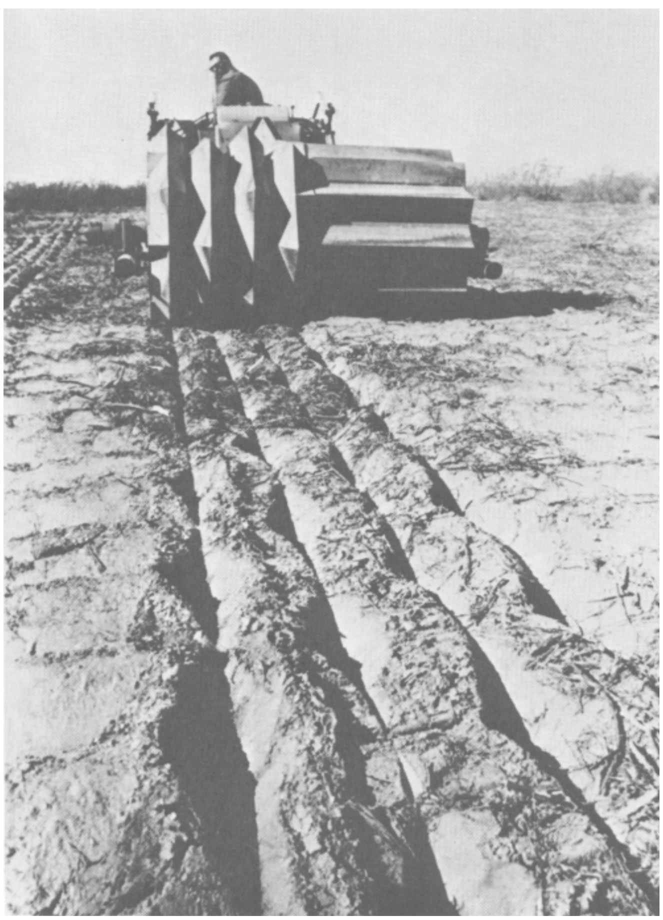

Figure 4. – Imprinting a desertified upland watershed converts the smooth sealed air-earth interface into the rough, open condition, thereby accelerating infiltration and revegetation processes.

Figure 5. – Imprinter seeding a 243-ha desertified floodplain near Cortaro, Arizona in November, 1987. Imprinting and seeding the floodplains as well as the upper parts of the watershed can prevent destructive flash flooding (and associated erosion and sedimentation) of the river channel.

Revegetation

Definitions

Generally, revegetation is the reestablishment of plant communities destroyed by the desertification process. Specifically, it is a process, beginning with seed germination and seedling establishment, that needs, creates and maintains a rough, open air-earth interface to reverse desertification and rebuild topsoil.

Two Examples

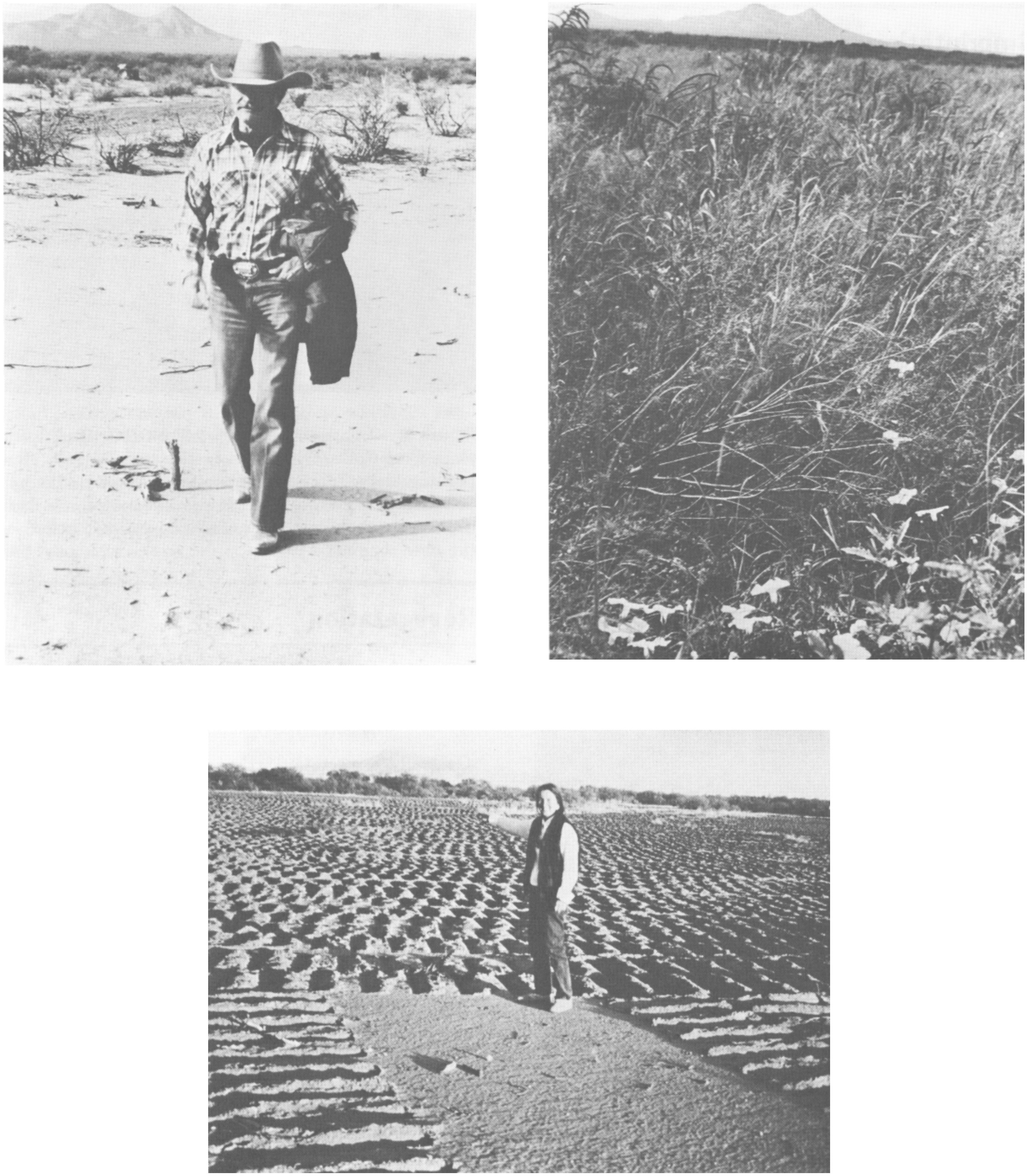

Figure 6. — Upland watershed revegetation through imprinter seeding of 13 species. Before imprinting (left): Barren rangeland on the Agua Blanco Ranch west of Tucson severely desertified through a century of overgrazing (Nov. 1982). During imprinting (center): Freshly imprinted land except for center foreground area of the picture (Nov. 1982). After imprinting (right): Vegetative response to imprinter seeding (Oct. 1983).

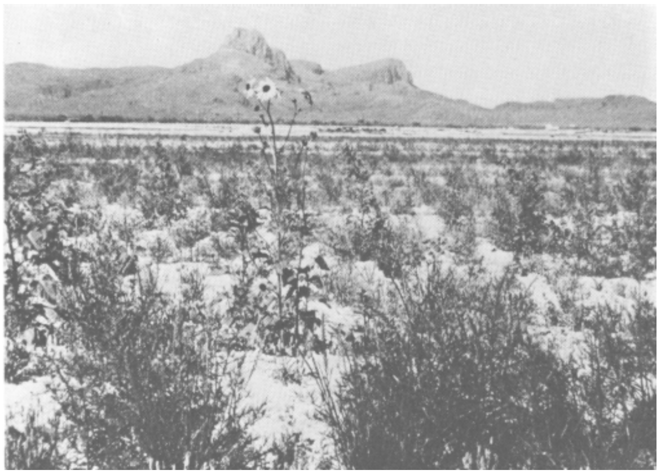

Figure 7. – Vegetative response to the imprinter seeding of the Santa Cruz floodplain shown in Figure 5. Winter rain brought up this good stand of annual and perennial cool-season species (May 1988).

Summary

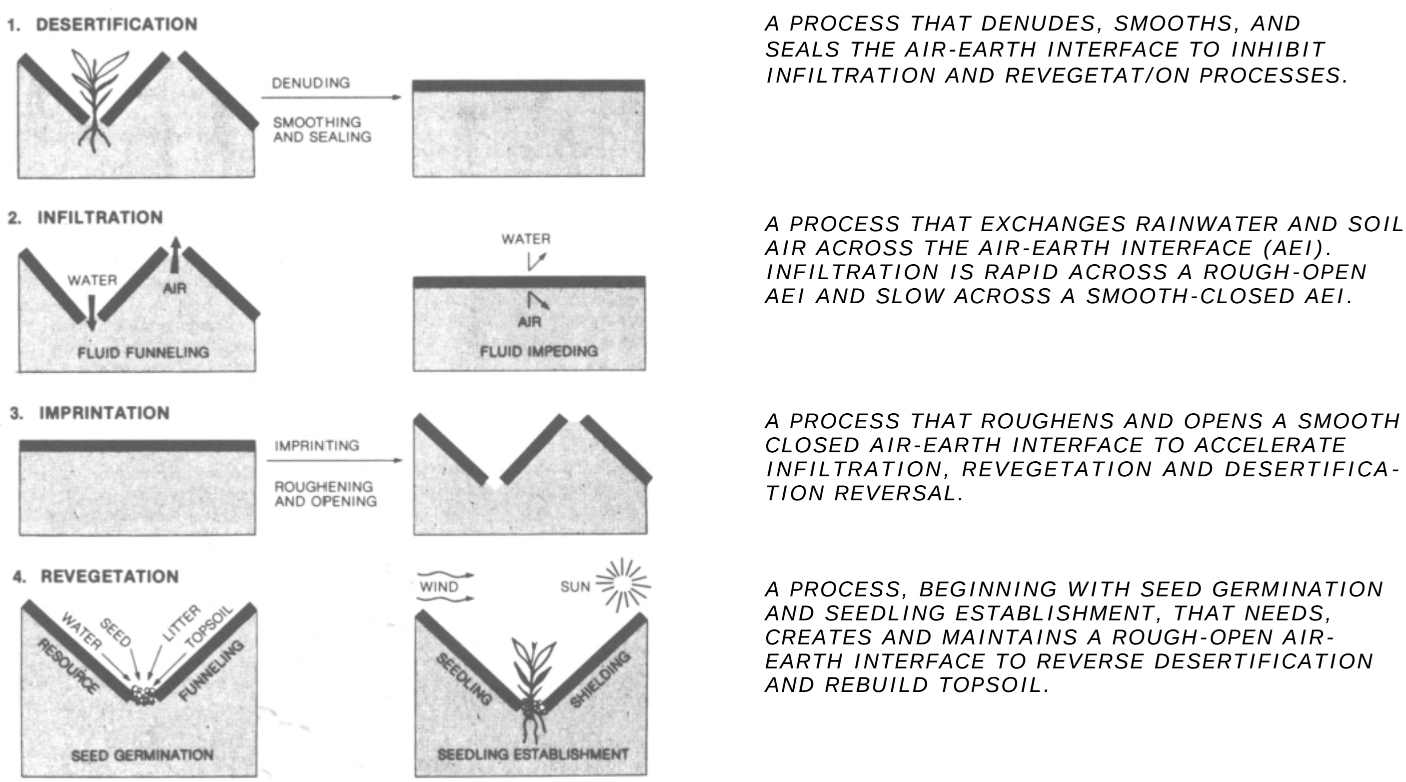

Figure 8. – The AEI Model evolved out of a quarter century of basic and applied research conducted under a wide diversity of plant, soil and climatic conditions. It integrates principles drawn from edaphology, hydrology, climatology, biology, and ecology to form a relatively simple and cost effective strategy for reversing land desertification through revegetation. An important application is the restoration of riparian systems to benefit people, wildlife and plants.

SESSION J: URBAN STREAMS

Two significant changes have occurred in riparian resource management, as it affects urban streams, since the first California Riparian Systems Conference in 1981. One has been the emergence of a strong movement at the urban neighborhood level seeking the preservation and restoration of the few remaining unculverted creeks flowing in cities. As a consequence of this, a new breed of participant; the urban volunteer activist, appeared in significant numbers at the 1988 conference. The increased awareness of riparian values at the grassroots level comes at a time when there is not much left of the State's riparian resources. In recognition of this, this new breed of environmentalist has moved the State to create a new Urban Creeks Restoration program, which is housed in the California Department of Water Resources. It disperses funds for a wide range of projects to protect and restore streams in urban areas. The movement has developed enough political clout, too, to influence federally or locally designed flood control and stream bank stabilization projects. In a few cases this emerging public interest has resulted in the drafting and adoption of new local regulations on development, open space planning, zoning and riparian corridor maintenance and management.

The other significant change that has occurred since 1981 has been the emergence of an environmental restoration movement and, with that, a group of restoration professionals. The formation of the California Riparian Study Group and the founding of a national group called the Society for Ecological Restoration are important steps in the establishment of a professional restoration discipline. Its major focus, at present, is on riparian systems.

Papers in this section provide examples of these two phenomena. Some of the papers were submitted by citizen volunteers who have been directly involved in designing (usually redesigning) flood control and bank stabilization projects. Some of the authors have contributed many hours of hands-on effort, seeking to conserve and enhance the riparian values of streams in their home areas. Among the speakers and panelists in the sessions on urban streams were environmental consultants and local, State, and Federal officials who are trying to respond to these public demands for more socially and environmentally sensitive projects. The reports presented here represent only a sampling of the papers given at the conference. They identify several, but certainly not all, of the technical, social, economic, and political issues growing out of the stream restoration movement. Most importantly, they call attention to successes that these volunteer groups and the associated government agencies are enjoying in meeting the urban stream restoration challenge.

A. L. Riley
California Department of Water Resources

THE WILDCAT-SAN PABLO CREEK FLOOD CONTROL PROJECT AND ITS IMPLICATIONS FOR THE DESIGN OF ENVIRONMENTALLY SENSITIVE FLOOD MANAGEMENT PLANS[1]

A. L. Riley[2]

Abstract: In 1982 a coalition of neighborhood and environmental organizations used a community organizing strategy of the early 1960's, referred to as "advocacy planning" to substantially redesign a traditional structural type of joint federal and local flood control project on Wildcat and San Pablo Creeks in North Richmond, California. Using a combination of foundation and other funding, the coalition designed their own water project that would preserve and restore the riparian values of these two highly urban creeks and would not only meet the important objective of reducing flood damages but would also retain the pair of streams as an important community resource. The advocacy planning process developed into consensus planning, in which all the government agencies and parties with an interest in the project formed a design team and arrived at a very different sort of flood control project. The project provides a useful model for both project design innovations and creates a design process which can have significant influence on the salvaging of natural riparian environments.

A flood control project is currently (1988) under construction on Wildcat and San Pablo Creeks in North Richmond, California, which was designed for the complementary objectives of reducing flood damages, preserving or restoring the riparian environment, restoring brackish marshes and fresh water wetlands, environmental education, recreation, and aesthetic enhancement of the community. The set of " Standards and Principles" used by the Federal water development agencies in the 1980's to design and fund water projects have, in effect, put the federal government in the business of single objective planning. This project imposed a multiple objective planning process on a planning system designed to discourage more than one objective. Important lessons can be learned from this project's fascinating history, design process, funding strategies and design features.

The History of Project Planning

Background

No one has questioned the claim that flood reduction measures are needed on Wildcat and San Pablo Creeks. The issue has been over the proper design of the project and how best to develop funding opportunities for it. Flooding due to overflow of Wildcat and San Pablo Creeks and to poor local drainage occurs almost every year, with more severe flooding (more than a foot of water) taking place in North Richmond about once in three years (Design Memorandum, USACE 1985).

North Richmond was developed during World War II when blacks who were brought in to the shipbuilding industry were segregated into a community on the Wildcat-San Pablo floodplain. As recently as 1980, Census figures showed 64.5 percent of the households as female headed and below the poverty level.

One of the earliest reports on the need for flood control was written by the Contra Costa County Flood Control District in 1956. In consequence of this, Congress authorized a feasibility study for flood control on the two creeks in the 1960 Flood Control Act. This resulted in a 1968 report from the Army Corps of Engineers (Army Corps) on alternative flood reduction plans, but no plan was recommended then for implementation because the prevailing poverty conditions forced the total benefits (largely as property to be protected) so low that no project option could pass the federal cost benefit test.

In the meantime, a Richmond Model Cities Program had begun, and by 1971 a community based plan was developed that featured Wildcat and San Pablo Creeks and the San Pablo Bay shoreline as a recreational commercial resource to serve as a focus for the redevelopment of the area. The Model Cities Program called for the Department of Housing and Urban Development to revive flood control planning. This led HUD to contract out for a privately prepared economic analysis. The more favorable cost benefit formulas from consultants that were engaged for this study enabled the Army Corps to conduct

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Citizen Volunteer, Berkeley, California.

a planning process reflecting the new pressures of the 1970's to increase public participation in project planning. This process yielded a new community supported flood control plan which received Congressional authorization in 1976. This plan reflected traditional structural principles of flood control planning and featured open concrete channels, closed culverts, and trapezoidal earth channels. It was unusual, even for the 1970's, in including environmental features such as fishing ponds, trails, and picnic areas.

When proponents of this project set about raising the required local share of the expense, they encountered difficulties on almost every front, not the least of which was the fact that some major beneficiaries would not agree to share in the project costs. Among them were Chevron Oil, the Southern Pacific Railroad, the Atchison, Topeka and Santa Fe Railroad (which had a train derail over San Pablo Creek in the January 1982 storm), and the Richmond Sanitary Company. This contributed to the failure of the local effort to raise the required sum for the project.

In 1982 Contra Costa County proposed a "bare bones" structural flood control project, to be constructed in cooperation with the U. S. Army Corps of Engineers, without any environmental amenities. They presented the plan on a "take it or leave it" basis, arguing that it was the only affordable alternative.

The Consensus Plan

Some North Richmond residents were resigned to accepting any flood control project offered. Others felt so strongly about the Model Cities Plan, however, that they wanted to retain some influence on the flood control design process and sought to explore a number of project options. In the spring of 1983 Ivy Lewis, a respected long time community leader, organized a meeting in North Richmond to react to the county flood control proposal. Ann Riley and Alan La Pointe, representing the Urban Creeks Council, and Phil Williams, a well known expert in hydrology, attended this meeting. The issues raised at that meeting defined the work for the next five years, as citizen volunteers sought to change not just the plan design but the planning process itself and funding strategy as well.

The North Richmond community groups, which included the Richmond Neighborhoods Coordinating Council, headed by Lillie Mae Jones, the Urban Creeks Council, the Save San Francisco Bay Association, and the Contra Costa County Shoreline Parks Committee, formed a coalition to request that a plan be developed to recognize Wildcat and San Pablo Creeks and the shoreline as important local and regional resources. Their statement pointed to severe technical difficulties in the county plan and identified a number of regulatory and funding problems associated with it.

There were also several important environmental concerns. One was that Wildcat Creek in particular had been identified by the California Department of Fish and Game as one of the last streams in the Bay Area which still had nearly continuous riparian environment along its length. This plan would convert much of it to a concrete and earth lined channel, complete with covered box culverts. Second, a number of hydrologists and environmental experts were concerned that the project would seriously degrade the important wetlands associated with the lower flood plains by concentrating the stream systems' sediment load on that area. Third, there were no plans to provide recreational open space and the related educational benefits for the local communities. Effects on adjoining regional parks were similarly ignored in the plan.

One of the technical concerns raised by Phil Williams was that the estimates of sediment moving through the creek system were substantially too low. He also expressed the view that the concrete lined channels would not provide the flood protection assumed by the project designers because the sediment would increase the hydraulic resistance and decrease the capacity of the channels. He was concerned, too, that the plan created costly and frequent maintenance needs, and that the proposed sediment detention basin on Wildcat Creek would not protect Wildcat Marsh from sedimentation. He was supported in his views by the well known hydrologist Professor Luna Leopold of the University of California, Berkeley.

The citizen's coalition also questioned the wisdom of locating a box culvert that would be carrying high velocity storm flows next to an elementary school. They anticipated difficulties in getting regulatory approval from State and Federal agencies for the County Corps plan (which the agencies called the "Selected Plan"), and they predicted trouble in obtaining funding for such a plan, given Washington's demands for increasing the local cost sharing requirements, and given its unattractiveness to other potential Federal and State participants.

Even though a planting of native trout in Wildcat Creek sponsored by the Grizzly Peak Flyfishers, East Bay Regional Park District and the Department of Fish and Game in September of 1983 increased public awareness of these environmental issues, the County still remained opposed to broadening the project objectives or responding to technical reviews. The Urban Creeks Council and the Richmond Neighborhoods Coordinating Council decided that the best strategy was to develop their own plan, and they were successful in obtaining

Vanguard and San Francisco Foundation funding to do so. Mary Jefferds, on the Board of Directors of the East Bay Regional Park District, was an early supporter of such a planning effort because she saw an opportunity in it to extend popular regional trails by linking Wildcat Canyon and the Point Pinole Shoreline Park through the Wildcat and San Pablo Creek flood management project and the marshes.

Additional financial assistance from Save the San Francisco Bay Association and the Regional Park District brought the final alternative planning budget to $50,000. With Phil Williams' assistance on the hydraulics, a "Modified Plan" based on a very different design philosophy was developed. The approach was to modify the existing creek channels to simulate the natural hydraulic shape of undisturbed streams, thereby continuing some of the normal fluvial processes. This would cause sediment to be deposited on the upstream floodplain and restore valuable riparian vegetation. The proposed concrete and trapezoidal dirt channels would be replaced in this plan by more natural low flow channels that would be bordered by flood plains and have set back levees, planted gabion walls, and riparian trees. Thus, regional trails and park facilities would become possible.

The citizen planners developed their own project cost estimates and funding plan and presented their "modified plan" at all the same meetings attended by the public and government agencies in which the "selected plan" was presented. Assembly Member Bob Campbell's staff lead in the search to identify new funding sources which would be made possible by the broader objectives of the modified plan. Through negotiation with the County they also helped develop a planning process to arrive at some sort of consensus plan. This included County appointed design and funding teams.

On February 19, 1985 the Contra Costa County Board of Supervisors approved the "selected plan" for construction but left the door open for the modified plan, conditioned upon the availability of funds.

Two outside opinions then swung the balance toward compromise. In June 1985, a legally required biological opinion from the U.S. Fish and Wildlife Service (USFWS) called attention to impacts of the "selected plan" on the marshes and their endangered species. Their opinion identified the modified plan as "the prudent and reasonable alternative."

The second blow to the selected plan came from the San Francisco Bay Conservation and Development Commission (BCDC) which found that plan inconsistent with the BCDC Bay Plan (McAteer Petris Act). The BCDC opinion found the modified Wildcat San Pablo plan to conform to the Bay Plan.

This series of events set the stage for the eventual development of a consensus plan for which the modified plan provided the major components. Construction began under this consensus plan in 1987 and continues today.

Contributions to the Flood Control Project Design Process

The Consensus Design Approach

The establishment of a project design team by the County Board of Supervisors has represented a unique contribution to federal flood control project planning. The team consisted of representatives from the U. S. Fish and Wildlife Service, the California State Lands Commission, the California Department of Fish and Game, the San Francisco Bay Conservation and Development Commission, the California Coastal Conservancy, the East Bay Regional Park District, Assembly Member Bob Campbell's office, State Senator Dan Boatwright's office, Congressman George Miller's office, the coalition of citizen groups, local land and nursery owners and, of course, the Contra Costa County Flood Control District and the U. S. Army Corps of Engineers.

It is important to recognize that this team was formed for the entirely practical purpose of coordinating and integrating the concerns of the regulatory agencies and the public. It would be incorrect to say that the County acted out of an enlightened intent to pioneer consensus planning. The design team was formed under crisis conditions caused by the lack of support for a traditional type of project and by the bad publicity that the proposed County Army Corps project had generated.

The team was charged with producing a fundable project that the regulatory agencies would accept and which the public groups could endorse. Meetings were held no less than once a month. In 1985 this sometimes meant as often as once a week. Throughout the five year planning effort the attendance at design meetings remained high, averaging approximately 20 a meeting.

Power blocks formed and the different interests on the team competed vigorously. Many of the meetings could only be described as grueling. An important turning point in the consensus making process came when a neutral person, who happened also to have good group management skills, was appointed to chair the team. This was James Cutler of the County Planning Department.

In this way a project was designed, funded and constructed in only three years—this after an unsuccessful 25 year planning history. One notable problem occurred when relevant interested parties were not included on the design team. Specifically, the Richmond Unified School District was not adequately involved in designing the part of the project which ran through their property near an elementary school. The School District held up the project by withholding the project's right of way until its concerns were met. The District also used the advocacy planning strategy, hiring their own consultant to design an alternative.

Another major problem developed when continuity in decision making and plan formulation broke down because personnel were constantly changing at the Army Corps and the County Flood Control District. One result was that construction plans which did not reflect the consensus of the design team were given to the contractors and a half mile of riparian vegetation that was to be preserved ended up being bulldozed.

Shortly thereafter, a levee was put in the wrong location. This blocked a plan to restore a marsh and jeopardized State funds for the part of the plan involving wetland enhancement. Assembly Member Campbell's office helped tighten the planning process, and the Design Team then made certain that minutes were adopted in public sessions and approved stream project cross sections and maps were published.

Project Design Features

One of the most important features of the citizen's "modified plan" was that the stream corridor or floodway was designed to remain within the same narrow right of way boundaries as the County Army Corps' plan, while providing the same level of protection from a 100 year flood event. The modified plan, however, provided for a channel geometry based on natural floodplain features in place of the standardized trapezoidal and rectangular channels and box culverts. It is commonly assumed that a strict geometric channel must be constructed if channel width must be limited. The new channel design called for a meandering low flow channel 10 to 15 feet wide, designed to carry what hydrologists call the 1.5 year recurrence interval flow. This is a "flood" that is barely any higher than the highest flow in the most ordinary of years. In the modified plan the low flow channel was to be bordered, in one reach, by a floodplain terrace where higher flows could spread, lose velocity and deposit sediment. Riparian vegetation would be included on both sides of the low flow channel. This design provides for trapping as much sediment in the upstream floodplain terrace as possible to keep downstream marsh areas from filling in. The plan also called for widening the slough channel through Wildcat Creek marsh at the mouth of the stream and excavating sediment there. This would increase the brackish marsh area and restore tidal action in the marsh.

As the consensus plan developed, the design team was able to provide a wider channel than either earlier plan called for because of the addition of lands to the project by two other entities. The State Lands Commission purchased some downstream land on Wildcat Creek to provide a transition zone between the riparian corridor and the bayshore marsh. This was designed to serve also as a sediment catchment area. Upstream on Wildcat Creek the School District donated additional land for the right of way when it discovered the land would provide them with more design options.

While the consensus plan is unquestionably a compromise between two design philosophies, the basic components of the modified plan were preserved in it. Features were retained largely because of the importance of managing the large amount of sediment, particularly in the Wildcat watershed, in order to avoid degrading the habitat of endangered species in the marshes.

The Waterways Experiment Station in Vicksburg Mississippi which was assigned the task of reviewing the project design required a change in location of an upstream sediment catchment basin before the Office of the Chief of Engineers would approve the design. This change ultimately raised the land acquisition costs for the project.

Funding History

The fact that this project made a transition from a single objective project that was concerned with flood control alone to a multiple objective project that would create a riparian corridor in the midst of the city, restore marshes, provide recreational, and educational opportunities and enhance the environment of a largely impoverished urbanized area made it possible to attract funding from State agencies that could not have been approached before. As a result, the East Bay Regional Park District committed $793,000 for a regional trail system which was then matched by another $793,000 by the Army Corps. The Park District later committed $19,000 to help enhance creekside educational opportunities near Verde School. The District may possibly commit more as the recreation and educational project element is finalized.

In addition, the California State Lands Commission purchased $240,000 of lands for the Wildcat Creek wetland transition zone, mentioned above. In February of 1987 the California Coastal Conservancy Board improved prospects for both the wetland and riparian aspects of the plan by authorizing an expenditure of $578,000 for marsh restoration and riparian enhancement. After the original restoration plan was upset by the construction mistakes in the Wildcat and San Pablo

Creek marshes and after the County was unable to identify willing sellers of riparian land parcels, the Coastal Conservancy headed a task force to come up with a new marsh restoration Plan. A total of $46,200 was used from the first Coastal Conservancy authorization, with $5000 going to the design team effort. The Conservancy Board then authorized an additional $314,870 to implement a revised restoration plan.

As of the fall of 1988, the consensus plan has attracted non flood control funds totalling at least $1,905,000. Various contingencies could raise that to $2,428,000. The design team's finance committee is not finished with its fund raising activities, however, and there are reasonable chances of more State or Park District monies becoming available.

The federal project cost sharing policies in the 1980s have stressed increasing the non federal contributions for projects and using both the ability and the willingness to pay as criteria for approving projects. Their policies have historically made it extremely difficult for a poverty community to meet the costs associated with a large project in this case $30 million. The strategy that this community found best to use in raising its non-federal share was to diversify the project and attract State dollars for these added benefits. This created a "Catch 22" situation, however. These new aspects of the project added to total project costs, which, under current federal policy, raised that side of the cost-benefit ratio. The prospect was that whatever money might be contributed for these new project elements would have no effect on financing the flood control project, leaving project approval just as far out of reach as ever. The Army Corps' project manager worked around this impasse by classifying the marsh restoration, riparian areas, wetland transition zone, etc. as enhancements occurring outside the project boundaries and therefore not part of the official project costs.

Thus, it turned out that there were ways around the bias that exists in evaluation and funding policies for federal projects, but it seems likely that few of the many disadvantaged minority communities that, by societal default, have grown up on some of the most severely flood threatened lands will be able to follow this route. The cost sharing requirements make it a local responsibility to purchase lands, easements and rights of way. This builds in a bias against the purchase of riparian preservation zones, trails and other environmental features in communities like North Richmond.

Technical Issues Reviewed

One controversial technical issue was that of estimating the sediment loads that would be carried by the creek. Philip Williams argued that the natural creek channel could be expected to carry higher sediment loads than the Army Corps had figured and predicted that the bed would accumulate deposits, reducing channel capacity. Widening the channel, which was the Corps' response, would further increase deposition, in Williams' view. He designed the project in the modified plan, with its narrow low flow channel and flood terraces to better transport sediment in suspension at higher velocities.

Philip Williams and the distinguished hydrologist Luna Leopold both questioned the ability of the proposed sediment basin to perform as a trap. Later, specialists at the Waterways Experiment Station of the Army Corps of Engineers independently expressed the same concern. A newly located basin further upstream, the higher velocity low flow channel, the floodway terrace and the wetland transition zone at the mouth all became features of the consensus plan for Wildcat Creek, with the aims of limiting deposition in the marsh and on the stream bed.

An additional design issue grew out ,of the requirement to mitigate for the loss of twenty four acres of riparian vegetation. The original 1982 proposal called for planting trees on some acreage located north of Wildcat Creek. The consensus plan integrated that wooded acreage into the project corridor, placing it along the low flow channel to help the stream form and maintain that channel and provide shade to help control of the growth of rushes, reeds and aquatic plants. These are seen as clogging the channel and inducing sedimentation. County Engineers did not want vegetation near the channel because they felt this would make maintenance difficult for them.

Another difficult issue was the assignment of "roughness" values for the Manning Equation to portions of the floodway containing vegetation. This affects decisions on how wide a channel must be built and how much vegetation must be cleared during maintenance operations. The choice of values is partly subjective. Thus, the Army Corps originally considered using a value of 0.100 for the riparian areas next to the low flow channel and 0.045 for the north flood terrace. Negotiation in design team meetings finally yielded an agreement to use a composite value for the low flow channel and south bank riparian forest of 0.050, conditioned upon keeping the low flow channel clear. A .035 value was assigned for the north bank flood terraces, which would be maintained in low shrubs and grasses.

Agreement then hinged upon the development of a consensus regarding a maintenance plan to keep the low flow channel cleared of vegetation until a riparian canopy could grow. This canopy would then be expected to shade out the unwanted vegetation which will fill much of the exposed low flow channel. The agreement was negotiated in this case between the County Supervisor and the Project Manager for the Army Corps of Engineers and was based upon using inexpensive hand labor provided by conservation crews. The potential crews include the State's Conservation Corps and a local East Bay Conservation Corps, as well as possible assistance from the State's new "workfare" program. It was also agreed that annual maintenance routines would be replaced by a program based on actual need. Maintenance activities, costs and impacts will be reduced by acting only to assure that specific channel capacities can be maintained.

Finally, in a move to make certain that the revegetation effort restore a riparian environment along the low flow channel, as recommended by both USFWS and the State Lands Commission, rather than simply landscape a flood control project, the County requested that the U. S. Soil Conservation Service (SCS) provide a landscape architect with experience in revegetating streams. They did so, under contract with the Army Corps, loaning Robert Snieckus to the project. Be will be using root wads and cuttings from plants on or near the site, together with seeds and container stock of species native to the locale. Specifications are provided in a September 1988 supplement to the Corps' design memorandum. Recognizing the competence of landscape architects in this role, the design team has requested that the Corps continue the SCS staff to do the planting.

The test of this innovative project will of course be in the product, with the questions being, first, will final construction meet the design team's specifications and, ultimately, will the flooding problems in North Richmond be significantly reduced?

RIPARIAN AND RELATED VALUES ASSOCIATED WITH FLOOD CONTROL PROJECT ALTERNATIVES AT WILDCAT AND SAN PABLO CREEKS[1]

Philip A. Meyer[2]

Abstract: This analysis will consider Riparian benefits from alternative project designs at Wildcat and San Pablo Creeks. Particular emphasis will be placed on quantification of riparian values and on the relationship of projects benefits for each project alternative to estimated costs of implementation.

Riparian habitat supports a number of economic values that are realized in the market place—production of timber and livestock grazing being two easily recognizable examples. Identification of the value of riparian habitat for recreational or aesthetic pursuits is more difficult to achieve in economic terms, as these benefits are seldom marketed. Concepts underlying economic evaluation of such non-marketed benefits are well developed (Knetsch 1983; Bromley 1986; Hogarth and Reder 1986; Cummings, Brookshire and others 1986; Meyer 1987). Meyer Resources (1982) has applied these techniques explicitly to riparian habitat—and over a range of ecological quality.

Our procedure in this paper will be to update selected recreational/aesthetic values developed for riparian habitat for the Sacramento River in Meyer Resources (1982), to insert them into the evaluative dialogue at Wildcat and San Pablo Creeks, and hence to gain insight into the role riparian values may play in project planning.

Riparian values represented here were developed in Meyer Resources (1982) for Sacramento residents, and focused on the Upper Sacramento River between approximately Colusa and Red Bluff. Values selected for this report were framed under two alternative hypotheses: a "willingness to pay" framework that presumed residents had no particular right to riparian habitat, but would have to compete with alternative uses to maintain it; and a "fair compensation" hypothesis that presumed that residents did have a right to the natural amenities associated with riparian habitat and that compensatory values should be associated with destruction of such habitat. These issues are more fully discussed in Meyer (1987).

Values in the Meyer Resources (1982) survey were also delineated by quality of riparian habitat, specifically: a stream where most riparian habitat has been removed, and little in the way of fish and wildlife is evident; a thirty foot riparian leave strip on each side of the stream, supporting a variety of fish and wildlife species, and considered by experts in the California Department of Fish and Game and the U.S. Fish and Wildlife Service to be approximately 3 to 4 times more ecologically productive than the prior degraded streamside; and full riparian vegetation for at least 1/4 mile on each side of the stream, considered by the same experts to be approximately 8 to 9 times more supportive of fish and wildlife than the degraded stream. Readers should refer to Meyer Resources (1982) for a more exact description of each alternative stream type.

Results from that survey, updated to 1985 dollars are presented in Table 1. Total values figures are based on a 2 percent discount rate and a 100 year time horizon. The values in parentheses are based on a 6.86 percent discount rate, equivalent to that used in earlier work on Wildcat and San Pablo Creeks by the U.S. Army Corps of Engineers. Increasingly, recent practice has been to use discount rates < 4 percent (eg. Lind 1982; Meyer Resources 1988).

Table 1 -Recreational/aesthetic values for selected riparian acreage.

Riparian Condition:	Willingness to pay to retain riparian habitat		Compensation Required if riparian habitat is lost	
	Annual value	Total value	Annual value	Total value
	in 1985 dollars per acre			
Stream banks largely bare	201	8,635 (2,927)	311	13,361 (4,527)
30 foot riparian leave strips	850	36,516 (12,373)	1,879	80,722 (27,352)
1/4 mile or more of riparian habitat on each side of stream	1,328	57,051 (19,331)	4,096	175,965 (59,625)

Options and Prior Analysis at Wildcat and San Pablo Creeks

Wildcat and San Pablo Creeks are urban creeks lying in Contra Costa Country, and flowing throughout the City of Richmond to greater San Francisco Bay (U.S. Army Corps of Engineers 1986). The two creeks

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] President, Meyer Resources Inc., Davis, CA.

have been subject to periodic flooding, and a series of progressively more habitat sensitive designs to deal with this problem have been suggested. Two of these plan alternatives are discussed here to facilitate our comparative analysis: a 1985 "selected" plan by the U.S. Army Corps of Engineers (1985); and a "modified" plan put for ward by a citizens group in 1985 (Philip Williams and Associates 1985). Both the 1985 selected plan and the 1986 revised plan display a return of benefits to costs slightly over 1.0, according to the Corps. Details of those plans will not be repeated here, and readers are referred to indicated source documents in that regard. The 1985 Corps selected plan was more adverse for riparian habitat than the 1985 citizen's modified plan. Estimated costs also differed between the two plans, based on U.S. Army Corps of Engineers estimates. AT time of writing, a Corps 1986 "revised" plan has also been developed. It does not provide sufficient data to be analyzed here however. Data required for this analysis has been summarized, and stated in 1985 dollars by Riley (1988). Results are presented in Table 2.

Table 2 - A Summary of comparative impacts on riparian habitat and of cost for two Alternative plans at Wildcat and San Pablo Creeks.

Comparative feature	1984 Corps selected plan	1985 Citizen's modified plan
Cost of the plan (1985 dollars)	$27.65 million	$27.96 million
Riparian acres preserved	0.0 acres	13.2 acres
Riparian acres restored	1.8 acres	9.1 acres

Source: Riley (1988), developed from U.S. Army Corps of Engineers (1985) and Philip Williams and Associates (1985).

A Comparison of Recreational / Aesthetic Benefits Associated With Riparian Habitat in the 1984 Corps and 1985 Citizens Plans

We are now in a position to compare the benefits associated with riparian habitat under the 1984 Corps Selected Plan and the 1985 Citizens Modified Plan. This comparison is achieved as follows. First, we note that the design configuration of the two plans (U.S. Army Corps of Engineers 1985; Philip Williams and Associates 1985) suggest an expanse of riparian vegetation that may fall somewhere between the "thirty foot riparian leave strip" and the "1/4 mile or more of riparian habitat" utilized by Meyer Resources (1982). We will utilize the more conservative "Thirty foot leave strip" value from Table 1 for this analysis.

Second, as there will be some sort of stream bank under any conceivable scenario, we will employ only the value differential between values for a "largely bare bank" and a "thirty foot leave strip" (table 1) in our calculations.

Third, for purposes of this illustrative analysis, we presume that no public trust or similar mandate applies to valuation of "existing" riparian habitat, but that such a mandate does apply to "restoration" of riparian habitat. We will consequently use values from the "willingness to pay" column of table 1 to value existing riparian habitat, and values from the "compensation required" column to value riparian habitat that would be restored. These conversions are arbitrary but likely conform to appropriate procedures for a real time analysis. Further, it will be found that they affect the absolute magnitude of values identified but have little effect on the relative value conclusions we will draw.

Proceeding in this manner, we integrate data from tables 1 and 2 to obtain estimates of the value of riparian habitat under the two plans (table 3). Values are presented using the recommended discount rate of 2 percent, and the higher discount rate of 6.86 percent employed by the Corps in their 1985 analysis.

Table 3 - Comparative values of riparian habitat under two alternative plans at Wildcat and San Pablo Creeks

	Plan	Value per acre		Total riparian value	
		2% discount	6.86% discount	2% discount	6.86% discount
1.	1984 Corps selected plan				
	0.0 acres preserved	27.9	9.4	0.0	0.0
	1.8 acres restored	67.4	22.8	121.3	41.0
	1.8 total acres			121.3	41.0
2.	1985 Citizen's plan				
	13.2 acres preserved	27.9	9.4	368.3	124.1
	9.1 acres restored	67.4	22.8	613.3	207.5
	22.3 total acres			981.6	331.6
3.	Additional benefits of the citizen's plan, relative to the Corps plan				
	7.7 acres preserved	27.9	9.4	368.3	124.1
	5.9 acres restored	67.4	22.8	492.0	166 .5
	13.8 total acres			860.3	290.6

In addition to the riparian values displayed in table 3, about 350 acres of high quality salt marsh may also be affected by outflows from Wildcat and San Pablo Creeks (U.S. Army Corps of Engineers 1986). We do not have data to develop an analysis comparable to that of table 3 for these wetlands. However, Meyer (1987) did identify qualified survey values for essentially undevelopable wetlands around San Francisco Bay. That survey identified rare permitted market sales in the San Francisco Bay wetlands are (eg. for sewage treatment facilities) which brought between $1,800 and $5,000 per acre–and asked respondents, on that basis, what preservation of wetlands for fish, wildlife and recreation was worth. Respondents estimated an average wetland value of $7,201 per acre. The usefulness of these data is limited to the contest in which it was presented to respondents. It provides strong evidence that San Francisco Bay are residents value fish, wildlife and recreational uses of remaining Bay wetlands as a higher priority than their development for other water uses–but the value absolutes provided by the survey would need to be reassessed as market context changes. Applying results from Meyer (1987) to salt marsh acreage potentially affected by Wildcat and San Pablo Creeks provides a value estimate for these wetlands of approximately $2.5 million. As noted, should these wetlands be considered for actual development, the values reported here would need to be reassessed, and would likely be considerably higher. Finally, as noted, I do not have sufficient data to estimate the differential effects of the two plans on these values.

A Conclusion Respecting Riparian Values, and Effects of Their Inclusion on Planning at Wildcat and San Pablo Creeks

Several conclusions seem apparent from our analysis. First, recreational/aesthetic values associated with riparian habitat can be substantial, even for relatively discrete acreage. This discussion does not address non-user concerns about protecting riparian resources in their own right, regardless of use (existence value), or passing them on to future generations in good condition. (bequest value). Where residents become preoccupied with existence and bequest issues, such values can dominate analysis (Meyer 1987). Even with our relatively conservative user only approach, significant riparian value results can be observed.

Second, for a range of "marginal" projects, failure to adequately consider riparian values may disqualify projects that can produce net benefits for citizens in excess of costs. Further, failure to consider riparian values will unduly favor projects with limited riparian feature, relative to project alternatives with stronger riparian feature. It is possible that both of these issues have affected the proposed project(s) at Wildcat and San Pablo Creeks.

Third, it is evident from our analysis, that the assumptions built into any economic evaluation of riparian habitat, particularly with respect to discount rate and whether riparian acreage should be valued via "willingness to pay" or "compensation required" technique, will have a significant effect on the level of benefit that will be identified.

Finally, the data provided here are for illustrative purposes. While they provide useful insight respecting improvements available to the Wildcat/San Pablo Creeks planning and project development process, the values we have used are inferred from elsewhere in California, and subsequent refinements have been made to the plans compared here. A more detailed economic assessment specifically designed for the Wildcat and San Pablo Creek areas would consequently provide significant further understanding of riparian benefits potentially associated with urban streams.

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REDESIGN OF A FLOOD CONTROL PROJECT BY CITIZEN INITIATIVE[1]

Bev Ortiz[2]

Abstract: This paper describes the process used to redesign a flood control project on three creeks in central Contra Costa County, California, about 15 miles east of San Francisco. Involved was door-to-door organizing to form a neighborhood group which in turn used a county-appointed committee, a city-appointed committee, a State grant and a private consultant working with the county staff to help achieve an acceptable project. It was redesigned to preserve the riparian and environmental values of the urban creeks while providing 25-year flood protection. Detention basins and bypass pipes are key components of the project. On-going volunteer projects are planned involving channel clearing, revegetation, and bank stabilization.

"When all other factors are omitted from the problem, flood control, or the regulation of the flow of water, is a hydraulic-engineering design problem and the solutions reflect this and little else. The engineers are blamed for the rigid and austere final result. But no one mentions the simple fact that we, through our legislators, have never injected factors such as the protection and enhancement of environmental quality into their engineering equations." (Osmundson 1970)

On February 9, 1984, the Contra Costa County, California, Planning Department issued "Notice of Preparation of an Environmental Impact Report for Drainage Area 46 Improvements (PW 84-6) Including Murderers' Creek and the East Branch of East Fork of Grayson Creek." As described in the Notice of Preparation, the proposed "improvements" consisted of the construction of open, concrete-lined channels, pipes, culverts and box culverts for creeks in Drainage Area 46, including portions of Murderers' Creek, the East Branch of the East Fork of Grayson Creek, Matson Creek, and several "lines" or smaller tributaries. The project was developed to "...decrease future flooding in the area based on ultimate development" of the watershed. The design was predicated on a 3-hour duration, 25-year storm. (Contra Costa County Community Development Department 1985).

The proposal modified an earlier, less extensive plan to provide 100-year flood protection in Pleasant Hill, California, by creating a 7-acre detention basin and lining 4,000 feet of the East Branch of the East Fork of Grayson Creek with cement (Environmental Science Associates, Inc. 1977). The latter had been rejected by the 1977 Pleasant Hill City Council "...because it would remove considerable land from tax increment." (See 1985)

The watershed of the affected creeks fell within the jurisdiction of several governmental bodies: three cities (Pleasant Hill, Walnut Creek, and Layfayette), one school district, one water company, two State Assembly districts, two Contra Costa County supervisorial districts, and the Contra Costa County Flood Control District which developed the plan. The creeks were also adjacent to about 300 households, many of which owned portions of the creeks.

A broad-based citizen effort to seek ecologically viable alternatives to creek channelization began the following August when one of the adjacent homeowners, the author, contacted the Urban Creeks Task Force of the Sierra Club's San Francisco Bay Chapter to receive a subscription to its Creekwalker's Journal. Subsequently, the Task Force sent notification of the flood control proposal. Over the next 3-1/2 years, local residents organized a successful campaign to develop alternatives to the plan which would leave the creeks intact while still solving flooding and erosion problems.

Citizens to Save Our Local Creeks Formed

The first step in opposing the flood control plan was to seek information about the political process and non-structural alternatives to channelization from knowledgeable groups and individuals, including the Urban Creeks Task Force and the Berkeley-based Urban Creeks Council. During this fact-finding process it was learned that a Notice of Preparation is required for such projects, and this document was requested and eventually received from the Flood Control District.

A petition was developed to "...urge the County to consider ecologically viable alternatives to this project which would leave these creeks and their surrounding environment intact" (Original petitions on file, Friends of Creeks in Urban Settings, Walnut Creek, California). Petition signers had an opportunity to become ad hoc members of the newly designated organization, Citizens to Save Our Local Creeks.

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[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Founder and President; Friends of Creeks in Urban Settings; Walnut Creek, California.

The next step was to publicize the project and its alternatives. An informational article and a mini-version of the petition was published in the November edition of a Sierra Club newspaper (Ortiz, 1984). The Club's San Francisco Bay Chapter also provided a small grant which covered costs of producing a leaflet about the project. Titled "Local Creeks Threatened," (Brochure on file, Friends of Creeks in Urban Settings, Walnut Creek, California). The leaflet described the proposal, provided background on its impacts, outlined alternative methods for solving flooding problems and provided addresses of public officials to whom letters of concern could be addressed.

Community Outreach

The most important phase in the creek preservation campaign was a door-to-door canvassing effort targeting people directly impacted by the project, i.e. people living adjacent to the affected creeks. Canvassers carried the brochure and petition with them, along with forms on which they recorded the following information: positive and negative comments about the creek, the name, address and phone number of respondents, and length of residency. The addresses of residences with absent occupants were noted so they could be revisited at a later date.

Resident contacts were invaluable for several reasons. First, they provided critical information about locations experiencing long-term flooding and erosion problems, making it possible to track consistently troublesome areas. A map of flood and erosion locales showed that the vast majority of problem areas were downstream of existing, inadequate culverts. Obstructions created by residents who installed well-meaning, but ineffective erosion-control devices were also located.

The contacts provided a means to educate individuals about non-structural alternatives to channelization which could provide flooding and erosion control while preserving the creeks. This effort culminated in a presentation by a California Department of Water Resources spokesperson about the alternatives. Residents with creek problems were specifically targeted for this meeting, which was attended by nearly 100 people.

Canvassing also brought people together over an area of mutual concern. Often, as walkers progressed along their route, residents were seen meeting in front of their houses to discuss the project. Lists were maintained of people who were given the leaflet, who were sympathetic to the creek, who were asked to sign the petition, and who were encouraged to write letters. Such individuals were also listed for notification of future public hearings.

Unsolicited donations resulted from the canvassing, as did a corps of people who wanted to become actively involved, including present and future public officials who owned creekside lots. Several people volunteered to circulate petitions, type and word process, create graphics and provide free copy work.

About 85 percent of the residents along the creek expressed support for the creeks. Many recalled pleasant childhood memories of the creeks; they saw the creeks as part of the area's "rural" heritage. Others expressed environmental and aesthetic concern. Some felt the project would be growth-inducing and feared their taxes would be raised to solve the runoff problems created by future development. Some feared loss of private property values; others distrusted government and felt the project was unnecessary.

Those who favored channelization expressed erosion and flooding concerns. One person felt the creek was unsafe for children; another wanted to be rid of the raccoons; and a third feared prowlers along the creek.

Concurrent with the canvassing, a directory of community organizations was obtained from the local Chamber of Commerce. Environmental, hiking, and historical organizations were targeted because of their potential concerns about the project.

Speaking engagements were arranged, information was exchanged, petitions were circulated, and endorsements were sought. Ultimately, nine organizations endorsed citizen efforts to preserve the creeks, ranging from a growth control organization and a democratic club to various ecology groups.

Invaluable contacts were made at organizational meetings. Some contacts spoke with public officials in their acquaintance while others published articles about the project in their newsletters. One Mount Diablo Audubon Association member, a high school science instructor, shared 21 years of ecological data which students under his direction had collected along a section of one of the threatened creeks, known locally as "The Ditch." (Lee, pers. comm. 1984; Lee 1986)

A key component in the preservation effort was public education about alternatives to channelization. This effort culminated in a presentation by A.L. Riley of the California Department of Water Resources about the alternatives. Residents with creek problems were specifically targeted for this meeting, which was attended by nearly 100 people.

Friends of Creeks in Urban Settings

As knowledge about, and concern and support for the creeks increased, residents decided to formalize their efforts by drafting organizational bylaws and establishing a dues structure.

CSOLC was renamed Friends of Creeks in Urban Settings (FOCUS), which elected its first seven-person Board of Directors in June of 1985. As outlined in the bylaws, "The purpose of FOCUS is to preserve and enhance urban creeks located in Contra Costa County, California. FOCUS recognizes the need to assure adequate drainage of rainwater from adjacent property, to prevent flooding of the creeks, and to prevent excessive erosion due to water volume and velocity in times of peak flow" (Bylaws in possession of author.)

Continuing FOCUS' tradition of education, the first membership meeting included a showing of "Our Little Creek Next Door," a slide show developed by the late Roland Hauck, an early-day Sonoma County creek activist, which is housed at the Sierra Club's San Francisco Bay Chapter office. Also, FOCUS developed an educational exhibit entitled "Creeks: A Problem or An Asset?" for which was awarded a first-place prize at the 1985 Contra Costa County Fair.

Creekscape

The same month that FOCUS elected its Board of Directors a University of California at Berkeley Master's Degree candidate in Landscape Architecture chose the group as the case study for his thesis, "A Citizen's Guide to Urban 'Stream Restoration." A "creekscape" was envisioned along a portion of the East Branch of the East Fork of Grayson Creek, the primary purpose of which "...is to combine a non-structural flood control solution, restored riparian zone and a recreational setting along an existing semi-public right-of-way."

Guiding principles of the creekscape proposal were listed as follows: "1. Before urban creeks can be recovered physically, they need to be psychologically reclaimed as integral parts of the community. 2. Streams can be seen as a theatre of imagination and play for children and a recreational context for adults." (Steere 1985)

Two public workshops were held to discuss ideas for the creekscape. Residents saw pathways, picnic sites, play equipment and creek revegetation as the most important components. While easement restrictions have made an East Branch of the East Fork of Grayson Creekscape difficult to implement, it remains a positive model for future projects.

Draft Environmental Impact Report

The early work of citizens to raise concerns about the project generated numerous phone calls and letters to public officials and government agencies, newspaper publicity, and a study session convened by the Pleasant Hill Planning Commission, all prior to issuance of a Draft Environmental Impact Report (DEIR). In July 1985, when the long-awaited *Draft Environmental Impact Report for the Grayson-Murderers' Creeks Watershed Area and Drainage Improvement Plan Drainage Area 46* (Contra Costa County Community Development Department, 1985) was issued, it contained a section on "Issues Raised by the Public" which highlighted FOCUS' and other's concerns.

By this time, FOCUS had already presented its petitions with over 2,000 signatures to the City Councils in Walnut Creek and Pleasant Hill. The organization had also been able to secure an agreement from the Contra Costa County Flood Control District to act as a clearinghouse for distribution of the DEIR to every resident adjacent to the affected creeks in addition to the more usual procedure of placing copies for citizen use in libraries and city offices.

Along with the DEIR, FOCUS members delivered notice of a DEIR workshop sponsored by County Supervisor Sunne Wright McPeak. The workshop was attended by a lively crowd exceeding 200 individuals. Supervisor McPeak chaired the meeting, which opened with presentations by the Flood Control District and FOCUS, followed by innumerable public comments. Then, at the end of the meeting, McPeak announced an intention to form a task force to look at alternatives.

Drainage Area 46 and Zone 46 Task Forces

The task force convened in October with 23 members. In addition to McPeak, her Administrative Assistant, and a Flood Control representative, the Drainage Area 46 Task Force had five community representatives without flooding problems, three community representatives with flooding problems, and three city, six Flood Control Zone 3B, and six FOCUS representatives.

Early on, FOCUS provided the task force with a memo outlining drainage area concerns and problems (based on its neighborhood survey) and suggested alternatives to channelization. Erosion and flooding problems were listed by street address, and described in the memo (Friends of Creeks in Urban Settings 1986). This data on problem areas was previously unknown to planning agencies, who were relying on hydrological projections.

The suggested alternatives included setbacks and on-site water control for all new development, including the use of flow metering devices, local detention basins, permeable pavement, and "softscape" surfaces; development fees for culvert improvements; bypass pipes and regional detention basins; creek revegetation; and riprap, gabions and check dams for erosion control. Creek widening in selected areas was indicated as a last resort. Finally, FOCUS recommended application to the California Department of Water Resources Urban Stream Restoration Program for a grant to investigate alternatives.

As the city most affected by the project, Pleasant Hill also established a task force on the creeks. This Zone 46 Task Force was comprised of Pleasant Hill's Director of Planning and Director of Public Works, three Zone 46 resident appointees, two FOCUS board members, one representative each from Pleasant Hill's Recreation and Park District, Redevelopment Citizens Advisory Committee, and Planning Commission, and one representative of the Mount Diablo Unified School District which owns redevelopment property along the creeks.

Urban Stream Restoration Grant

FOCUS applied for a Water Resources grant, November 1986. The grant application asked for $19,250 to hire a hydrologist to prepare a plan which would preserve the creeks while solving flooding and erosion problems; fund a citizen cleanup and revegetation project; and prepare a brochure and slide show which would educate the public about creek preservation techniques and alternatives to channelization.

Widespread public support provided the underpinning for a successful application to this first-year program, from which FOCUS received the single largest award. The application received the endorsement of 10 community organizations: 7 environmental organizations, 1 historical society, and 2 growth control groups. It also received the endorsement of Democratic Assemblymember Tom Bates who sponsored the legislation making the grant program possible, Republican Assemblymember Bill Baker, the Contra Costa County Board of Supervisors, the City of Walnut Creek, and the Diablo Valley College Department of Environmental Horticulture.

FOCUS sought sponsorship for its grant from Contra Costa County, but pulled its request when the County Board of Supervisors referred the matter to the Flood Control District. FOCUS then sought and received sponsorship from the City of Pleasant Hill.

Task Force Recommendations

In January of 1986 Supervisor McPeak presented the Drainage Area 46 Task Force recommendations to the County Board of Supervisors. The recommendations included a section of "proposed policies" that were nearly identical to those outlined in the FOCUS memo. Another section of "recommended alternatives" called for minimizing flood inflows by construction of detention facilities in the upstream watershed, keeping the creeks "in their existing state with the exception of minor deepening and widening in small, local areas," and "diverting the excess flows through bypass lines to a detention basin." (McPeak 1986)

In response, the Board of Supervisors unanimously adopted McPeak's motion to reject the proposed channelization project and accept the Drainage Area 46 Task Force Report. Later the same year, Pleasant Hill's Zone 46 Task Force recommended that Pleasant Hill adopt an ordinance allowing the collection of development fees to enable improvements of existing culverts.

Focus Grant

In April of 1986, FOCUS was awarded its State grant. After reviewing requests for proposals from hydrological consultants, FOCUS retained the firm of Philip Williams and Associates to seek alternatives to channelization in accordance with the grant. The firm had previously assisted interested individuals in drafting alternatives to a similar channelization proposal for Contra Costa County's Wildcat Creek.

By the time the consultant was retained, the Flood Control District had already begun to redesign the channelization project as per Drainage Area 46 Task Force recommendations, setting the stage for a cooperative working relationship between the consultant and District. While this process was taking place, FOCUS organized two successful creek cleanups and started raising native vegetation from locally harvested seedstock for its revegetation effort.

The first cleanup occurred on April 4, 1987, with the cooperation of Eco Info, Inc., a Walnut Creek-based ecology organization, the City of Pleasant Hill, the East

Bay Municipal Utility District, and the Mount Diablo Unified School District. That morning 30 citizen volunteers and 1 television crew watched as Assemblymember Bates planted the symbolic first tree. By day's end, the tired, but proud volunteers had removed all manner of "garbage" from the creeks, ranging from two schoolyard baseball backstops and two dead cats, to the requisite shopping cart. They then retired in deference to food and music in the yard of an historic, creekside house. The second cleanup was timed to occur before peak winter rains. The latter was accomplished with the help of Supervisor McPeak's office and the East Bay Conservation Corps, whose field coordinator had attended the earlier cleanup.

A New Plan

By the latter half of 1987, the revised plan for the creeks was completed. The plan called for the establishment of three detention basins and a series of bypass pipes to accommodate flood waters. Since the original lines were now eliminated, the work is estimated to cost anywhere from 2 to 5 million dollars less than the original 18 million dollar projection (Kent 1987). While the plan has some drawbacks—one house will have to be removed and Brookwood Park in Pleasant Hill will be impacted by placement of a detention basin there, three miles of creek habitat will be preserved for future generations to enjoy.

A Negative Declaration (Contra Costa County Community Development Department 1987) issued for the plan, indicating no adverse environmental impacts, was soon adopted by the two task forces and three cities within the drainage area. On January 12, 1988, it was unanimously adopted by the Board of Supervisors. At the time of its adoption, the Board authorized establishment of a third task force to study ways to mitigate impacts of the Brookwood detention basin. The task force will also discuss the ultimate size of the detention basin at the site owned by the Mount Diablo School District, the same site that had been proposed for a detention basin in 1977 and subsequently rejected.

The County is presently seeking funding through the United States Army Corp of Engineers to implement the plan. For its part, FOCUS' work is far from complete. The group's educational efforts will continue with the help of a brochure and slide show produced through State grant funds. Creek cleanup and revegetation efforts are also underway. Plans have begun to apply for grants for a comprehensive restoration effort on the creeks, a component that is lacking in the new plan.

FOCUS continues to provide advice, information and assistance to requesting groups and individuals, as it had during the previous three years. It also continues to work for preservation of threatened creeks throughout Contra Costa County.

Finally, FOCUS remains active on a Contra Costa County Board of Supervisor's Internal Operations Committee-appointed task force. Established in February of 1986, this task force has made recommendations regarding creek and drainage issues for incorporation in the County's revised General Plan. The latter is also working on a revised drainage ordinance for the county emphasizing creek preservation through setbacks.

Conclusions

The redesign of the Drainage Area 46 channelization project was successful because of several factors. Most important was the early organizing of community residents, liaison work with community groups, work on other creek preservation projects, and the positive stance taken to seek alternatives to channelization rather than merely oppose the project. Because every resident concern was validated, even residents with creek "problems" became advocates of alternatives. The political support obtained from politicians, the ability to retain a hydrological consultant through a State grant, and citizen efforts to clean and restore the creek all contributed to the ultimate redesign.

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INNOVATIONS IN STREAM RESTORATION AND FLOOD CONTROL DESIGN MEETING FLOOD CAPACITY AND ENVIRONMENTAL GOALS ON SAN LUIS OBISPO CREEK[1]

Wayne Peterson[2]

Abstract: Can a natural flowing creek be increased in drainage capacity to protect an adjacent community from flooding while still maintaining a natural habitat? San Luis Obispo constructed one such project on over a mile of Creek as a part of a housing development. The City found that some of the mitigation measures included in the project worked while others did not. In the years since, the project has been evaluated and improvements recommended. We will probably do another such project but in a different way as described in this paper.

San Luis Obispo is a City of 38,000 in a rural California coastal county located midway between Los Angeles and San Francisco. The area was first settled by Europeans in 1772 when the Mission San Luis Obispo de Tolosa was founded by Father Serra. The mission was located on the banks of a flowing creek, now called San Luis Obispo Creek. The creek drains an area of 84 square miles. The creek comes out of the Cuesta, dropping about 2000 feet in a distance of 3 miles. San Luis Obispo Creek is one of the southernmost steelhead fishery's in the state. (U.S. Army Corps of Engineers October 1986)

The large fish are seen in limited numbers in the creeks downtown segment during the winter. The community that grew up around the mission was built in a flood plain. Early history reports periodic flooding. In spite of this, around 1900 the city fathers decided that the creek was a real impediment to development of the downtown. To get rid of it, they built walls on the sides and allowed property owners to build their buildings over the creek. Along three downtown blocks most people don't know that the buildings and streets bridge the creek.

The post-war years were drought years. The community was growing and few remembered that the City could be flooded. At least this was true until 1969 when the rains came and the water rose. Most of the City was flooded. Everyone said, "This has got to be a 100 year storm – it won't happen again for another 100 years." In 1973 it happened again.

Concern for the Creeks

Before the 1969 flood the citizens had begun to recognize what an important asset the creek could be. During the past 20 years two important projects have been built which show this recognition and also the community concern for flood prevention and the environment. The attached map shows the location of these two project.

A development project that first focused this interest was called Mission Plaza. This project was the result of a decade of planning and plenty of conflict. Construction was only begun after a referendum. The project involved the creek immediately in front of the mission. The street between the mission and the creek was closed, the area along both sides of the creek was cleaned up and landscaped. The area is not riparian in the sense that it provides for the needs of wildlife. It provides instead a comfortable escape for the species that frequents the immediate region. Humans. They flock here and enjoy the sound and site of moving water, the trees, birds and each other. Many activities are scheduled for this area. This project has done much to make the whole creek an appreciated asset.

Planning for Flood Protection

After the flood of 1973 the politicians got busy. The city formed a Waterway Planning Board to review was done, and should be done with the creeks. The Board of Supervisors of the San Luis Obispo County Flood Control and Water Conservation District formed a Zone of Benefit to prepare studies on how to prevent future flooding and conduct maintenance to improve the flow of the creek. The authority for this action is in the "San Luis Obispo County Flood Control and Water Conservation Act" pursuant to Chapter 1294 of the Statutes of 1945 of the California State Legislature. (Nolte August 1977, pg. 1) The City and the Zone worked closely with the California Department of Fish and Game to develop a form of brush and tree maintenance that would improve the flood flows of the creek, minimize

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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the amount of debris carried in the flood waters and maintain an appropriate habitat for the fish and other wildlife during low flows. The water only flows deep and swift during heavy rain and for a few hours after the rain stops. This only happens every couple years. The Corps of Engineers reports that San Luis Obispo Creek in the downtown carries 7,600 cubic feet of water a second during an Intermediate Regional Flood (Corps of Engineers November 1974, pg. 26) in the downtown. Normal flows are like that of a trickling brook. In fact this summer it is dry in many sections.

The City's Waterway Planning Board, besides reviewing existing obstructions to creek flow and new projects that may cause an obstruction, developed standards for creek bank protection along the creek. These design standards were prioritized in order from the most desirable, an earthen channel with lots of vegetation along the banks, to the least, a concrete channel. (City of San Luis Obispo June 1983) The City since has approved projects using all of these designs as they were appropriate. The Waterway Planning Board also worked closely with the County Zone of Benefit to assure the development of a flood control policy and program that could be supported by the city council.

The Zone of Benefit began a program of stream gauge measurement and hired a consultant who was directed to identify the extent of the problem and recommend how flood protection could be achieved.

About the same time the Army Corp of Engineers began their own study to find if there was some way that the Federal Government could assist in the solution. The two programs were closely coordinated and used a common data base. One of the first things we received from the Corps study was a Federal Insurance Rate Map and the City entered the federally subsidized flood insurance program.

Solutions

The county's study recommended a mixture of structural and non-structural projects:

1. New development projects were to be limited and built above the 100 year flood level. This level was first defined by the Corps of Engineers study.(Corps of Engineers November 1974)
2. A serious maintenance program was recommended.
3. A program identifying and removing so-called bottlenecks through projects that were compatible with a future 100 year channel.
4. The construction of a 100 year channel from the south city limit north to the downtown.
5. The construction of one of three solutions to solve the capacity limitations of the under-city culvert.

(Nolte August 1977)

These five recommendations represented a significant change in the way the City looked at development. The concept of a 100 year flood level was unknown by the community and there was almost no creek maintenance program. Bottlenecks existed in the creeks and no one was concerned. The total recommended program was estimated to cost over 12 million dollars. The final recommendations were never totally accepted by the City.

Maintenance

Each year the City, along with the Zone of Benefit, conducts an annual maintenance program. The maintenance program cooperates fully with the California Department of Fish and Game and involves a combination of cutting, trimming, and spraying the various trees and shrubs along the creeks in order to maintain a tunnel through the vegetation which will allow high-water flows to occur while still maintaining a shaded stream during low flows.

Improvements

Most of the bottlenecks to high-water flow were removed by the City. These are primarily manmade things like sewer and water pipes, retaining walls, undermined trees, and other so called improvements of the past that limit the flow in the creek. All new construction projects adjacent to the creeks are reviewed closely to assure that they are safe from flooding and will not prevent the city from solving the flooding problem in the future. Since the City joined the National Flood Insurance program and it has vigorously applied those standards. Private development has been required to improve the flood capacity of the creek as a condition of development. This is particularly true when we can show that the development will be the prime benefactor. Some projects build a bypass channel parallel to the creek, most just build back from the creek so that a future project can be built by the City in the future.

Increasing Stream Capacity

One particular housing project built over 5000 feet of improvement in the main creek as a condition of development because their project was in a flood zone and could not have been built otherwise. This project followed the guidelines for creek channel widenings suggested in the County's Zone of Benefit study. The project design was worked out carefully with the involvement of many agencies and consultants. The project provoked a significant amount of discussion and still does. Environmental groups, California Department of Fish and Game, and U.S. Fish and Wildlife Service did not like the project.

Nevertheless the project was built with all the required permits in the fall of 1978 and spring of 1979.

In 1982 the City hired a consultant to review the project and to report on how the mitigation measures worked. In 1984 a class at California Polytechnic State University at San Luis Obispo (Cal Poly) also studied this issue and provided a report to the City. Included were recommendations on how the project could be improved.

The Project

A housing project called "Tract 592" (fig. 1) was proposed adjacent to the creek. The flood plain information maps showed the site to be subject to sheet flow originating from the creek upstream of the project. The project, as a condition of approval, had to eliminate the potential overflow flooding. Design guidelines stipulated that the creek section should be able to carry a 100 year design storm and meet the Army Corp of Engineers design standards. The project was also to be designed so as to maintain existing and to restore lost habitat along the creek.

Unique Design Requirements

The design called for widening of the creek waterway by setting back one bank only. The new bank would be sloped at two feet horizontal to one foot vertical. The bottom of the widened area was to be three feet above the flow line of the creek. The creek bank on the side being widened was not to be disturbed below a point three feet above the flow line of the creek. Willows, shrubs and other vegetation would he left undisturbed along this low bank area. The other side of the creek was to be left totally undisturbed. At a point between the creek and the construction work a silt fence consisting of an engineering fabric supported on a wire fence was to be constructed along the entire length of the project. This fence was to prevent disturbed soil from the adjacent construction project from finding its way into the creek. New trees and shrubs were proposed along the top of the new bank and the disturbed area between the creek and the new bank was planted with a native grass mixture. Willow slips were to be planted along the interface between the creek natural bank and the widened bench area. There were some changes in the kind of trees and shrubs planted along the top of the new bank. One typical change was to plant native trees where non-native trees were called for on the plan.

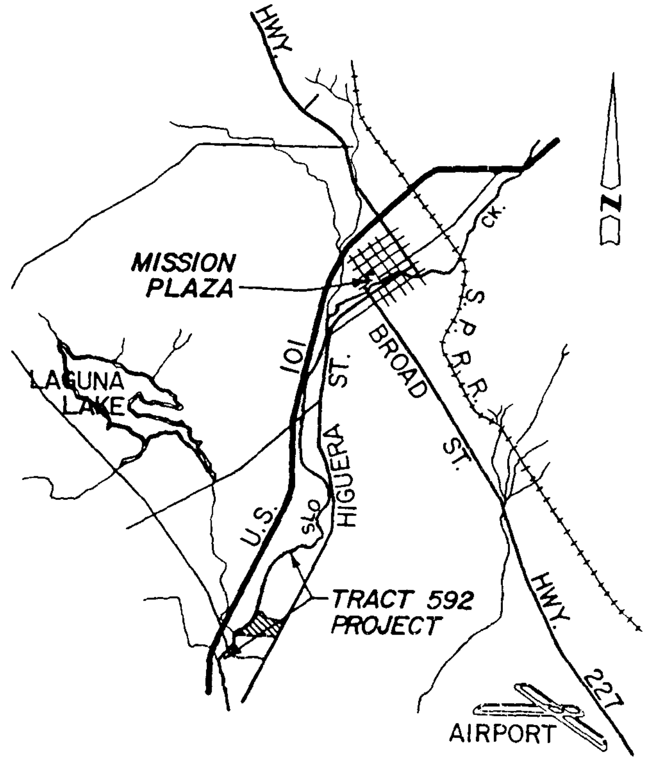

Figure 1–Map of the city of San Luis Obispo showing location of Mission Plaza and Tract 594.

How Did the Project Work?

In July 1982, MDW Associates of San Luis Obispo prepared a report for the City entitled "Tract 592 Creek Modifications: An Evaluation". The report was prepared "...to achieve a better understanding of the consequences of a proposed project to modify another, larger section of San Luis Obispo Creek." The report noted that the survival rate of trees and shrubs planted on the top of the new bank was not very good. Those that did survive were generally those that were native to the area. They were arroyo willow, red willow, fremont cottonwood, and sycamore. The shrubs that did best were elderberry, coffeeberry, holly-leafed cherry, mountain mahogany, and toyon. The biologists felt that none of the plantings on the new bank could replace the habitat lost since they were to far from the streams edge. The willows planted along the stream's edge, and the seedlings of some of the riparian trees establishing themselves are expected to ultimately develop into a new riparian forest if left alone. The investigation of streamside wildlife revealed fewer individual birds and species of birds than in similar areas along the stream. The biologist felt that in a few years the tree sizes should increase to a point where the overstory canopy would possess the necessary habitat stratification to support a greater number and diversity of birds. Aquatic wildlife was sampled and revealed higher numbers of organisms in relation to stream flow than in unmodified sites on the stream. The report stated, "These data suggest that extensive modification of the creek bank and removal of the riparian vegetation will not result in long-term damage to the creek if the revegetation *of the stream bank* (close to the threadline of the stream) is implemented." The report also confirmed that no significant siltation had taken place as a result of the project This meant that the design maintenance of the silt fence was successful.

The MDW report of July, 1982 and the Cal Poly University report of 1984 lead me to recommend the following guidelines for future channel widening projects.

The same antisiltation measures incorporated in Tract 592 should be used. These measures should include a silt barrier constructed immediately downstream of the construction site, approved by Department of Fish and Game, prior to any grading. The silt barrier should be removed with all accumulated sediment at the end of the project, and the streambed restored to ‘as near an original condition as possible.’ A filter fence should be constructed of fine-mesh material adjacent to the stream along the entire length of the project, following grubbing and clearing operations but prior to grading. The fence should be removed after project completion and after the vegetation becomes established.

Disturbed areas should be hydroseeded immediately after completion of the grading. Graded areas should not be left smooth. The contractor should be required to run a bulldozer up and down all slopes with the blade up, leaving horizontal grooves to slow the sheet flow of water. In some soil situations straw should be laid down and tracked into the slopes by the tractors. Drainage from the areas outside of the channel should be controlled to prevent erosion of the newly created slope banks.

The part of the Tract 592 revegetation program which was most successful in terms of re-establishing the stream ecosystem was the planting of the 2500 willow slips along the threadline of the stream. This practice should continued in future projects. The landscape plan should concentrate the plantings to the immediate area of the low flow stream. Figure 2, *Recommended Landscaping Concept,* illustrates this idea. Key points of the design are:

Only *one bank* should be modified along any portion of stream.

Riparian trees and shrubs should be left undisturbed within 6-10' on the low flow stream wherever possible. If it is impossible to save the existing trees and shrubs adjacent to the low flow area, new trees and shrubs should be planted. Willows do the best here but for reasons of debris management alternative trees may be considered. It would be best if the new trees were planted on berms about four feet high within this strip. If the berms are constructed as ‘islands’ they will help establish the young trees by protecting them from most flood conditions. Where trees are retained or planted, it is appropriate to prune branches from their trunks as needed to assure that they will not obstruct flood flows (six to eight feet above the grade of the creeks flowline). This measure implies that trees to be planted must be large enough to be able to withstand such pruning.

Vegetation should be planted within the channel area behind the riparian corridor to establish erosion control, or if desired, to provide for public recreation fields or other aesthetic purposes. The need for this area to carry flood flows and the distance from the low flow channel means that plantings in this area will achieve little if any biological mitigation. Additionally, if this area is to be improved for public recreation, it may be necessary to discourage public access to the stream. Too much public access may be as detrimental to the riparian habitat as the original widening project. To this end, species such as poison oak and blackberries should be included in the stream plantings to protect the integrity of the stream corridor from excessive intrusion of humans.

Project plans should specify that the landscape contractor is responsible for at least one years' maintenance of all trees and shrubs planted for the creek modification. The project should be closely inspected to assure that all trees and shrubs receive adequate watering and that plants which die or are uprooted are replaced.

The plants used should include entirely native plants and should concentrate on those species found to be most successful in the Tract 592 landscaping (willow, elderberry, cottonwood, coffeeberry, holly-leafed cherry, toyon, sycamore, live oak, white alder, etc.). Where significant trees are to be removed (i.e. over 8" in trunk diameter), replacement trees should be planted in a ratio of five to one. The Department of Fish and Game should be included in the planning, design and implementation of any project involving streambed alteration. A streambed alteration agreement must be executed with that agency prior to construction.

The City has not conducted any streambed alteration projects on any scale in the last few years. Projects proposed have usually resulted in significant public and political controversy. While the Tract 592 project did have problems and did not perform in every respect as we may have liked, it did provide us with an excellent example of what happens when the stream banks are altered. Hopefully, the community's desire for flood protection will be addressed in the near future. By using the experience of the past the concerns of all can be met.

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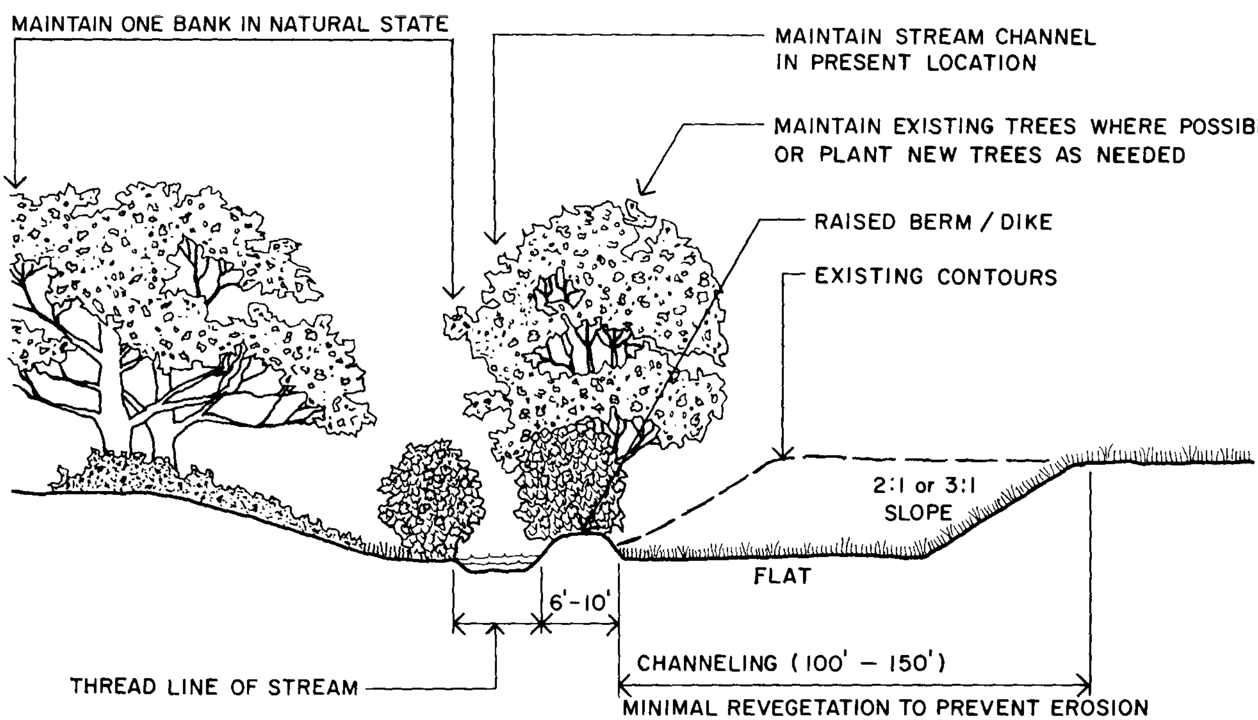

Figure 2—Recommended landscaping concept.

PUBLIC PARTICIPATION AND NATURAL HABITAT PRESERVATION ALONG ARCADE CREEK, DEL PASO REGIONAL PARK, SACRAMENTO, CALIFORNIA[1]

Timothy J. Vendlinski and Steven N. Talley[2]

Abstract: Thirty-six hectares (90 acres) of riparian forest, high terrace oak woodland-savanna, and upland vernal pools were preserved along Arcade Creek in Sacramento, California as a result of citizen involvement in a city-sponsored master plan process for Del Paso Regional Park. Citizens formed an organization and called for a comprehensive Environmental Impact Report to evaluate project impacts, and to develop commensurate measures to avoid and mitigate environmental damage. The organization used the CEQA process to provide city staff, consultants, and City Council members with detailed proposals for accommodating development and preserving critical natural habitat. These proposals were largely adopted by city staff and the Council. The City is making the park available for academic research intended to promote restoration of the park's disturbed habitat. The citizen's organization is pursuing natural habitat designation for the park's biologically sensitive tracts that remain unprotected.

On 22 January 1985, the Sacramento City Council unanimously approved a revised Master Plan and Final Environmental Impact Report (FEIR) for Del Paso Regional Park in Sacramento, California (City of Sacramento, 1985). The action ended a 2.5-year public involvement process whereby development of a world class amateur softball complex, soccer/rugby fields, and picnic areas was balanced with the permanent preservation of 36 hectares (90 acres) of riparian forest, oak woodland-savanna, and vernal pools (fig. 1). This paper discusses how citizens utilized local and State public participation mandates in negotiating an agreement between interest groups and the City of Sacramento to protect a profile of the pre-settlement Sacramento Valley.

Arcade Creek and Del Paso Regional Park

Approximately 80% of Arcade Creek's 10,240 hectare (25,600 acre) watershed is developed. Once intermittent, the creek now maintains a summer flow from urban run-off, and swells to flood stage during periodic winter storms. The City of Sacramento owns and manages the 270 hectare (680 acre) Del Paso Regional Park; a roughly 4.8 kilometer (3 mile) stretch of Arcade Creek passes through the park's northern boundary.

In 1915, Del Paso Park was slated for development patterned after San Francisco's Golden Gate Park. However, fiscal constraints and the site's remoteness from the city center forestalled development until 1932 when the City began constructing golf courses. By 1980, park facilities included three golf courses, a trap shooting club, a baseball field, a private equestrian club, and community service organizations such as the Sacramento Science Center and Junior Museum. Approximately 99 hectares (247 acres), including the riparian corridor, remained undeveloped (City of Sacramento, 1982).

Del Paso Park became valued by the Sacramento Audubon Society for its diversity of bird species and accessibility. The Sacramento Science Center and Junior Museum built a wheelchair-accessible interpretive trail on its 5 hectare (12 acre) parcel south of the creek and developed a nature appreciation program. Also, equestrians, running teams, and nearby residents discovered and enjoyed the streamside trails.

A Conceptual Master Plan for Del Paso Park

In summer 1982, the senior author investigated the status of Del Paso Park's undeveloped land. The City was updating its city-wide park master plan. A key element of the city-wide plan was to develop a site-specific master plan for Del Paso Park.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988: Davis California.

[2] Environmental impact analyst, U.S. Environmental Protection Agency, San Francisco, Calif.; and volunteer consultant for natural area interests, Sacramento, Calif., respectively.

Figure 1– Oak saplings, mature "heritage" oaks, and vernal pools occupy a 16 hectare (40 acre) terrace, contiguous with Arcade Creek, that was preserved via the CEQA process. Photograph courtesy of Van Pierce Miller.

Besides expanding or renovating existing facilities, various community groups proposed using the park's undeveloped land for a softball complex, soccer/rugby fields, tennis courts, a frisbee-golf course, a velodrome, and polo fields.

In September 1982, the City held its first public meeting regarding the Del Paso Park master plan. Prior to the meeting, the senior author drafted a flier that described proposed park attendance at the upcoming meeting. Friends helped distribute the flier to over 100 households neighboring the park. At the well attended meeting, most of the neighbors expressed their contentment with the status quo, that is, the current level of park facilities and undeveloped land was satisfactory. It was evident that these same residents might support a sensitive development plan if it could maintain, indeed improve, environmental quality in neighborhoods surrounding the park.

To accomplish this objective, detailed information was needed to identify the parcels most critical to the park's biological integrity, and to quantify the amount of land required to sustain the park's raptor and mammal populations. The senior author contacted local naturalists to begin developing the necessary data. During this seminal phase of coalition building, respected bird watchers testified at City Council meetings about the need to preserve upland oak woodland-savanna contiguous with riparian forest to retain an "edge effect" desired by many avian species. Occasionally, an arborist would explain that the oak reproduction within Arcade Creek's now fallow high terraces was a California rarity. But beyond these technical opinions, both the citizenry and local government lacked the scientific expertise to make ecologically sound land-use decisions.

In the conceptual Del Paso Regional Park Master Plan sent to the City Council, the staff responded to community concerns by relocating the proposed softball complex from the park's east end, adjacent to residences, westward to an open tract bordered by the creek, a golf course, and a freeway (Interstate 80). The City proposed to designate Arcade Creek's active floodplain as natural habitat, along with other sites too small and/or isolated to develop. On 16 March 1983, the City Council approved this conceptual plan and its attached Negative Declaration, and stated that "environmental analysis will be conducted on each element of the master plan prior to construction." (City of Sacramento, 1983).

Developing a Biologically Sound Master Plan

At the behest of a concerned City Councilwoman, the senior author began organizing monthly meetings, independent of city-sponsored meetings, and encouraged residents to identify common goals and expectations. He also sought media coverage to focus community-wide attention on the resource issues involved with developing Del Paso Regional Park. The Sacramento Bee newspaper's Neighbors affiliate became interested in the public participation angle of the park planning process and, on 10 November 1983, printed the first in a series of articles devoted to Del Paso Park.

New faces appeared at the monthly meetings, including activists from local environmental groups (Environmental Council of Sacramento, Sacramento Audubon Society, and the Sacramento chapter of the California Native Plant Society). We named our organization the "Arcade Creek Restoration Project" (ACRP) and, in February 1984, began writing a monthly newsletter entitled *Creekspeak* to discuss local environmental issues, report on park cleanup projects conducted by the City and community volunteers, announce future ACRP meetings, and promote attendance at city-sponsored forums.

In February 1984, ACRP requested that the City, as part of the aforementioned city-wide park master plan, create a policy for ensuring identification and acquisition of sites with significant natural or cultural character, and for managing these areas for passive recreation (Vendlinski, 1984). The City responded by stating that "identification and acquisition of sites containing significant native plant communities, historical or archaeological resources, or examples of ecological relationships, is a legitimate function of the Department", and that these resources are of educational and recreational importance (City of Sacramento, 1984a).

In July 1984, ACRP mapped dominant vegetation and landforms within undeveloped park parcels. We discovered that valley oak (*Quercus lobata*) and interior live oak (*Quercus wislizenii*) were reproducing over broad areas of the park's high terraces and uplands. Relatively rare blue oak (*Quercus douglasii*) reproduction was documented in the vicinity of increasingly scarce, albeit degraded, vernal pool habitat along the western parcel's high terrace-upland ecotone, the proposed site of the softball complex (fig. 2). We transmitted this information to the City's Director of Parks and Community Services, underscoring the dearth of blue oak reproduction in California since the 1880's, and the value of the park's vernal pools (Talley and Vendlinski, October 1984a).

As the City prepared to implement the Del Paso Park master plan, ACRP was concerned that the staff might interpret the conceptual facility boundaries, approved by the City Council, as essentially fixed. We asked the staff to view these boundaries as malleable, because they were generated using a Negative Declaration rather than a formal environmental study. Moreover, we remained wary of the city's approach of documenting environmental impacts of individual park elements as funding became available; an approach that might miss cumulative impacts.

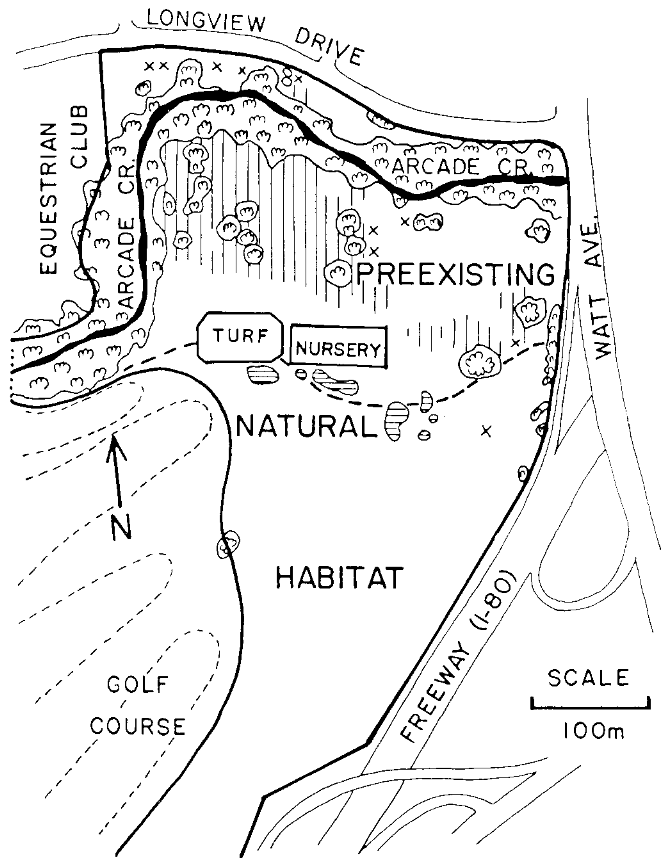

Figure 2– Selected natural habitat features in western Del Paso Regional Park prior to master plan implementation included Arcade Creek's riparian forest and associated oak woodland (stippling), oak reproduction areas (vertical lines), individual young oaks (x's), and vernal pools (horizontal lines). Remaining areas were annual grassland except for a tree nursery and turf production area. The high terrace extends from the dashed line north to the southern edge of the riparian forest.

In September 1984, the City committed itself to preparing an Environmental Impact Report (EIR) pursuant to the Californian Environmental Quality Act (CEQA). The CEQA Notice of Preparation (NOP) proposed siting the softball complex on the western parcel's environmentally sensitive oak terrace and uplands (fig. 3). ACRP arranged a scoping meeting with city staff and their environmental consultants. We urged them to replace their preferred alternative with a softball complex situated further south to avoid the park's unique environmental elements. The staff responded with a second alternative that, although similar to ours, located the complex too far north to avoid displacing the vernal pools (fig. 4). The City also offered a third alternative for a linear, rather than circular complex, well south of the vernal pools. While the third alternative was environmentally superior, it was clearly inferior from a recreational standpoint.

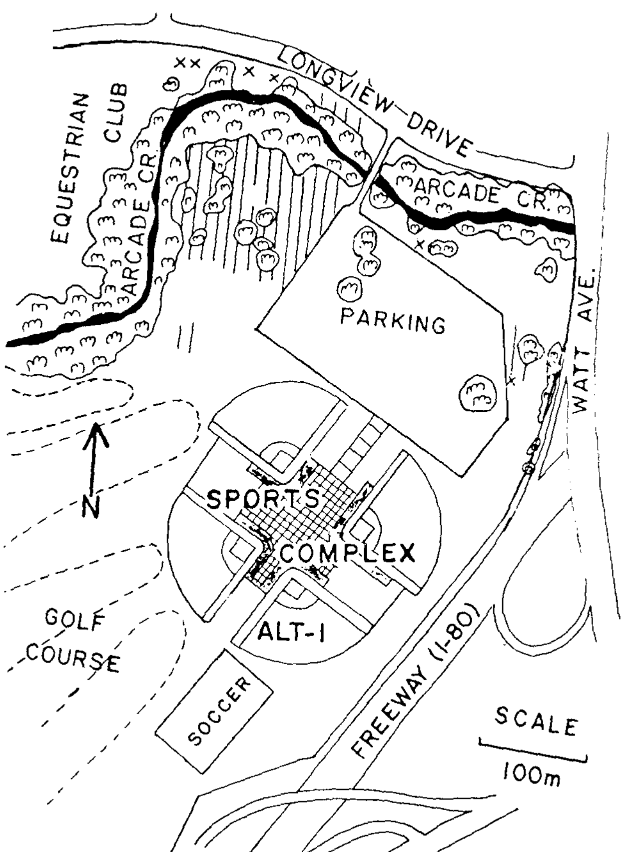

Figure 3— Principal environmental features of city alternative-1 included siting a 700 car parking lot just south of Arcade Creek, resulting in the loss of vernal pools and the core of the western terrace's oak woodland and oak regeneration areas.

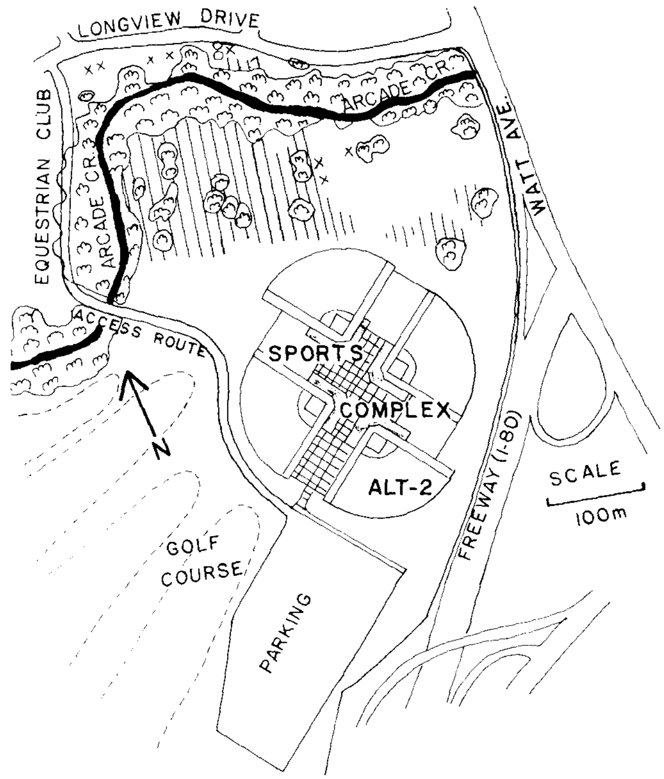

Figure 4— City alternative-2 featured a setback of the softball complex to preserve high terrace oak woodland and oak regeneration areas, however, it would still eliminate vernal pools.

At the early public meetings for the EIR, residents, athletes, and environmentalists gathered to present their views regarding the staff's site-specific design proposals. ACRP's proposal for an "alternative-2 type" sports complex that would avoid impacting the vernal pools and oak habitat was endorsed by speakers from local environmental groups and, importantly, drew praise from softball association representatives. Nevertheless, the City instructed its consultant to analyze all three alternatives rather than use the CEQA process to refine alternative-2.

Using the city's precise topographic maps, ACRP continued its technical appraisal. On 15 October 1984, ACRP provided the City with quantitative data demonstrating that cut-and-fill requirements for the construction of alternative-1 were actually greater than for alternative-2. We also submitted two variations on alternative-2 that would save the vernal pools and their watershed, and create an approximately 16 hectare (40 acre) natural area on the western parcel (Talley and Vendlinski, October 1984b).

In November 1984, the City issued the draft EIR. It found that all three proposed softball complex designs offered by the City "would result in direct and indirect impacts on oak regeneration areas, large oak trees, vernal pools, and riparian vegetation, which would be inconsistent with both City and County policies" (City of Sacramento, 1984b). The city policy in question was the one proposed by ACRP and incorporated into the city-wide park master plan; it recognized the legitimacy of identifying and acquiring sites containing significant plant communities or examples of ecological relationships. The draft EIR did not analyze the detailed proposals submitted by ACRP.

During the public hearing on the draft EIR held 14 November 1984, ACRP proposed a mitigation package aimed at "preserving and enhancing wildlife, plant, and aesthetic values throughout the park" (Talley, 1984). In summary, the mitigation package would do the following:

- restore the ecological integrity of the western creek terrace and vernal pool watershed, including the removal of the tree nursery and turf production facility that together covered 2.6 hectares (6.5 acres);
- combine recreation elements in the park's eastern end to allow for the protection of a high creek terrace contiguous with the already designated riparian natural habitat; and
- landscape the new park facilities and selected golf course rough areas with locally native plant species.

On 28 November 1984, we went before the City Council's Planning and Community Development Committee to describe the grave environmental consequences of alternative-1, and the avoidable impacts of alternative-2. We were concerned that the environmental consultants were not evaluating our proposals at their client's direction, and we deemed it necessary to directly address members of the Council. Prior to the Committee's meeting, we visited each Council member and supplied them with our written design and mitigation proposals.

On 10 December 1984, as the consultants worked to complete the final EIR, the Director of Parks and Community Services asked citizen leaders to meet with city staff for the purpose of designing site-specific recreational facilities and delineating natural habitat boundaries. The staff incorporated most of ACRP's proposed mitigation measures into an implementation plan, and prepared to send this plan to the City Council for approval. However, citing relocation costs, the staff chose not to recommend the removal and restoration of the 1.8 hectare (4.5 acre) turf production facility.

On 22 January 1985, the City Council unanimously approved the final EIR and the aforementioned implementation plan. Furthermore, the Council directed their staff to phase-out and restore the turf production facility, thereby partially offsetting the loss of creek terrace habitat to construction of the softball complex.

The softball complex would be located south of the vernal pools, while the access route across the creek would be built on the freeway side of the western high terrace to minimize conflicts with wildlife and equestrians. The proposed parking lot site was shifted from the sensitive creek terrace north of the softball facility (and south of Arcade Creek) to a highly disturbed parcel south of the facility between a golf course fairway and the freeway (fig. 5). On the eastern end of the park, the soccer/rugby fields would be combined with a neighborhood park, thereby allowing for the preservation of an additional 13 hectares (33 acres) of riparian forest and high creek terrace. A total of 36 hectares (90 acres) of riparian and upland habitat throughout the park would be designated as "natural habitat", protected from off-road vehicles by an extensive post and cable barrier, and preserved in perpetuity. Landscaping for the softball complex and new park elements would consist of locally native species except for turf grass.

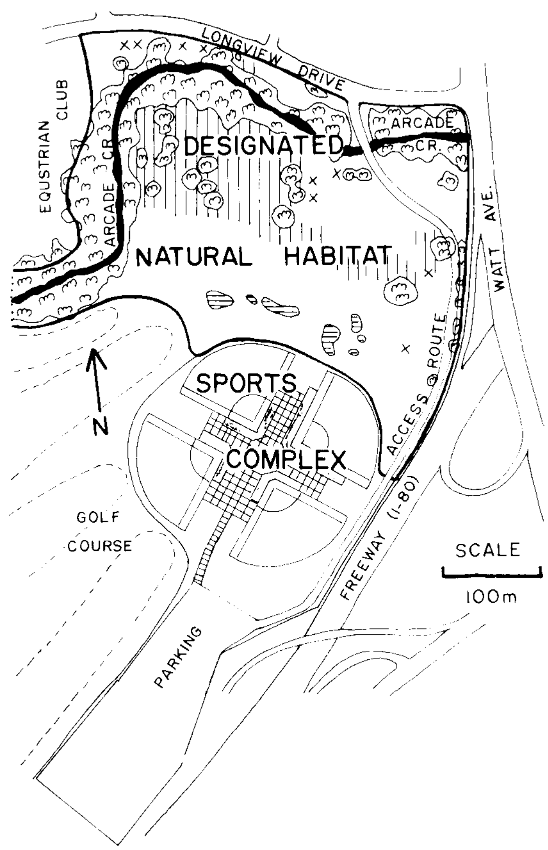

Figure 5– The implementation plan for the Del Paso Regional Park softball complex featured a setback of athletic facilities to preserve the primary environmental amenities between Longview Drive, the freeway, the golf course, and the equestrian club. Designated natural habitat is bounded by a solid line. Note the removal of the tree nursery and turf production facility from the designated natural habitat.

The Del Paso Regional Park Master Plan owes its success to the iterative technical process and public participation requirements mandated by CEQA. Today, thousands of people participate in year-round softball leagues at the park. A recently published interpretive pamphlet invites visitors to "discover" local wildlife along improved park trails. Still, there is unfinished business. Several sensitive park parcels remain unprotected; and while the City welcomes academic study to the park, it has yet to make a fiscal commitment toward research, resource management, or habitat restoration.

Making Public Participation Work

If citizens want to influence government decision-making, they must become technically credible, cognizant of bureaucratic and political pressure points, and skilled at the art of compromise. They must grasp the laws and policies governing their situation, and determine the link between what is desirable and what is possible. They must define their cause in specific terms and use the media to rally support. If a "policy gap" exists that impedes their progress, they must participate in the policy-making arena to fill the void. They must work until their vision becomes an institutionalized part of government's operation. Finally, they must persevere to ensure that their gains are not eroded by political whim or lost via decay of institutional memory.

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ARROYO MANAGEMENT PLAN (ALAMEDA COUNTY); A PLAN FOR IMPLEMENTING ACCESS AND RESTORING RIPARIAN HABITATS[1]

Kent E. Watson, Jim Horner, and Louise Mozingo[2]

Abstract: Innovative techniques for restoring riparian habitats are of little value without a community endorsed plan for their implementation. A flood control district commissioned the Arroyo Management Plan in order to determine how it might provide public access and improve habitat along its current and future channels in a fast-growing area of Northern California. The Plan, prepared by landscape architects involving local communities and agencies, emphasizes the goals and action items that local agencies need to implement in order for the public to regain the use of their streams and arroyos. The paper discusses the Plan and how it is being implemented.

This paper summarizes an adopted plan for the implementation of public access and riparian habitat restoration along flood control rights-of-way. Even though the plan was sponsored by a flood control district, a major plan recommendation is for the involvement and cooperation of all the relevant agencies in the service area in implementing the policies of the plan. In addition to constructing, operating and maintaining recreation and habitat improvements, and accepting liability for these uses, these agencies, particularly the cities, in their role as planning and zoning administrators, can use the plan to guide development adjacent to current and future flood control channels.

Introduction and Background

The Arroyo Management Plan is a master plan for public recreational access and riparian habitat restoration along the flood control channels and arroyos in Zone 7 of the Alameda County Flood Control and Water Conservation District of northern California, U.S.A. The Zone generally encompasses the cities of Dublin, Pleasanton, and Livermore and surrounding area within eastern Alameda county, an area of approximately 160 square kilometers. Like many areas in the San Francisco Bay Region influx of new industries and consequent development pressures are changing these once small communities into sprawling cities which are quickly encroaching onto the open land.

As an agency which interacts with the many city, county, and recreation agencies in the area, Zone 7 saw an opportunity to utilize its legal mandate for rights-of-way along stream channels in a manner which not only fulfills its primary goal of flood control but also provides the public with the added benefit of a recreation and open space system in this urbanizing area. The plan envisions non-motorized travel or recreation along, within, or across natural arroyos or modified channels. Typical uses and benefits expected include walking, hiking, jogging, bicycling, equestrian use, picnicking, nature study, general play, transportation and urban relief.

Two fundamental considerations guided formulation of the plan: 1) at no time is the primary concern of Zone 7 with flood control and water conservation superseded by provisions for public access; and 2) Zone 7 only acts as a coordination agency, not an implementation agency. Responsibility for implementation and maintenance of the access lies with the existing agencies which are already responsible for other recreation and open space systems.

The Arroyo Management Plan (Watson, 1985) is the product of a thorough planning process beginning in August 1984. It included data collection such as (1) site reconaissance; (2) review of all relevant plans and agency roles; meetings and interviews with nearly 20 agencies; and (3) interviews with 18 other flood control districts and related agencies involving administrative structure, liability, security, design standards, development and maintenance issues related to recreational uses. The Plan involved 1) data interpretation of drainage improvements, land uses, transportation and a trail feasibility inventory which resulted in a list of constraints and opportunities and a discussion of benefits of natural arroyos; and 2) discussion of implementation ideas with options and scenarios, and funding sources.

The above data were presented in graphic and synoptic form at a public evening meeting in Pleasanton. Comments from attendees were received and noted. This input, along with additional agency comments, became the basis for the final draft plan. This draft was presented at a second public meeting in Livermore. After minor revisions, the final plan was presented to the Zone 7 Board and adopted in concept in May 1985.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Principal/Landscape Architect, Kent Watson & Associates, Landscape Architects, San Francisco, Calif.; Landscape Architect, Alameda, Calif.; and Planner, San Francisco, Calif., respectively.

The complete Arroyo Management Plan is in two parts: the Arroyo Management Plan, a 23-page summary document (the basis of this paper); and the Initial Progress (Background) Report. The summary document contains the essence of the Plan. The 68-page Background report contains the detailed supporting data which were developed during the planning process.

Summary

The primary products of the Arroyo Management Plan are: a) policies and action items outlining agency responsibilities for development, operation, maintenance and security of arroyo trails; b) a set of typical design standards or cross sections (in a format for grant submittals); and c) an overall master plan map showing the location of trails (not included here).

In general there is both a strong overall demand for and very localized opposition to public access along the arroyos. Local general plans consistently call for natural appearing and accessible arroyos. An existing arroyo trail is popular and receives steady use.

Public access along the arroyos was critically reviewed by adjacent landowners. Predictably, some expressed concern about security and privacy. The Plan addresses these concerns by suggesting design standards which provide adequate buffers for privacy and keeps clear of areas in which a trail would be intrusive.

Zone 7 does not have to change its organizational structure to provide public access and opportunities for habitat restoration. The Plan recommends that Zone 7 not engage in the construction, operation and maintenance of recreational trails and habitat improvements along the arroyos, but rather encourage local cities and park districts to undertake these activities along the arroyos as they have elsewhere.

Zone 7 may incur additional costs caused by less convenient maintenance procedures. Such costs, however, can be justified in the face of the rapid urbanization of the Zone 7 area. Failure now to permit and to plan for multiple use of existing (and proposed) flood control channels can only result in even more costly and disruptive attempts to carve out recreation and open space systems later from thoroughly developed land.

The primary responsibility of Zone 7 for flood control and water conservation need not be compromised by inclusion of trails into the same rights of way. Examples from the Santa Clara Valley Water District amply prove that accessible channels can fulfill both recreation and flood control needs. The Arroyo Management Plan presents a unique opportunity to the District and the surrounding community to develop an integrated and economically feasible recreational open space system.

Administrative Recommendations

Based upon the findings of this study, it is recommended that the Zone 7 Board of Directors encourage and promote additional recreational use of the Zone 7 rights-of-way by allowing access along selected arroyos to the extent compatible with the primary responsibilities of flood control and water conservation. The following policies were recommended for adoption:

Policy A

This policy would permit trail uses along selected existing Zone 7 channels and support dedication of additional rights-of-way widths along selected future flood control projects shown in this Plan to provide adequate space for identified trail uses. It would allow and encourage arroyo trail uses where other agencies will construct, operate and maintain trail improvements, and the particular agency will accept liability for these uses. These Action Items were recommended:

1. Request the City Councils of Pleasanton and Livermore, the Alameda County Board of Supervisors, and the East Bay Regional and Livermore Area Park District Boards to approve resolutions that would: a) support the Arroyo Management Plan; b) express cooperation with Zone 7 in applications to funding sources, and; c) support funding for project implementation within their own jurisdictional areas from outside sources for which Zone 7 is not eligible.
2. Request that law enforcement agencies patrol trails within their respective jurisdictions.
3. Preparation of long term legal instruments with the cities and park districts which assigns responsibility for implementing trail improvements on Zone 7 lands or easements.
4. Cooperation with and support of city or park district efforts to obtain manpower or funding for trail or facility construction, operation and maintenance.
5. Review and approve designs for trail improvements.

Policy B

This policy would support and encourage city and county policies which would facilitate the construction and maintenance of public access trails along flood control rights-of-way. These action items were recommended:

1. Request that cities institute Conditions for development on all developers of subdivisions adjacent to the arroyos, e.g., circulation patterns of parallel, loop, and cul-de-sac streets as per Santa Clara Valley Water District's (see Fig. 1) creative creekside street design brochure.

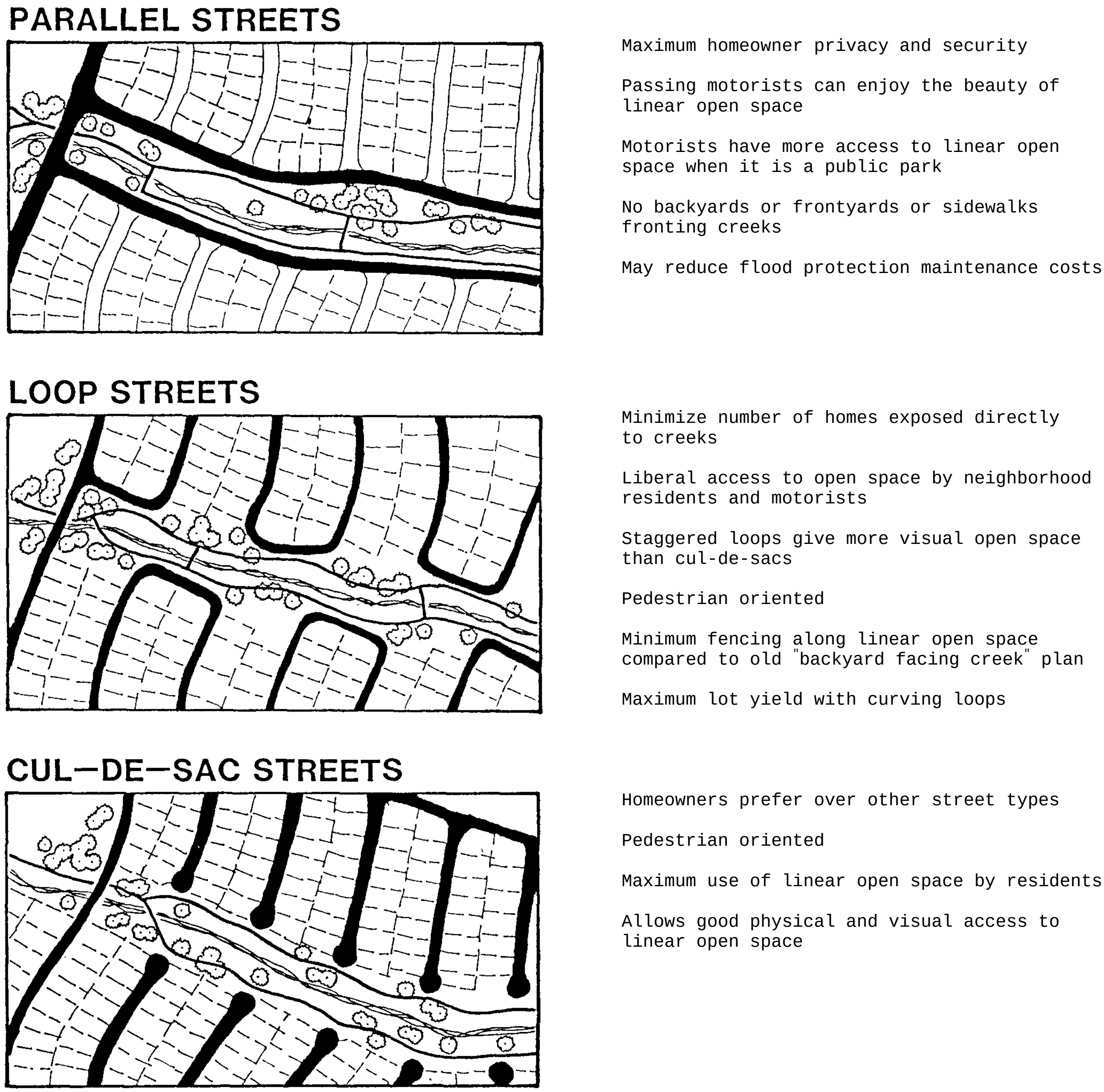

Figure 1 — Street Design. The appropriate layout of streets adjacent to arroyos can accommodate and encourage access onto flood control channel trail systems while safeguarding the privacy of adjacent residents. Originally shown in a brochure produced by the Santa Clara Valley Water District these alternative designs all provide frequent and easy access from nearby streets while enhancing the surrounding neighborhood.

Figure 1— Street Design.

2. Request that cities consider incentive zoning where developers would receive a density bonus for contributing to trail development.
3. Request that cities update approved Bicycle Plans in order to qualify for Metropolitan Transportation Commission gas tax funds and Transportation Development Act Federal funds for bicycle trails.
4. Request that appropriate agencies incorporate trails/parks (trailhead) development and maintenance in their work programs as necessary for project facilitation including purchase of additional supplies and equipment for free labor work crews.
5. Encourage cities to implement land use and water management techniques and use of materials which improve groundwater recharge, reduce channel maintenance expenses and adverse environmental impacts (Background Report contains brief descriptions of techniques).

Policy C

This policy would strengthen communication and coordination between Zone 7, other relevant agencies, and developers affected by the Plan. This Action Item was recommended:

Sponsor the creation of a quarterly convening Coordinating Council to provide a consistent forum for the exchange of information between Zone 7, other agencies, and developers; an earlier and more active role for Zone 7 in planning and design of channel and stormwater systems; and discussion of the implementation of the Arroyo Management Plan.

Policy D

This policy would provide the public with information on the values of a well-planned flood control right-of-way that includes access improvements. These Action Items were recommended:

1. Publicize the plan widely, in a concise format, to build support and educate community organizations and land developers.
2. Print brochures illustrating preferable creekside street designs (see Santa Clara District example) for planning department distribution.
3. Provide brochures which promote land use and water management techniques, and construction materials which reduce or delay storm runoff.
4. Distribute trail maps to interested public agencies and trail related organizations. Update the maps as segments are completed. Show potential trail development outside of Zone 7 to show its completion.

Policy E

This policy would promote construction and maintenance techniques that recognize the public benefits derived from public access in naturalized settings. Encourage trail improvements that harmonize with the surrounding natural and man-made environment. These Action Items were recommended:

1. Modify or discontinue use of herbicides and pesticides along trail segments to be compatible with public access and riparian vegetation.
2. Restrict Zone 7 maintenance to property line fences and flood control channels. Permit other agencies, through legal instruments, to maintain riparian vegetation and trail improvements above the 15 year flood plain.
3. Permit bottom growth of reeds and cattails to occur between sediment removal operations To the extent feasible without creating a flood hazard. (Allow overexcavation at the time of silt removal to retain adequate flow capacity.)
4. Analyze the suitability of using excavated sediment for bermed channels (see Fig. 2, Option B), and man-made recreation landforms.
5. Accept dedication of channels with a maintenance road on only one side for heavy equipment access. (The trail within the channel can provide secondary access for lighter flood control maintenance vehicles.)
6. Minimize adverse impacts of trails or channel modification on existing or potential riparian habitats. Protect topsoil and existing trees.
7. Provide adequate space for new riparian habitats to be developed where substantial land-altering construction is needed to create or relocate a channel for flood flows,

Design Standards

Existing Flood Control Channels

Although existing channels vary, they are all fenced to preclude public access, have uniform side slopes, lack overstory vegetation, and are designed for maintenance efficiency. The net result is a sterile, uninviting, and visually meager environment. In order to become suitable for public access the channels need to be open and attractive with as rich a variety of natural elements as possible. Obviously, those channels which have vestiges of the natural riparian environment come the closest to these standards, but all the flood control channel configurations have potential to be readapted to create a viable and exciting open space system.

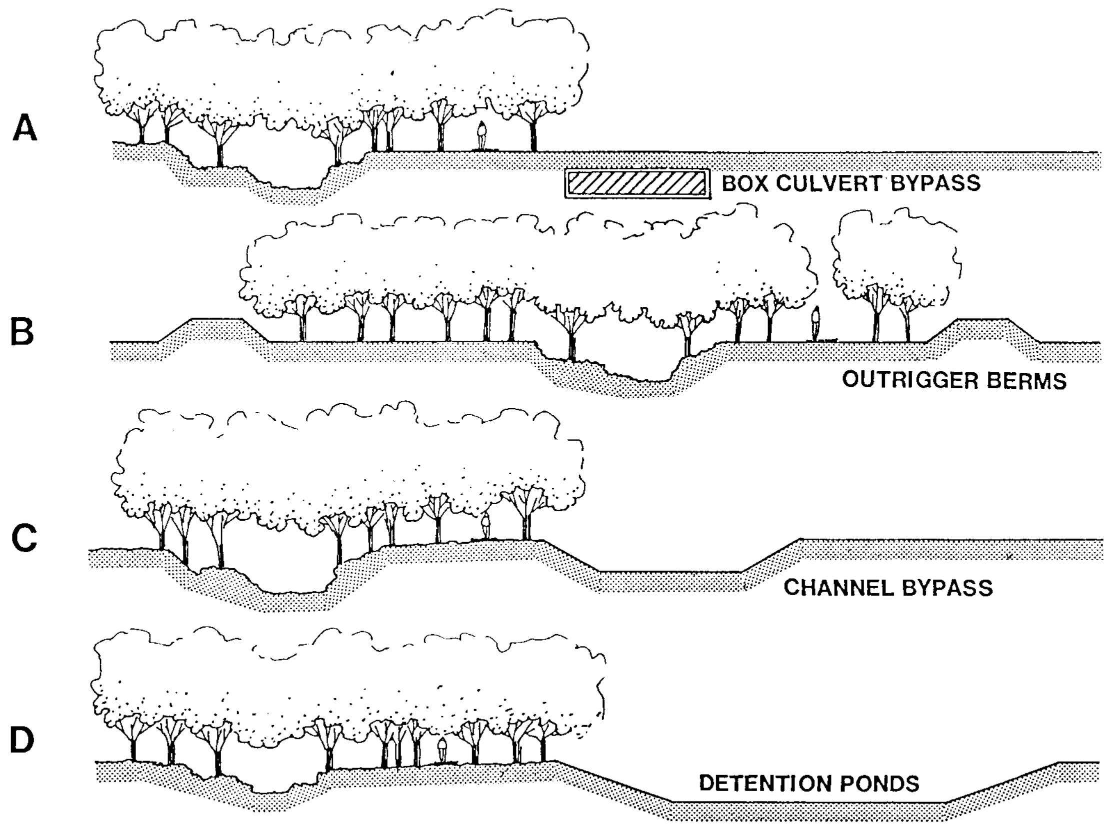

Figure 2– Riparian preservation options.

Flood Control Channels Designed for a Public Trail System

Recommended New or Adapted Flood Control Channels

Trails along flood control channels can be developed by: a) restricting maintenance vehicles to one side of the channel; b) preserving any existing riparian habitat; c) reintroducing riparian habitat above the 15 year flood plain where it has been destroyed; d) permitting bottom growth and shrubs below the 15 year flood plain; e) opening the bottom of the channel to equestrian use; f) establishing a paved trail in lieu of the second maintenance road; and g) providing adequate access points (fig. 3).

These changes would involve no radical reconfiguration of the existing channels, or additional width to the right-of-way. The right-of-way would remain fenced in order to protect the privacy of adjacent landowners.

Recommended New Channel Construction Where Additional Lands are Available

In certain cases, especially those where future rights-of-way will be established, Zone 7 may wish to choose for park and recreation purposes, in conjunction with other appropriate agencies, to vary its standard right-of-way (fig. 4). This would allow more leeway in the construction of the channel to include non-uniform variable side slopes, additional trail opportunities, meandering streambeds, and larger areas where riparian habitats can be preserved and/or re-established (see below). This additional right-of-way would require a greater degree of coordination between concerned agencies. The result of implementing this new type of channel construction would not only be a more varied, attractive, and natural-appearing trail system, but a significant park and open space system which could incorporate a wider range of facilities and activities.

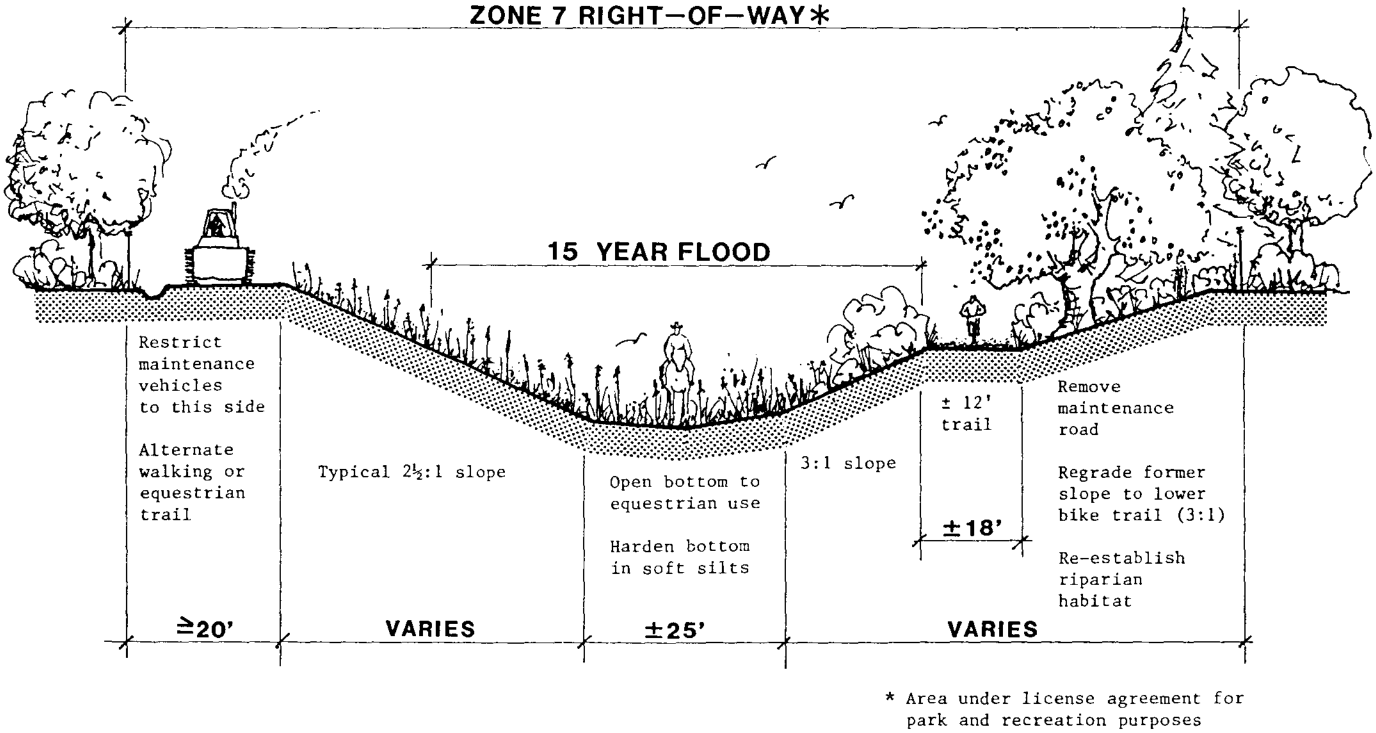

Figure 3- Recommended new or reconstructed ultimate channel.

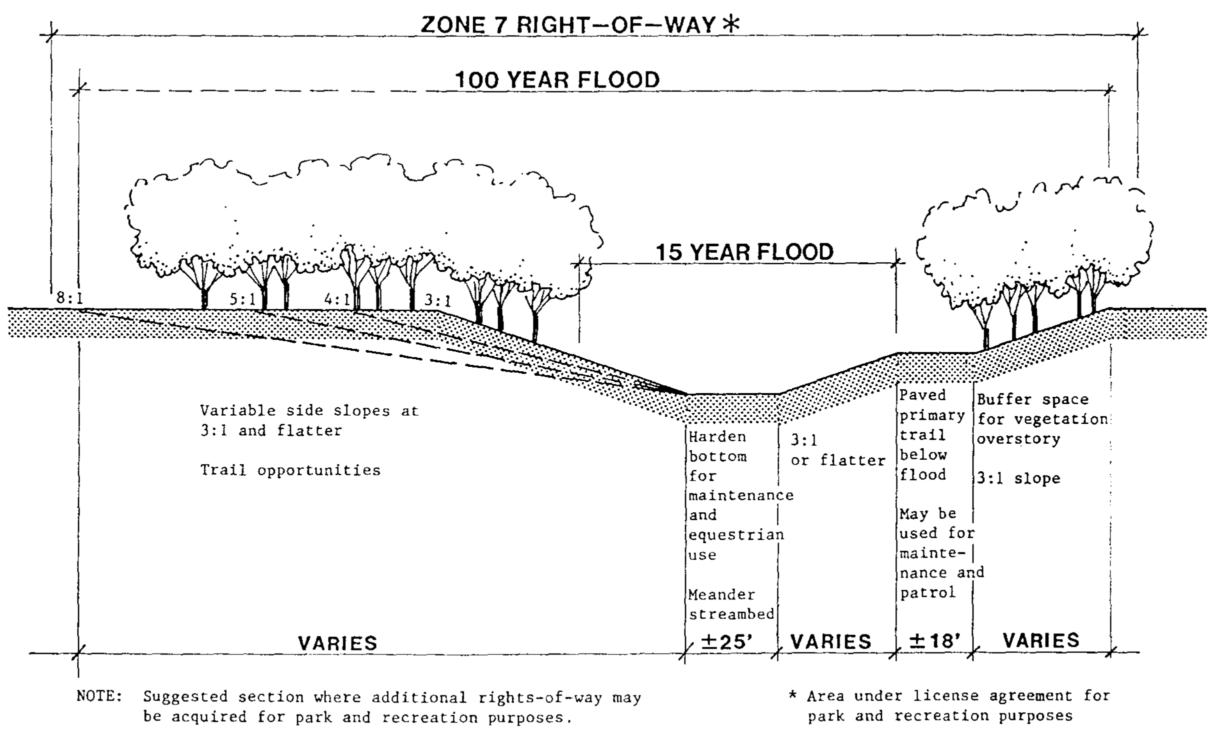

Figure 4- Recommended new channel construction.

Riparian Woodland Preservation Options

In future development of flood control channels consideration should also be given to methods which can preserve existing riparian habitats while accommodating increased water runoff (fig. 2). As illustrated in the cross sections these are: a) box culvert bypass, h) outrigger berms, c) channel bypass, and d) detention ponds. These options have the double advantage of providing public access and preserving ecologically valuable habitat.

Facilities Standards

The Plan lists eight items. Of those, two specifically address revegetation and habitat restoration:

"e) Revegetation should be directed by the Alameda County Flood Control District 'Revegetation Manual' (Harvey and Stanley Associates, 1983). The District should disallow last minute plant replacements un-der landscape maintenance guarantee conditions and include native or native-like wildflowers in their stan-dard hydroseed mix."

"h) The most natural-appearing flood control channels will: Vary side slopes; Have natural surfaces (earth, boulders); Support an overstory of native or naturalized trees and an understory of riparian plant materials; Have a variable width gravel bottom, allowed to support islands, aquatic plants, sand bars; Vary the vertical alignment of trails; and Minimize use of fences, signs, trash cans or other street furniture."

Epilogue

Largely because of budget constraints and maintenance priorities no channels have been retrofitted to the configurations recommended in the plan. According to one of the Plan's early advocates, the current Zone 7 Board lacks a majority of directors who are interested in seeing a more active implementation of the Plan. Perhaps as growth continues, there will a renewed interest in utilizing the channels as a means of gaining open space.

Three years after its adoption, however, the Plan is being used. The East Bay Regional Park District Board adopted a resolution of support in 1985. The City of Pleasanton Planning Department, uses the Plan to guide development adjacent to the channels. The street design options have been particularly useful. The Livermore planning staff uses the Plan as a reference document. The author was recently contacted by the City of Livermore regarding an additional study for an urbanizing section of Arroyo Las Positas. The staffs of the City of Pleasanton and Zone 7 exchange information regularly relating to proposed developments along arroyos. While no formal Coordinating Committee has yet been established, the creation of such a group is still possible, given the explosive growth of the region. Perhaps the additional exposure of the plan through these proceedings will bring it to the attention of other decision makers of the region who can see to its implementation.

Acknowledgments

We thank Bill Owen, landscape architect, and Maria Vermiglio, planner, for their data contributions to the original plan. We also thank Margaret Tracy, Zone 7 Director, and the Zone 7 staff for their support.

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SESSION K: COORDINATING INTEREST GROUPS

In the same sense that the riparian environment serves as a meeting ground for many forces and processes, a large number of interests converge in today's lively concern for riparian conservation and management. This convergence of interests could in fact be the theme for a whole new conference—hopefully in less than 7 years. The issues are that pressing and the interest is that great. In this final session, we consider several of the possible perspectives.

Richard Spotts speaks strongly here for consideration of a wide range of interests along the Sacramento River as flood control and water delivery systems are intensified.

Feelings have always run high, too on the subject of using riparian lands for grazing. John Ross, who represents the cattle producers, spoke of the multiple political binds that his people face, and he sought, in this session, to open doors for cooperation. Bill Flournoy, a rancher who is also a grazing permittee on public land, spoke in this session of his own profound appreciation of these riparian lands and of his efforts, as a participant in and leader of a challenging new "Coordinated Resource Management Program" to integrate grazing use and riparian resource protection. His paper describes that experience.

The Paper by Ice *et al.* has been moved to this section because its focus is more on a legislative approach to satisfying varied interest than it is with riparian environments of forested lands.

Duncan Patton explains how riparian interests have gathered forces in his state to form the Arizona Riparian Council. This group enjoys strong participation from the research community in its effort to integrate the many concerns over Arizona's disappearing riparian systems.

Dana L. Abell
University of California, Davis

CONFLICTS IN RIVER MANAGEMENT: A CONSERVATIONIST'S PERSPECTIVE ON SACRAMENTO RIVER RIPARIAN HABITATS—IMPACTS, THREATS, REMEDIES, OPPORTUNITIES, AND CONSENSUS[1]

Richard Spotts[2]

Abstract: The Sacramento River's historic riparian habitats have been reduced by over 98 percent due to cumulative, adverse human activities. These activities continue to jeopardize the remaining riparian habitats. The results of these trends is more endangered species conflicts and listings, coupled with less fish, beautiful scenery, and other resource values. This paper provides a conservationist's perspective on how these resource losses could be stopped, and eventually reversed, through a combination of less-damaging bank protection methods, reliable mitigation for unavoidable impacts, willing seller acquisitions, and restoration projects. A consensus approach is suggested which could expedite conservation measures while reconciling landowner, local government, and flood control concerns.

As the only representative of a private conservation group participating on this conference's plenary session panel, I will provide a conservationist perspective on Sacramento River riparian habitat problems and how to solve them. I believe that the Sacramento River is an ideal subject for this panel, based on my work to protect its riparian habitats over the past several years. This river exemplifies many of the most difficult challenges facing riparian conservation, such as resolving flood control, local government, and landowner concerns. At the same time, it also offers many exciting opportunities, such as identifying better bank protection methods, improving mitigation, and working cooperatively with landowners. But first I want to give an overview.

Impacts

In 1848, the Sacramento River had an estimated 800,000 acres of riparian forests. Early explorers described jungle-like forests extending up to 1 mile in places on each side of the river. Today, only about 12,000 acres—less than 2 percent—remain. Except for a few dense stands, much of the remnant habitats are relatively small, narrow, scattered bands along portions of the river. The historic habitat losses contributed to an estimated 80 percent reduction in fisheries, and to the growing list of endangered, threatened, rare, and candidate species. These habitat losses were primarily caused by agricultural conversion, water development, bank protection and flood control projects, and urban growth.

Threats

Unfortunately, the causes of past habitat losses continue, and the Sacramento River's dwindling riparian habitats (and their endangered species and fisheries) remain in jeopardy. Over 80 percent of the remaining habitats are in private ownership and might be lost to agricultural conversion or other development (USFWS, 1984). An ambitious Army Corps of Engineers and State Reclamation Board flood control project is getting underway which may result in over 20 miles of additional rip-rap bank protection (USACE, 1987a). Another massive rip-rap project is on the horizon: Phase III of the Sacramento River Bank Protection Project. The infamous Chico Landing to Red Bluff Project, or some scaled-back version, may be resurrected.

Meanwhile, the U.S. Bureau of Reclamation is promoting new water marketing and contracts. This involves selling more water for off-stream uses which may adversely alter river flows and encourage conversion of habitats to agriculture. There are many more threats, including a proposed City of Redding in-river hydro project, huge water diversions and fish losses by the Glenn Colusa Irrigation District, and ongoing pollution and unscreened river water pumps.

Remedies

Federal, state, and local government agencies are responsible for many of the most serious past habitat losses, as well as for proposing future projects with additional, significant impacts.

Overall, taxpayers have subsidized far more riparian destruction than riparian conservation. This is especially true with respect to government- sponsored bank

[1] Presented at the California Riparian Systems Conference, September 22-24, 1988; Davis, California.

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protection and flood control rip-rap projects, water development and marketing, and agricultural programs.

It is ironic that the cause of these problems must ultimately be the source of any solutions. In other words, the riparian "remedies" lie in changing the instrumentalities of our democracy from riparian destroyers to riparian conservers and restorers. The foundation to accomplish these changes is already established through public support and existing environmental laws. Many public opinion polls in recent years demonstrate overwhelming and growing public support for increased conservation of wildlife and other natural resources. Most people know that we are losing ground in saving endangered species and maintaining the natural diversity and abundance of our native species. Most people also are frustrated that government has not been more effective in reversing these sad trends. For example, when the legislature failed to allow any environmental acquisition bonds, Californians enthusiastically rallied together in 1987 to qualify and in 1988 to pass (with over 65 percent approval) Proposition 70, a $776,000,000 initiative bond measure for wildlife, parks, open space, and coastal protection.

This public support and awareness is reflected in many federal and state environmental laws. These laws include the National Environmental Policy Act (NEPA), Endangered Species Act (ESA), California Environmental Quality Act (CEQA), and California Endangered Species Act (CESA). These laws could be potent tools to protect riparian habitats, but they have generally not yet lived up to their intent or potential due to lax government compliance. The overall purpose of these laws is to protect and restore listed species; to pursue less-damaging alternatives to projects posing significant adverse impacts; and to fully mitigate any unavoidable adverse impacts.

These laws apply whenever government agencies propose a discretionary project or program. There are procedural and substantive aspects to comply with these laws. Procedurally, documents are prepared, circulated, reviewed, and adopted. Substantively, the document process is supposed to result in more environmentally enlightened government actions. Too often, the agencies become adept at fulfilling the procedural requirements, while justifying the status quo. Thus, government agencies must keep the substantive "heart" of these laws uppermost in mind; to wit, they have a duty to honestly pursue less-damaging alternatives and to fully mitigate adverse impacts. They must also not jeopardize any listed species or their critical habitats. Meanwhile, the public must learn to distinguish between voluminous paper shuffling and tangible improvements in government actions.

The Sacramento River Bank Protection Project (SRBPP) involves ongoing rip-rap construction which destroys riparian habitats along portions of the Sacramento River. The SRBPP is jointly-sponsored by the U.S. Army Corps of Engineers and the California Reclamation Board. I believe the SRBPP offers a relevant example of problems in achieving substantive compliance with environmental laws. I have monitored SRBPP environmental documents and decisions over the past few years. Most of this monitoring has been painful and frustrating because of the substantial "credibility gap" between what SRBPP documents say and what actually occurs.

While the procedural quality of SRBPP environmental documents has markedly improved in recent years, there has not been a corresponding improvement in SRBPP decisions and actions. Less-damaging alternative bank protection methods are considered in detail, but most are never tried. The Corps has a special aversion to using "experimental" methods. This leads to an obvious "catch-22." The Corps reasons that since rip-rap has been used historically it is economic and effective. Alternative methods have not been used so they are "experimental" and therefore likely to be more expensive and less effective. Of course, the only way to break this stalemate is for more use of alternative methods to determine their genuine costs and effectiveness. One alternative method, the "palisades", is being tested at one site. This is a positive step, but additional "palisades" sites are necessary to gain data under a variety of river conditions.

Aside from giving alternatives short shrift, there has also been an appalling SRBPP history of glacially-slow, inadequate, and illusory mitigation for rip-rap habitat losses. Phase I of SRBPP was constructed over a decade ago, but there has not yet been any mitigation. Government agencies are now in the process of resolving what Phase I mitigation should occur and where. Congress appropriated $1,000,000 in 1987 for Phase I mitigation, and some encouraging work is underway. But it will be more months and perhaps years before the Phase I mitigation outcome is known.

For SRBPP Phase II, conservation "Right 8" easements were acquired to provide mitigation. A 1987 U.S. Fish and Wildlife Service (F WS) study found that only 32 percent of these easements had high-value habitat, while 21 percent were moderate, and 46 percent were low in value (USFWS, 1987). On 82 percent of these easements, adverse management practices were preventing habitat restoration. In essence, most of these easements were not enforced, nor were they fulfilling their promised level of habitat mitigation.

In recent meetings and environmental documents, the Corps and Reclamation Board have promised to do a better job in providing mitigation, including improved management of the "Right 8" easements. It is too soon to determine if most of these latest promises will be kept. But there are already both some negative and positive signs.

On the negative side, despite my repeated requests for firm written commitments, the Corps and Reclamation Board still refuse to specify if, when, or how they will post, monitor, and enforce the "Right 8" easements to correct problems identified in the 1987 FWS study, ensure easement compliance, and encourage habitat restoration.

Other unresolved issues relate to whether the new mitigation team has a specific itinerary for informing all relevant landowners and local reclamation districts of easement problems; what role FWS, the California Department of Fish and Game (DFG), and perhaps other government or private parties might play in better managing these easements and restoring habitats; and whether necessary staff and funds will be provided to do promised mitigation work.

Another problem arose when a post-construction inspection of a rip-rap project found that riparian trees were destroyed despite approved environmental documents which promised to retain them. The Corps' response to this shocking revelation appears to be "so what." They state that circumstances change, and they may need to deviate from promises in approved environmental documents (Scholl, 1988). Circumstances do change, but the solution lies in providing more up-to-date and accurate environmental documents. If the Corps' cavalier attitude continues, it will cast further doubt on the integrity of environmental documents and widen the already large "credibility gap."

On the positive side, Congressman Vic Fazio, Assemblyman Patrick Johnston, the State Lands Commission, FWS, DFG, EPA, and others have worked to correct mitigation deficiencies. For example, Congressman Fazio's work was pivotal in achieving the federal funds for Phase I SRBPP mitigation. It is hoped he will continue to press for mitigation reforms. Assemblyman Johnston pushed legislation to transfer management of mitigation easements to DFG. At this writing, the Department of Water Resources and Reclamation Board oppose this

legislation but negotiations toward a possible compromise are underway. The State Lands Commission prepared and executed a new master lease governing Sacramento River rip-rap projects. This lease contains many welcome environmental conditions. However, the State Lands Commission must remain vigilant, because the strength of this new lease will depend upon the degree of monitoring and enforcement.

It is difficult to balance these negative and positive signs, and speculate on whether mitigation will remain "too little, too late" or become reliable and effective. I can only hope that as more people become aware of these problems, there will be ever-growing pressure to solve them. I also hope that the recalcitrant government officials, particularly some Corps higher-ups and engineers, will come to realize that: they are taxpayer-subsidized public servants; the public wants timely and effective mitigation; the relevant laws encourage such mitigation; and poor mitigation will only hasten endangered species conflicts, "jeopardy opinions", and more environmental legislation and litigation. The influential farmers who promote rip-rap to protect their investments and perhaps increase their property values should likewise recognize that adequate mitigation is fair, reasonable, and ultimately in their self- interest.

Opportunities

At this juncture, I will figuratively shift from reverse (how government is destroying riparian habitats) to forward (how government is protecting riparian habitats). Some very exciting progress has occurred with respect to acquiring and protecting Sacramento River riparian habitats.

In September 1984, the FWS released a study documenting the importance of Sacramento River riparian habitats, the threats to these habitats, and made recommendations for habitat protection. A broad coalition of environmental, wildlife, sportsmen, fishing, and other groups then urged Congress to establish a new Sacramento River National Wildlife Refuge (SRNWR). In 1986, Congress gave FWS $150,000 and authorized a SRNWR feasibility study. The overall purpose of this study was to determine whether this refuge could be compatible with flood control and landowner concerns. In October 1987, FWS presented the study to Congress. The study found that the SRNWR was feasible, and could be established consistent with flood control and landowner objectives. The study include a FWS commitment that only willing seller refuge acquisitions would occur, and FWS would work on a site-specific basis with the corps and Reclamation Board to allow necessary flood control work. The study identified 66 riparian habitats sought for preservation between Colusa and Red Bluff, and ranked these habitats in four categories. The study estimated it would take between fifteen and twenty million dollars over the next five years to achieve the recommended refuge acquisitions.

In December 1987, Congress appropriated $1,000,000 to initiate SRNWR willing seller acquisitions. At this writing, FWS is preparing the necessary environmental document for public review. This year Congress is considering additional SRNWR appropriations. Perhaps another $2,000,000 will be available in FY 1989. Despite this progress, however, continued strong public support will be needed to keep this refuge moving forward.

Some landowners and local government officials have expressed concerns vis-a-vis the SRNWR. For example, landowners are understandably upset that this new refuge may increase their existing problems with respect to public trespass, vandalism, poaching, and littering. I and other refuge proponents understand and appreciate these concerns. We recognize that the refuge must be carefully planned and managed to eliminate these problems. We will work for strict refuge policies on public uses, coupled with supervision and enforcement. We also recognize that most landowner interest in negotiating for possible SRNWR acquisitions will involve easements. These easements provide habitat protection while precluding public access. Of course, we hope that some larger fee acquisitions will eventually occur, and that limited public uses—such as hiking, nature study, and birdwatching—will be allowed so long as they are controlled and compatible with refuge habitat objectives. People who want to camp or picnic should be directed to state or local parks.

A local government concern is the possible loss in property tax revenues. However, Congress appropriates funds each year to pay "in lieu" taxes to local governments. If there is nevertheless fear that these federal payments will not be adequate, we will work to overcome any shortfall.

Farmers have expressed concerns that the refuge may increase: EPA enforcement of future pesticide label restrictions designed to protect endangered species, pesticide drift complaints, and wildlife-crop conflicts. These concerns are difficult to understand because refuge acquisitions per se should not affect these activities. EPA's pesticide label restrictions will presumably seek to protect endangered species on a site-specific basis, whether these sites occur on private or public land. The controlling factors are the presence of endangered species and a known threat from pesticides. The EPA program has absolutely no connection to the refuge, other than the coincidence that they are both intended to benefit endangered species. If anything, farmers should welcome the opportunity to consider selling their land, either in fee or easement. If they find the EPA pesticide label restrictions onerous due to endangered species on their property, at least they have the option of receiving the fair market value for their property. Without the refuge and Congressional funding, they would not have this option.

The pesticide drift concern revolves around farmers being "good neighbors." If a pesticide applicator causes unauthorized pesticide drift onto another's property, it may kill trees and otherwise harm crops or animals. The neighboring landowner may have legal remedies to stop future drift and be compensated for losses. These remedies are not changed by virtue of refuge acquisitions. Of course, a refuge manager should have the ability to seek these existing remedies, if appropriate, as a neighboring landowner. There are already four major federal refuges, plus federal easement areas, located in the Sacramento Valley, but we are not aware of any serious pesticide drift controversies.

With respect to wildlife-crop conflicts, it must be remembered that the refuge acquisitions are sought to protect existing riparian habitats. We are not aware of any data showing that these particular habitats are creating significant wildlife-crop conflicts. If the concern is that these habitats might someday create these conflicts, then what is the solution? Destroy all remaining riparian habitats? A responsible approach is that if these problems are documented, whether from private or public riparian habitats, the interested parties should work together to develop appropriate management solutions.

Another landowner recommendation has been that refuge acquisitions should be coupled with a commitment to resurrect the Chico Landing to Red Bluff Project. This Project involves rip-rap on outside bends along this stretch of the river. It was stopped by a FWS "jeopardy opinion" under the Endangered Species Act because of harm to the threatened valley elderberry longhorn beetle. There are several problems with this recommendation. The rip-rap project, given uncertain mitigation implementation, could destroy more riparian habitats than the refuge protects. It would violate the federal Endangered Species Act to pursue this project, in light of the "jeopardy opinion." The project has a questionable cost-benefit ratio, since there is no clear correlation between the project costs and corresponding reductions in downstream dredging costs. Finally, the ecological integrity and fisheries production of the river depends upon the natural cycle of continued erosion and habitat succession. The project is designed to thwart this cycle and it thereby could devastate the natural values that the refuge seeks to protect.

Besides SRNWR, other positive acquisitions have occurred and many more are anticipated. The Wildlife Conservation Board (WCB), Bureau of Land Management, Nature Conservancy, and Trust for Public Land have acquired some Sacramento River riparian habitats. The successful Proposition 70 initiative bond measure includes $4,000,000 earmarked for WCB Sacramento River riparian acquisitions. The Sacramento River Preservation Trust was instrumental in achieving this Proposition 70 funding. It is important to underscore that these are willing seller acquisitions. Other state funding sources for possible future acquisitions include the Environmental License Plate Fund, Energy and Resources Fund, Wildlife Restoration Fund, and voluntary endangered species tax check-off account.

Consensus

My Sacramento River work has generally convinced me that there is a link between the breadth of coalition support and concomitant cooperation among interested parties and the relative speed and progress in achieving conservation objectives. In other words, conflict and stalemate achieve much. A comparison of my Remedies and Opportunities discussions should help illustrate this linkage. This is not to say that conflict itself is bad. It is often necessary before concerns are taken seriously and a foundation for compromise and cooperation is established.

The single most promising observation vis-a-vis Sacramento River riparian habitat conservation is that the ingredients for compromise, cooperation, and perhaps even consensus are now present, and the parties are resolving conflicts and moving closer together. The progress on SRNWR is one example. The so-called "S.B. 1086" studies and negotiations, pursuant to Senator Nielsen's legislation for a Sacramento River action team, advisory council, and report, are another. These and other opportunities are helping to educate people, identify concerns and conflicts, and provide the means for resolving them.

Please let me offer a scenario for consensus, including accompanying prerequisites. Conservationists should accept the fact that some level of further rip-rap may be needed for bona fide flood protection and to safeguard essential facilities, such as roads, bridges, etc. Conservationists should also accept that local governments have legitimate property tax concerns, and landowners have reason to fear rowdy refuge visitors. Conservationists should agree to support necessary flood control projects, work with local governments for adequate "in lieu" tax payments, and work with landowners for appropriate refuge management and re-strictions on public uses.

For their part, the Corps and Reclamation Board should fairly try and evaluate less-damaging alternative methods, use such methods wherever possible, and work to provide reliable and effective mitigation for both past and future habitat losses. In addition, they should work diligently with FWS and DFG to solve the dilemma of mitigating "heavily shaded aquatic" habitat losses along the river.

The landowners and local government officials should accept that riparian habitats must be protected and that opportunities for willing seller acquisitions are positive and desirable. They should help conservationists lobby for additional acquisition funding. They should accept that the river must be allowed to erode and meander in some reaches where it poses no significant public safety or flooding threat. They should accept that the taxpaying public does not wish to subsidize rip-rap to protect their private property from erosion, but that they have the option to shift this risk to the public through riparian acquisitions. The taxpaying public should accept that their funds will be spent for these acquisitions because it is the best hope of fulfilling their desires for improved endangered species, riparian habitat, and fisheries conservation.

I urge everyone to work to bring this scenario to fruition. If successful, it could serve as a persuasive precedent for riparian conservation elsewhere.

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RIPARIAN AREA MANAGEMENT: PRINCIPLES, POLITICS AND PRACTICES [1]

John W. Ross and Sheila L. Massey[2]

Probably the one area of agreement among those involved in riparian area management is that riparian areas are important and must be given close management attention. Each interest group, however, comes to this common ground from a different perspective.

Livestock producers view riparian areas as sources of abundant feed; good grazing management is necessary to maintain the productive value of the riparian for the future. Anglers see riparian areas as critical habitat for fish – their concern is adequate streamflow and shade to keep water temperatures at appropriate levels. Picnickers and other recreationists enjoy the scenic beauty of a riparian meadow. Watershed managers are concerned about the run-off or water production capacity of riparian areas.

Although these perspectives are not necessarily incompatible, it is hard to discern any compatibility from the rhetoric over riparian areas. It is possible, and desirable, to mutually satisfy the one common interest: the welfare of the riparian area. However, no one gets everything they want. Each group achieves some part of its interests, and the overall objective is met in the process.

This is not an easy task, but the tools and the methodology are available. Such concepts as the Experimental Stewardship Program (ESP), technical review teams (TRT's), inter-disciplinary teams (IDT's) and Coordinated Resource Management & Planning (CRM) have proven effective in dealing with other issues as well as with riparian area management. Many of the interest groups are familiar with these processes and are willing to work with them.

If we can agree that we share an objective – the welfare of the riparian area – and a principle – the need to manage the riparian area, we can move on to the more contentious points: The politics of riparian area management and the practice of riparian area management. In discussing the politics, we give our perspective on the forces motivating some of the participants in the issues arising from riparian area management. We will also make some suggestions for problem resolution.

In discussing the practice, we cite examples from the experience of the California Cattlemen's Association members in dealing with state and federal agencies and private groups on riparian area management. We offer some prescriptive measures to enhance the management of riparian areas, as one concerned users group.

Political Implications

The riparian area management issue has grown rapidly in public attention. The increased awareness arises from several different sources: genuine regard for wildlife, watersheds and forage quality for grazing based on scientific analysis; aesthetic appreciation yet uncertainty in the face of a rapidly changing environment, and other concerns. Some of the concerns are understandable to livestock producers, and we will work to resolve these differences. Other concerns we cannot accept, for they are the antithesis of our business.

As an analogy, consider the timber industry and the spotted owl. While some people are legitimately concerned about the status of the spotted owl, others use the spotted owl issue as a shill to obtain their real objective: prohibitions on timber harvests in "old growth" forests!

It is similar with livestock in riparian areas. Those who would remove livestock from the public lands have seized upon riparian area management as their latest tool. They speak of "water quality" and "wildlife," of "pristine purity" and "aesthetic values," but what they really mean is "remove the cattle." (It is tempting to speculate about the basis for their intense dislike of livestock; perhaps as a nation is removed from its agrarian heritage, a rejection of that heritage occurs). Faced with this type of agenda, reaching consensus is difficult or even impossible.

Another interest group at least acknowledges that livestock grazing is a legitimate factor (even a management tool) on riparian areas. They are willing to work with other interests, including the consumptive–but renewable–uses such as timber and grazing. Clearly, however, concerns over water quality, fishery protection and other issues must be considered along with grazing, in the view of this interest group – working together does not mean unanimous agreement.

The mainstream organizations have adopted a position of moderation on the consumptive use side of the issue; they are willing to cooperate with other interests. The California Cattlemen's Association (CCA) has taken this approach. CCA is a sponsor of the CRM program (the first agricultural group to become a sponsor), and we have requested that the Society for Range Man-

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Executive Vice President and Director of Regulatory Affairs respectively, California Cattlemen's Association, Sacramento, CA.

agement (SRM) develop a coalition so that environmental and consumptive use interests can work together on specific watershed and riparian area management questions.

At the extreme, of course, there are the consumptive users who will resist any and all change, preferring to produce livestock in their traditional manner. These people do tend to be as strongly "pro-livestock" as the anti-cattle people are "anti." They point out, not without some basis in fact, that riparian areas can withstand greater grazing pressure and will recover sooner than upland areas. They consider the issue to be overblown in importance.

Where does this leave us in terms of the political overtones of our mutual objective — the welfare of riparian areas? There are two camps that are clearly polarized — the radical preservationist and the rock-ribbed traditionalist livestock producer. But in between these two poles fall a number of groups and individuals. Hopefully, it is they who will set the course for riparian area management.

Federal agencies, principally the U.S. Forest Service, bear the brunt of mediating the conflicts over riparian area management. Since they must be more responsive to the "public interest" than private landowners, they are the first target for changes in management practices. However, we are seeing the focus of riparian area management being broadened to encompass private lands as well.

These agencies are generally fulfilling their difficult role of mediating the conflicting concerns of various interests quite well. Perhaps an indication of their success is the fact that no one is entirely happy with what they are doing. The agencies have embraced the Coordinated Resource Management process and the Experimental Stewardship Program. They are using technical review teams for problem resolution, and interdisciplinary teams which operate on an ad hoc basis to make recommendations on specific problems.

Interestingly enough, the principal state agency involved in the riparian issue, the Department of Fish & Game (DF&G) tends to mirror the views of the more radical groups. Citing the "Public Trust Doctrine" as its authority, the DF&G has filed a number of objections or appeals of county general plans, national forest plans, etc. The DF&G's solution is often a narrow one, focusing exclusively on the wildlife and fisheries aspect of the riparian area.

DF&G's tactics can be heavy-handed: CCA members have been threatened with arrest or fines. Relations between the DF&G and landowners are worse in California than in any other western state — and probably worse than in any state in the nation.

The California Department of Forestry and Fire Protection (CDFFP) also has a role in rangeland management, especially on wildland subject to risk of fire and on land considered "hardwood rangeland," where management of oak trees is a consideration. CDF's involvement in riparian areas has been more focused on timber harvest than on rangeland issues.

The debate over riparian area management is advancing through four means, used by all interests in varying degrees: (1) public influence through the media — newspaper articles, television reports and "documentaries," magazine articles, etc.; (2) political influence through direct lobbying, political action committees, volunteer support for campaigns, etc., at both the local and state levels; (3) judicial activity through litigation of specific environmental issues; and (4) heavy involvement in regulatory activity oversight, including formation of "regulatory watchdog committees," and utilization of the appeals processes of the agencies to block or promote activity.

Some groups are more sophisticated than others in availing themselves of these means to influence decisions over riparian areas. As the process for influencing legislation and regulations has changed to include more public involvement, traditional power bases have also changed. Groups that relied upon direct and personal contact are now finding it necessary to argue their case before the public and are becoming more aggressive in doing so.

The political interplay is probably a necessary fact, but it can be frustrating for people who are more interested in direct action to manage riparian areas. While the politics goes on, the work of riparian area management must continue — we cannot afford to lose sight of our objective: the welfare of the riparian area.

These political battles may gradually change the framework for riparian area management. We would prefer, however, to work directly with other groups to resolve problems between us, and seek a more immediate effect on riparian areas.

Practical Riparian Area Management

Before talking of management practices, we need to define "riparian area." Each state and federal agency has a slightly different definition, and definitions vary when applied to different situations. A valley riparian habitat such as in the Sacramento or San Joaquin valleys is different from foothills, desert or mountain riparian areas.

However, a general definition probably suffices: "The area in and along streams containing forage and other plant species that are more dependent upon water than upland species." The real issue is how the area should be managed — from our point of view, how livestock will be managed in the area — so the definition is not so important. Management decisions should be made "on the ground" where all parties can view the riparian area directly.

Most of the focus in riparian area management is on the stream zone, but all activities in the watershed are important for a riparian area. We must continually be reminded to manage the total resource-base, not just a piece of it.

Managing the total resource requires that we understand all of the factors impacting upon a riparian area, including timber harvest, grazing, road construction, and certain recreational activities like off-highway vehicles, hiking and fishing. All have impacts on riparian areas and appropriate management strategies must include each use.

Grazing has clearly been identified as one – perhaps the first major – use of riparian areas that may need to be changed. Fortunately, some individuals who are truly concerned with use of the resource do understand that livestock can be part of a management plan for riparian areas. They know, too, that livestock producers, if approached properly, are open to efforts to improve riparian areas.

The objections raised to grazing include overgrazing, streambank degradation from trampling and compaction, loss of vegetation which acts as a filter for sediment during periods of flooding, loss of streamside willows and brush to shade the water and maintain its temperature and, to a lesser extent, water quality considerations related to livestock waste. Whether these objections have merit depends upon the circumstances in each case – in riparian area management, blanket statements are generally not appropriate.

Our experience has led us to question each objection in most cases; our first thought is, understandably, whether the motivation behind the objection is for the riparian area or simply an outgrowth of anti-cattle sentiment. Hopefully, we can move away from this position, but it will require acknowledgement that cattle have a legitimate role in riparian area management!

Further, we have been frustrated over attitudes that imply we should be "forever damned" for past practices. These practices may have been standards for the time; often they were based on the recommendations of the agencies and our universities. The bottom line is that our focus should be on resolving problems for the future, rather than on recriminations about past practices.

The livestock industry is accepting responsibility to be part of the solution. By the way, part of the solution is to correct misperceptions of other resource interests about our use of the resource, as well as having our own misperceptions corrected! Being part of the solution also means demonstrating that livestock grazing is an important management tool for riparian areas.

Dr. Sherm Swanson, Extension Range Specialist, University of Nevada, Reno, notes that "All streams are not created equal." His message is that some streams have high potential for rehabilitation, while rehabilitation funds would be wasted on other streams. He has refined a stream classification system that (1) identifies streams by their current state and potential for rehabilitation and (2) identifies management practices that will lead to riparian area improvement.

The work done by Dr. Swanson, and many other range professionals, provides a livestock operator with the kind of information necessary to evaluate and manage riparian areas. He also identifies "best" management practices (depending upon the current status and potential for rehabilitation) for each type of stream. Where "best" practices are not feasible, he recommends "acceptable" practices; again, the recommended practices are ones that producers can use as a practical, working framework for riparian area management.

Some of the practices include (1) establishing riparian (meadow) pastures, then grazing these pastures with either rotation grazing or season-long grazing at light stocking rates; (2) developing sources of water near streams rather than forcing livestock to streams to drink; (3) concentrating grazing in the early growing season or at the peak of the season; (4) herding cattle to assure better distribution over the entire grazing area (both riparian and upland); (5) changing salt distribution to influence grazing and stock watering patterns, and (6) improving range in upland areas, including seeding, to improve forage potential in those areas.

We would implement these methods through the very processes that federal agencies use. For example, we would participate in the Forest Service and Bureau of Land Management Experimental Stewardship Program where decisions are based upon input of technical review or interdisciplinary teams. It is essential that permit holders participate in these teams and this process.

The state agencies have less well-defined processes; The Department of Forestry & Fire Protection and the State Board of Forestry rely upon the Range Management Advisory Committee (RMAC) for some input on range and riparian issues. The Fish & Game Commission, however, does not have a means for formal input from range users and professionals. Perhaps the Fish & Game Commission would consider establishing a range and riparian advisory committee – or would use the existing RMAC.

Working through these existing processes and directly with other interest groups, we hope to make progress on riparian area management. However, some of the issues may be sufficiently complex or have such significant economic implications, that we may have to resort to litigation to sort the complexities out. Recent U.S. Supreme Court decisions do offer some assurance that landowners have redress from unreasonable costs or loss of property use resulting from regulatory agency decisions. These cases may become important in the riparian area management debate.

Prescriptive Measures for Riparian Area Management

It is especially frustrating to livestock producers that so many interests ignore or do not understand the role of livestock on public lands. To satisfy a variety of environmental and land use issues, the best answer may be to keep the livestock on the land. However, many are not willing to even listen to this concept.

The agendas of those who are unwilling to consider a role for livestock producers may be self-defeating. Consider the case in which removal of livestock from public lands causes a ranch to no longer be economically viable. The rancher must then consider alternatives uses for the base ranch property, including development. So, although the cattle are off the public land, the valley or foothill ranch that once provided open space and wildlife habitat is divided into 20 to 40 acre ranchettes – or smaller parcels.

The first prescriptive measure, then, is to broaden the focus of riparian area management to account for the role of livestock producers in providing values beyond their use of the riparian area. However, this means recognizing their need to earn a living from the available resources.

Riparian area management requires money, sometimes significant amounts of money. Often, certain interests argue that who should pay depends upon who benefits, who bears the cost if the work is not done and what caused the condition in the first place. While there may be some merit to a benefit - cost debate, it would be unfortunate to be unduly mired in a debate over costs.

Sometimes, management practices were based upon then-current knowledge; and cooperation between land users and federal agencies led to the policies that allowed degradation of the resource base. In those cases, assigning "blame" and costs may be difficult or even inequitable. Instead, we hope to be able to shift the focus Lo what needs to be done, and attempt to gain consensus that all interests will share in the costs of riparian area management.

Our second prescriptive measure is to establish public funding for riparian projects deemed to be in the public interest. If there is truly a public interest, then part of the costs should be allocated to the public, as well as to any private beneficiaries. The costs born by livestock owners should be credited to them as either an in-kind or a direct contribution to the project.

The third prescriptive measure is to assure that management issues are addressed through a statewide, multiple interest resource coalition. It is critical that representatives of the several interests participate – and commit – to the coalition objective: The welfare of the riparian area.

The California Cattlemen's Association is committed to developing this kind of coalition. We have requested that the Society for Range Management (SRM) that it, the organization representing range professionals, work with other professional groups and trade and environmental organizations to establish this coalition.

Similar interests in Oregon have already developed a coalition that may be an example for us in California. The Oregon Watershed Improvement Coalition (OWIC) was established by the Northwest Section of the SRM; its purpose is to bring together scientists, users and other interests to work on specific projects. OWIC has funds available for cooperative projects with state and federal agencies, landowners and other interests to directly change riparian areas. OWIC has been successful in mediating conflicts between disparate interests, and has a record of successful riparian area rehabilitation.

There is precedent for the coalition and the cooperation here in California, too. The state has one program that provides financial incentive to landowners for fisheries and wildlife habitat maintenance and development, called the "Ranch for Wildlife" or P.L. 580 program. The program is generally successful. More important, the program offers an incentive, a positive reward, to modify or change production practices, rather than the disincentives that are all too often used.

Conclusion

We have tried to cover, in broad overview, the concerns of livestock producers, how we as livestock producers perceive some of the other interests and what we think can be done to resolve any differences. We are committed to being part of the solution to problems of riparian area management. We urge and invite other interests to join us in formation of a coalition to address questions on riparian area management, and to work toward achieving our mutual goal of protecting the welfare of the riparian areas.

INTEGRATED RIPARIAN AREA MANAGEMENT ON THE TULE LAKE ALLOTMENT, LASSEN COUNTY[1]

Bill Flournoy, Don Lancaster, Paul Roush[2]

Abstract: The Bureau of Land Management, Alturas Resource Area with the cooperation of the Tule Lake Allotment permittees and private landowners has embarked on a riparian enhancement program for the allotment which crosses many traditional boundaries and barriers in land management and land management planning. Currently in the plan development stages the concept provides for a multi-disciplinary planning document which includes all program management in one plan, the development of which is guided by a thirteen member steering committee drawn from the general public representative of a broad range of resource interests. The planning concept recognizes the interplay of all resources in the proper and effective management of riparian systems as well as the importance of proper management of adjacent private lands. The private lands controlled by the permittees in the allotment (10,433 acres) will be included in the planning effort and public access to these parcels will be guaranteed.

I would like to share with you today a large-scale riparian improvement project we have undertaken on BLM and private lands near Madeline, California. I would like to emphasize at the outset that we have actually accomplished very little on the ground so far, but we have a unique opportunity to make major strides in enhancing our riparian areas, improving our wildlife habitats, and providing more feed for our livestock all in one stroke. We believe this is possible because we are working in a large allotment with lots of diversity in range and wildlife habitats; we have developed a planning process which can incorporate all of our needs; and we have a dedicated group of individuals from both the private and public sectors who are working hard to see the process through.

Project Location

The Tule Lake Allotment lies in Modoc and Lassen Counties, east of U.S. Highway 395 between the towns of Likely and Madeline.

The allotment is managed by the Alturas Resource Area of the Susanville District, Bureau of Land Management. It encompasses 59,600 acres of land including 10,433 acres of private land and a 16,950 acre Wilderness Study Area.

This allotment is made up of relatively high elevation topography flanking the southern and western tip of the Warner Mountains. The elevation varies from 4,500 feet in the north to 6,200 feet in the east, while the peak of Tule Mountain rises to 7,098 feet.

Allotment History

This allotment lies in the direct path of the historical major sheep trail to the Madeline Rail head of the late eighties, early nineteen hundreds and was first managed by the BLM in 1938. In the late 1950's a major reduction of 50 percent of the permitted livestock was made by BLM and a rest-rotation grazing system implemented. The system did not work in this allotment as all pastures could not be grazed late in the season due to lack of late water. Also high elevation pastures could not be used early due to snow conditions. Late water was available only in the perennial riparian areas which were, by necessity, grazed late each year. This resulted in extensive degradation of the riparian zone. Cedar Creek, the primary perennial creek which flows into Tule Reservoir crosses on private lands and is now entrenched in a 10'-20' cutbank. The creek flows across the hardpan and supports virtually no riparian vegetation. Former large spawning runs of both rainbow and brown trout have virtually disappeared. Compounding the grazing and riparian management problem was the heavy encroachment of juniper and proliferation of big sagebrush in the uplands which curbed forage production and availability. Recognizing the dwindling carrying capacity, the operators took an additional 30 percent voluntary reduction in the late 70's at which time a deferred-rotation system was initiated. This system alternated early use between the two early pastures and used the lowland pasture after seed ripe each year. This system has been adhered to for over ten years and has resulted in modest riparian/meadow improvement in the early use pastures and has improved aspen regeneration throughout the allotment. However, the basic problems in the allotment persist; juniper and big sagebrush continue to dominate the uplands and the perennial riparian systems continue to deteriorate.

[1] Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

[2] Rancher, Likely, California; Farm Advisor, U.C. Cooperative Extension, Modoc County; Wildlife Biologist, BLM, Alturas, California.

BLM Riparian Initiative

In 1986 the BLM Washington Office reviewed its riparian policy and directed each State Director to select certain riparian "Demonstration Areas" to evaluate and demonstrate riparian improvement techniques. Then in 1987 the Bureau issued an updated Riparian Area Management Policy which reaffirmed BLM's commitment to maintain, restore, and improve riparian areas (U.S. Department of Interior, Bureau of Land Management; Instruction Memorandum No. 87-279; September 30, 1988). The Susanville BLM District Manager, reacting to this riparian emphasis, selected the Alturas Resource Area to undertake a "Riparian Initiative." The Resource Area expanded the "Demonstration Area" idea. Though the development of individual riparian projects is a good means of demonstrating techniques and accomplishments on a small scale, we believe it does not demonstrate the broad range of resource interaction and spectrum of user groups affected by and involved in riparian management. The riparian issue needs to be addressed on a broad front which includes meadows, ephemeral drainages, seeps and springs, perennial streams, and of equal importance - effective management of the uplands to provide forage and high quality water yield. We found that to address riparian management properly we needed to look at entire watersheds or complexes of watersheds to see how all resource use affected or was being affected by riparian management. The Tule Lake Allotment was chosen as the first Demonstration Area; it has diverse riparian systems to work with; it has a somewhat problematic history with respect to managing livestock; and it has permittees and private landowners willing to cooperate.

Integrated Planning

To facilitate the planning process for this expanded riparian concept, traditional planning modes needed to be discarded in favor of an integrated planning process. Extending the traditional role of the range conservationists and the rancher planning for the livestock management, the wildlife biologist planning for wildlife management, the hydrologist for watershed management, etc., the process will include on-the-ground strategies for all resource management in a single document. The plan, in addition to crossing the boundaries between resource disciplines, crosses the private/public land boundaries as well. In the Tule Lake Integrated Resource Management Plan the entire 10,433 acres of private lands will be fully included in planning and project implementation.

Public Involvement

Too often the debate over proper management of riparian areas or other habitats takes place only between the rancher and BLM. The remaining spectrum of user groups which may be equally concerned with the proper management of these resources is not heard from or involved in these decisions. To broaden the input into the planning and decision-making process, the Alturas Area Manager appointed a thirteen person Riparian Steering Committee to insure that all aspects of the riparian issue are heard and understood. The committee includes two permittees, and representatives each from Cal Trout, DFG fisheries, DFG big game, California Four-Wheel Drive Association, U.C. Cooperative Extension, local government, Regional Water Quality Control Board, SCS, Organized Sportsmen of Modoc County, Audubon and Sierra Club, and a grant writing specialist. The committee serves as a vehicle for interest group representatives to participate in the shared decision-making process and provides a means for getting information to the public on the benefits of proper riparian management. All phases of plan preparation will involve the Steering Committee from the identification of issues, inventory, survey and design of projects, soliciting of funding, and implementation. The project has attracted the interest of the Izaak Walton League Public Lands Restoration Task Force and The Nature Conservancy who have both attended Steering Committee field trips and are eager to participate in the process.

The Integrated Plan document will carry the signatures of each of the Steering Committee members, indicating the plan is a consensus, supported by the group as a whole and individually. Funding will be solicited in the same manner. Funds will be sought toward implementation of the whole project package rather than for each separate resource.

Project Status

The Steering Committee met first in July, 1987. The mission of the group was determined and a field tour of the area was provided for a general overview. The Alturas Resource Area staff drafted issues for the plan which they presented to the public. These issues were revised by the Steering Committee in June, 1988. The committee directed the Alturas staff to complete an inventory and a draft plan for their review in mid September. The inventory has just been completed and alternatives for the draft plan are currently being formulated.

General features of the draft plan are as follows. Pasture 1, an uplands pasture with very little riparian habitat is a BLM Wilderness Study Area and can not receive significant treatment until final disposition of the wilderness issue by Congress sometime in the 1990's. Pasture 3, the second upland pasture, is recommended to be split into riparian and upland segments. Extensive mechanical juniper removal in the riparian portion coupled with short duration "flash grazing" which removes livestock when meadow utilization reaches prescribed levels will improve water yield and improve meadow cover. The upland portion will receive extensive prescribed burning to provide more forage to support livestock. In Pasture 2, the lowlands pasture with the large perennial drainage Cedar Creek, the permittees who own the private lands along the creek, propose to remove all livestock from the riparian zone through a huge exclosure and to work with BLM to provide a public easement for access along the creek for enjoyment of the recovered fishery. Extensive prescribed burning and mechanical juniper clearing along with further division of the pasture into four separate units, will increase upland forage production and provide a means for resting portions of this pasture which to date is being grazed each year.

The plan further includes specific meadow and spring enhancement through exclosures and water developments, new water sources for livestock, site-specific aspen enhancement prescriptions including juniper removal, prescribed burning, and temporary and permanent exclosures, and extensive mitigation of wildlife habitats such as bitterbrush and mahogany in vegetative treatment areas.

Summary And Conclusions

At this time all of these measures are tentative and subject to review by the Steering Committee in October.

In closing, what we have already come to realize is that the decline of our fisheries, the decline of our riparian systems, the decline of upland water yield, and decadence of browse and forage for both livestock and wildlife are all interrelated. Once the livestock operator, the wildlife advocate and the other interest groups begin to visualize this demise together and begin talking about it in terms they have in common, they find themselves on common ground and receptive to working toward the same goals. This is the essence of the whole effort we have undertaken in the Tule Lake Allotment. Identify your shared problems and their solutions, share the decision-making process, pool your resources to get the work done, then share your successes (and failures) with the public and stimulate them to participate.

RIPARIAN PROTECTION RULES FOR OREGON FORESTS[1]

George G. Ice, Robert L. Beschta, Raymond S. Craig, and James R. Sedell[2]

Abstract: Forest Practice Rules under the Oregon Forest Practices Act were modified in 1987 to increase protection of riparian areas adjacent to timber harvest operations. These modifications addressed concerns about water quality protection and retaining trees as sources of large woody debris for future stream channel structure. The rule changes triggered debate about the quantity and quality of trees that should be left in riparian zones. Issues still under discussion include the silvicultural consequences of these rule modifications, and the need to better predict the costs and benefits of the rule changes.

The management of riparian forests in Oregon has changed greatly since the 1960's and 1970's. In those years, the major riparian concerns were these: removal of log jams to keep streams open for fish passage; management of logging slash to avoid deaeration or excess leaching of organics; provide shade to minimize stream temperature increases and control of sedimentation from activities adjacent to streams. The Alsea Watershed Study, begun in 1959, provided an example of water and stream quality impacts that can result from unusually intense forest harvesting and site preparation (Moring 1975, Beschta 1978, Hall and others 1987). This study influenced Oregon's Forest Practices Rules, which were the first in the United States to specifically address protection of water quality (Brown 1978). Since their adoption in 1972, these rules have been reviewed and modified in response to new research and expanded demands on forest resources.

This paper chronicles the development and implementation in 1987 of rules specifically designed to improve protection of riparian habitat for fish and wildlife.

Pre-1987 Rules and Objectives

Before 1987, the Forest Practice Rules concerning stream management zones focused on protecting water quality, specifically: temperature, dissolved oxygen, and suspended sediment. For example, the Rules (Oregon State Department of Forestry 1983, 629-24-545[1]) required timber operators to:

> Fall, buck, and limb trees so that the tree or any part of it will not fall into or across any [fish-bearing] class I stream. Remove all material that gets into such a stream as an ongoing process during harvesting operations. Place removed material above high water level.

This rule kept fresh slash out of streams to maintain dissolved oxygen levels. Other rules promoted shading of streams, protection of streambeds and streamside vegetation from disturbance, and control of sediment- carrying drainage from up-slope sites. Although the pre-1987 rules were developed to protect water quality, the language allowed for individual interpretation of what was required on each site. The rules did not specifically protect existing large organic debris in streams or manage for future recruitment of large organic debris.

Environmental groups questioned whether these rules adequately protected fish and wildlife values. To address these concerns, the State Forester appointed a technical task force to review the existing Forest Practice Rules for riparian zones. In December 1985 the task force presented a report that recommended substantial modifications to the Rules (Carleson and Wilson 1985). These modifications included new definitions describing the riparian area. They also included rules that would reduce management disturbance and retain large trees (including conifers) within the riparian zone. In April 1987, after a lengthy debate by industry and environmental groups, the Board of Forestry adopted new Forest Practice Rules effective August 1987 for operations near streams.

1987 Modifications to the Rules

The new rules identified three zones (fig. 1) near significant fish- bearing streams: aquatic area, riparian area, and riparian area of influence. The aquatic area includes the stream channel (or lake-bed or wetland) to the high water level. The riparian area is the zone next to the aquatic area, and it generally includes wet soils and water-loving plants. The riparian area of influence is the transitional zone between the riparian area and the upland vegetation. Together, the riparian area and riparian area of influence make up the riparian management area (RMA). Under the new rules, the

[1]Presented at the California Riparian Systems Conference; September 22-24, 1988; Davis, California.

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width of the RMA on each side of the stream shall average three times the stream width but shall not average less than 25 feet (7.6 m) or more than 100 feet (30.5 m).

The new rules maintain some on-site management flexibility. For example, the RMA width must only average three times stream width: RMA width can vary according to terrain and management requirements. However, the new rules identified some basic requirement for RMA's. The five major "leave" requirements for RMA's are:

1. Leave 50 percent of the preoperation tree canopy within the riparian area.
2. Leave live conifer trees equaling at least an average of 9 trees per acre (22 trees/ha) and at least 10 square feet of basal area per acre (2.3 m^2/ha) within the half of the RMA closest to the stream or within 25 feet (7.6 m) (whichever is greater). [For a buffer strip 100 feet wide on each side of the stream, this rule indicates that at least 2 conifers per 100 feet of stream need to be left.]
3. Leave all downed wood in the aquatic and riparian areas and unmerchantable downed wood within the riparian area of influence.
4. Leave 75 percent of preoperation shade over the aquatic area.
5. Leave all snags that are not a safety or fire hazard in the RMA area.

Other rule changes set limits on management activities allowed in the RMA. They also added a classification of special tributary streams which influence the temperature in significant fish-bearing streams. Specific rules are being developed for these types of tributaries.

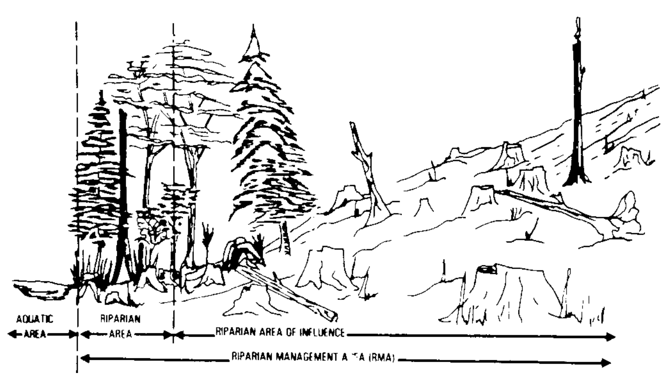

Figure 1— Classification of the Riparian Zone Under 1987 Oregon Forest Practices Rule Amendments

Concerns About Rule Modifications

During the debate about how the rules should be changed, industry, environmental groups and the Board of Forestry were hampered by the difficulty involved in quantifying benefits of different riparian management alternatives. Environmental groups supported stricter standards and greater retention of trees in the RMA. They argued that (as the technical task force reported) large organic debris is needed for stream habitat protection and that future sources (big trees) need to be retained. Environmental groups recommended that RMA's retain at least "18 conifers over 14 inches DBH per acre of riparian management area comprising at least 20 square feet basal area of conifer" (Ketcham and Houck 1987, p. 24). Half or more of these conifers were to be of merchantable quality. Andrus and Froehlich (1987) have found that some riparian forest conditions (such as terraces) probably were never heavily stocked with conifers. In part because forest stands are rarely fully stocked and these recommendations would have allowed little or no harvesting in the RMA, the Board did not adopt these recommendations (Oregon State Board of Forestry 1987).

Representatives of the forest industry argued that water quality was already being protected by the existing rules and that additional costs for providing woody debris should be compensated (Ice 1987, Wilson 1986). A tour of sites managed under the pre-1987 Rules showed that the majority of riparian zones were already meeting the proposed standards (Carleson and Wilson 1985). The forest industry was particularly distressed by the inequity of stream protection requirements for timber management when compared to other land uses (i.e. agriculture, range, urban development, etc.) Important uncertainties for industry were the quantity and quality of woody material needed by streams, the degree of management constraints that would result from the new rules and the level of reduce economic returns.

The Board of Forestry weighed both arguments, and approved new rules that promoted recruitment of some large organic debris while allowing limited harvesting and management in RMA's.

Application of the New Rules

Although the forest industry did not support the changes made in 1987, it has always had a high level of compliance with the Forest Practice Rules. Compliance is fostered by a State Forest Practices Program which emphasizes avoiding problems. A series of Forest Practice Notes is published to educate operators about the need for regulation of forest practices, and to clearly describe management requirements (Oregon State Department of Forestry 1987a). In addition, the State Forester must be notified 15 days before forest management operations. Preoperation inspections help the operator choose the best available management practices. An average of about 70 percent of high- priority sites (those with the greatest potential for resource damage) receive one or more preoperation inspections. For areas where the risk of landslides is high, written plans must be submitted before operations begin. Since 1981, less than two percent of active operations have received forest practice citations (Oregon State Department of Forestry 1987b).

Barringer (1987) described the economic effects of the new rules on a 30-acre private timber sale on the west slope of the Cascades. Under the new rules, 13 acres would have to meet basal area and stocking level requirements for large conifers. The value of this timber was about $32,000. The low basal area and stocking levels for large conifers in this stream reach would allow little removal of timber. Operating, under the previous rules, the timberland owner was able to harvest some of the timber within the buffer strip and recover about 75% of the value from the buffer. Where stocking levels and basal areas for large conifers exceed minimum requirements, opportunities exist to select cull and low timber values to maximize economic return to the landowner while still meeting the functional requirements of the riparian area. Similarly, Olsen and others (1987) found costs to landowners increased, largely in response to restrictions on harvesting of conifers.

Wells Creek, in the central coast of Oregon, provides an excellent example of the changes in management practices for riparian zones. Wells Creek is a Class I (fish bearing) stream, which flows through an industrial tree farm. The east side of Wells Creek was logged before the new rules. The west side was harvested under the new rules. Both operations occurred within months and had preharvest inspections by Oregon Department of Forestry staff. Figure 2 shows conifers and hardwoods left. The west side of Wells Creek has about 11 live large conifers per acre (27 trees/ha) with a basal area of about 47 square feet per acre (11 m^2/ha). There are also about four times as many hardwoods as conifers, and the basal area of the hardwoods is about twice that of the conifers. On the east side there are 4 large live conifers per acre (10 trees/ha) with a basal area of 33 square feet per acre (8 m^2/ha). Hardwood basal area is less (30 square feet per acre) on the east side, but there are several thickets of smaller hardwoods that were not counted. Despite the lost revenue of leaving these trees, there was good cooperation between the landowner and Department of Forestry staff in installing this riparian management area.

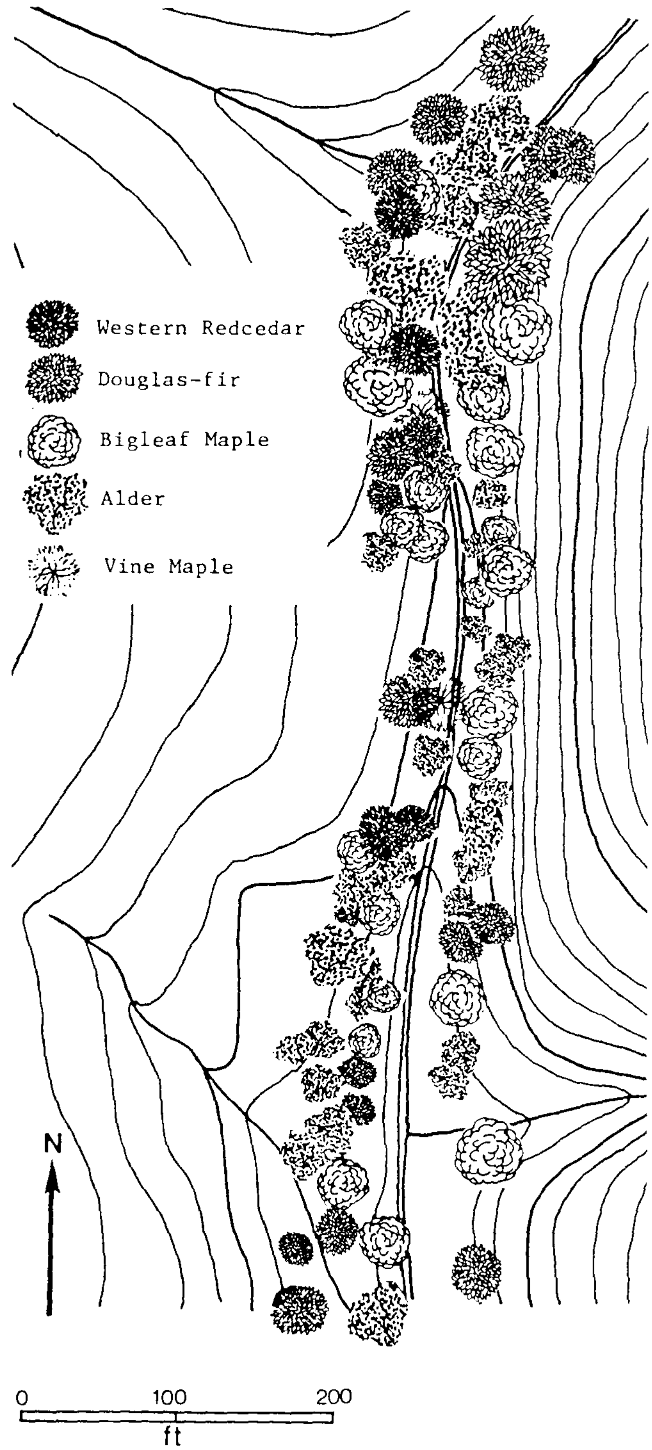

Figure 2— The Wells Creek Stream Management Zone Showing Trees Left Under New (West) and Prior (East) Forest Practice Rules

Issues Remaining

No one was completely satisfied with the final Rules. There is continuing concern about whether enough large organic debris will be available for streams to maintain or enhance channel structure and fish habitat. Quantitative data is lacking on the amount of woody debris necessary or optimum for wildlife habitat in riparian zones and up-slope areas.

Environmental groups continue to be concerned that the RMA is not wide enough to protect water quality. Forest managers question who is going to be held liable when trees are blown down into the stream and divert flow or cause other damage. For example, when trees left adjacent to streams blow down and disturb the channel that can cause short-term increases in suspended sediment for domestic water supplies (Oregonian 1987).

Silviculturally, some riparian areas could develop stable shrub communities that will contain no large trees. Hibbs (1987 p. 61) indicates that "...side light will allow the development of a shrub understory. As existing trees senesce, a gradual succession to a shrub community will probably occur. No tree regeneration is likely in the absence of deliberate efforts to secure it." If so, an improved understanding of how conifers regenerate in riparian areas is needed.

The economics of who pays for stream protection or stream enhancement—and how much it will cost—is still open to debate. Although much of the land and timber affected by riparian management guidelines is in private ownership, other values such as water quality, wildlife and fisheries are generally considered to be in the public domain. Thus the Oregon Forest Practices Rules will continue to be reviewed and modified as they have for the last 15 years, as new research is completed and new resource demands arise.

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FORMATION OF THE ARIZONA RIPARIAN COUNCIL: AN EXAMPLE OF LASTING PUBLIC INTEREST IN RIPARIAN RESOURCES[1]

Duncan T. Patten and William C. Hunter[2]

Abstract: The increasing responses to symposia devoted to riparian resources in the past decade have created a need to channel this enthusiasm into a permanent organization. The Arizona Riparian Council was formally organized in October 1986 to provide an annual forum for local coordination of management and research activities. In addition, the Council draws support from individuals representing management agencies, conservation groups, research institutions, and user groups. The importance of forming such local or regional groups is facilitating better communication on the local level, which may lead to greater advocacy of protecting riparian resources on a national level based on grass-roots support.

The 1970's and 1980's have been a time of dramatically increased interest in riparian resources. This interest can be attributed to a need for more information for proper management of these resources or an increase in public knowledge of an ecosystem that is becoming endangered throughout the United States as well as the world.

This desire for more information on riparian resources has resulted in a continuing flow of workshops, symposia and conferences on the topic (Johnson and Jones 1977, Warner and Hendrix 1984, Johnson and others 1985, Kusler and Riexinger 1986, Savannah River Ecology Lab. 1986, Patten 1987, Society of Wetland Scientists 1987). This conference, on California riparian systems, is just one example of such a meeting, but it is unusual in that it follows up a successful conference held in the early 1980's (Warner and Hendrix 1984). All of these conferences have one goal, in addition to that of information transfer or exchange of ideas, which is to bring together a cross section of those interested in riparian resources to work toward a common goal of preserving riparian systems.

Most of these conferences are attended by individuals from a broad geographical region. These conferences result in a short term exchange of ideas and a proceedings that is useful to those working on riparian systems, but which soon becomes outdated. Therefore, continual interaction of those interested in riparian resources is needed, as well as integration of ideas, concerns, activities, research, and outreach and education programs. This need was the impetus behind the development of the Arizona Riparian Council, a group with a limited geographical scope and thus common goals.

Formation of the Council

The Arizona Riparian Council was conceived at the First North American Riparian Conference held in Tucson in April 1985. An informal meeting was held to determine the potential for creating a State-wide riparian advocacy group that would address the issues facing management, conservation, use, and research of riparian areas in Arizona. The meeting was attended primarily by resource managers and academic researchers; however, these individuals also represented, in part, some of the conservation organizations and riparian users within the State. That meeting demonstrated a great deal of interest in establishing a grass-roots organization within Arizona. The information presented at the conference (Johnson and others 1985) showed that riparian areas within Arizona and the Southwest were at a critical state, and either an effort was needed to protect them through basic management and legal means supported by information from research, or degradation of those riparian areas would increase. It is estimated that only 10 to 15 percent of the lower elevational riparian areas in Arizona remain, and only a small percentage of all riparian areas in the State are not drastically disturbed.

After the Tucson meeting, inquiries were sent to interested individuals within the State to determine their commitment to organizing a council and to identify critical issues and concerns. The issues that were identified were grouped into major categories that have been used as part of the organizational structure of the Council: water resources and instream flow, inventory and classification, protection and enhancement, land use, education, and institutional arrangements and policy.

In November 1985, the first organizational meeting of the Arizona Riparian Council was held in Phoenix. This meeting was used to select the first interim officers of the Council and to have initial meetings of the committees that would make up the working component of

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the Council. The committees were based on the categories identified above. Over 50 individuals attended this meeting. Again, they represented primarily management agencies and academia; however, conservation organizations such as the Audubon Society and Sierra Club were also present. These organizations were interested in getting involved in an organization that might help develop needed information on riparian resources, which could be used in an advocacy position for appropriate riparian management and developing legislation for riparian conservation.

The constitution and bylaws of the Council were developed before the first annual meeting of the Council in October 1986. This was the first official meeting of the Arizona Riparian Council. Riparian was generously defined in the constitution to encompass all areas of concern: "The term 'riparian' is intended to include vegetation, habitats, or ecosystems that are associated with bodies of water (streams or lakes) or are dependent on the existence of perennial or ephemeral surface or subsurface water drainage" (page 1, Constitution and Bylaws of the Arizona Riparian Council).

The objectives of the Arizona Riparian Council, as stated in its constitution and bylaws, are:

1. To stimulate and support studies in all phases of ecology, management and protection, and related intrinsic values of riparian systems;
2. To provide a clearinghouse of information among all agencies, organizations, and individuals engaged in work on riparian systems through appointment of work committees, preparation of bibliographies and abstracts, and related methods;
3. To function in an advisory capacity on questions involving management, conservation, and protection of riparian systems, and to adopt such measures as shall tend to ensure the continued survival and maintenance or riparian systems;
4. To establish programs whereby the public is made aware of the importance or proper management and protection of riparian systems; and
5. To publish symposium proceedings and transactions of meetings in order to present current information on problems relating to the preservation of riparian systems and to commend outstanding action by the public and professionally engaged individuals supporting the purposes of the Council."

The themes of these objectives were taken, in part, from the Constitution of the Desert Fishes Council, a much older organization with similar conservation goals.

Activities of the Council

The Arizona Riparian Council is functioning through three different levels of its organization: Executive Committee, Steering Committee and Standing Committees. The Steering Committee, composed of the volunteer chairs of the standing committees, has become the guiding group for the Council as a whole. This committee develops directions for the Council, plans themes and programs for the Council's annual meetings and addresses letters of concern on riparian management decisions and policies to appropriate State or Federal agencies. Input to the Executive and Steering Committees, which together function as the administrative body of the Council, comes from the activities of the Standing Committees. Some of the activities of the standing committees are presented as examples of the importance of these committees toward achievement of the goals of the Council.

The *Classification and Inventory Committee* has developed a hierarchical, open-ended, and digitized riparian classification system which gives users the flexibility to aggregate or disaggregate information, add new elements as knowledge is refined, and organize riparian information into computerized databases. Representatives of this committee have met with Federal and State agency personnel to attempt to create a uniform riparian classification system for Arizona, that might be used throughout the Southwest and perhaps North America.

The *Water Resources Committee* has been working with the Arizona Department of Water Resources to help develop methodologies for evaluating requests for instream flow rights by land management agencies and private landowners.

The *Education Committee* produces the Council's quarterly newsletter. It is also preparing a slide show on the importance of riparian areas for use in the Arizona school systems and at other public gatherings. The Education Committee, with State and Federal agencies and other conservation education organizations, has cosponsored successful riparian workshops for teachers.

The *Land Use Committee is* compiling a list of wildlife or livestock related research projects in the State and is soliciting information on wildlife and livestock riparian management practices to share with riparian managers.

The *Protection and Enhancement Committee is* developing an annotated bibliography of papers and publications dealing primarily with riparian protection, reestablishment and mitigation. This bibliography should be available in early 1989.

The *Policy and Issues Committee* has taken the position that it should work toward advocacy of positions developed by other committees. It has asked the other committees to develop brief policy statements for it to work from.

Annual meetings of the Arizona Riparian Council are based on a general theme, which is covered in the plenary sessions, and also offer a day of technical papers covering new information developed from management and scientific research within the State. In this way, both lay people and scientists learn and share at the meetings.

The first annual meeting held in Flagstaff reviewed some of the riparian issues within the State, including legal aspects of instream flow and directions of riparian management of the National Forests within Arizona. The emphasis of the second meeting held in Wickenberg, Arizona was to bring together organizations with similar goals of riparian conservation. These included The Arizona Nature Conservancy and the Commission on Arizona Environment. Future meetings will bring together users of riparian systems to develop a dialogue between them and the Council.

Membership

Membership in the Arizona Riparian Council is open to all those interested in the objectives of the Council. In spring 1988, membership was nearly 400. Individuals are from backgrounds as diverse as ecology, wildlife management, hydrology, botany, education, conservation, water development, range management, and environmental law. Although the general public is represented in the membership, to strengthen the grass-roots support of the Council membership is encouraged from user groups such as ORV clubs, rafting clubs, ranchers, and the sand and gravel industry. Without these user groups, the Council represents only those who either study, manage or wish to preserve riparian habitat. Interaction, although vastly improved since formation of the council, still can be better.

Outlook

The Arizona Riparian Council should continue to grow and develop new programs as its committees and education program become more successful in their outreach efforts. As issues are identified and positions taken by the Council, a greater advocacy effort is planned towards developing legislation and management policies that will ensure wise use or protection of the limited riparian areas in Arizona. An all-out effort will be made to work with riparian management agencies, legislators, and user groups to develop policies and activities that will offer long-term appreciation for healthy and vigorous riparian habitats in the State. When this is achieved, the Arizona Riparian Council will have fulfilled its objectives. Meanwhile, the improved communication due to the Arizona Riparian Council may lead to greater grass-roots advocacy of riparian protection on a national level.

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Appendix

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Author Index