EE0008946 - Advanced Compact Generation Module with Fish Safe Runner Technology

Rainbow trout, post turbine passage

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Project Overview

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EE0008946

Project Summary

Advance the design of a compact, modular low head generation system within the framework of ORNL's Exemplary Design Envelope Specification (EDES) for Standard Modular Hydropower (SMH). Conduct preliminary design of a family of compact run-of-river overflow bay generation modules utilizing fish-safe Natel turbines; mature and test the usage of advanced manufacturing methods to enable fish-safe runner geometries that do not compromise on efficiency; and evaluate fish inclusion performance for key migratory species.

Intended Outcomes

- Enable usage and acceptance of advanced manufacturing in the production of next-generation, fish-safe runners
- Awareness, quantification, and application of fish inclusion as a viable design strategy backed by peer-reviewed publications
- Provide guidance and references for: improved run-of-river plant design, methods of analyzing fish safety and plant performance, modularity tradeoffs, and EDES updates

Project Information

Principal Investigator(s)

- Abraham Schneider, CTO, Natel Energy

Project Partners/Subs

- Pacific Northwest National Laboratory
- ORNL Manufacturing Demonstration Facility
- Kleinschmidt Group

Project Status

Sunsetting

Project Duration

- Project Start: April 2020
- Project End: September 2022

Total Costed (FY19–FY21)

$1.05M

Project Objectives: Relevance

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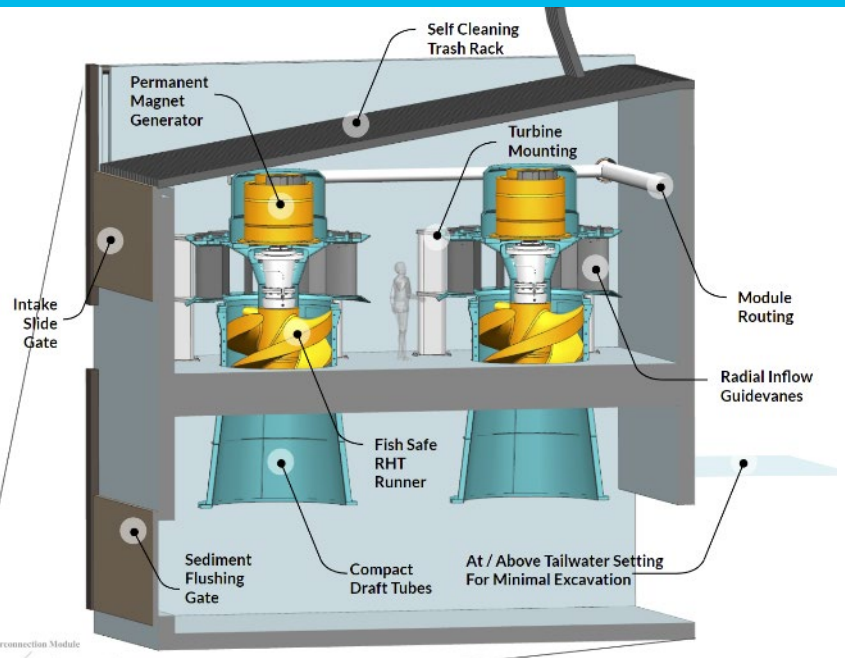
Relevant Challenges	Relevant Approaches	Project Objectives	Long Term Outcomes
Limited opportunities for new affordable growth	Innovate new tech incorporating ecological + social objectives	Design compact generation modules suited for low head, distributed, river-connecting plants	New, low-impact run-of-river project opportunities
Addressing environmental impacts	Leverage new manufacturing and materials	Advanced design and manufacturing methods enabling efficient, fish-safe runners	Increased environmental resiliency of turbines and plants
Lack of access to information to support decision-making	Support testing and testing infrastructure	Roadmap and progress for establishing fish inclusion through testing and stakeholder engagement	Mitigation of environmental impacts and curtailment via retrofits
	Develop monitoring and mitigation technologies	Fish passage datasets and publications w/sensor fish correlations	Improved regulatory and design decision-making
	Establish metrics and support research on environmental impacts	Application of and recommended improvements to the SMH EDES	
	Support development of systems and standards		

Project Objectives: Approach

Module Architecture



Module and Turbine Concept

SMH EDES

Natel RHT Concept

Existing Industry Methods, Designs, Materials

Advanced Manufacturing Applied in Key Area (Runner)

Module and Turbine Level Risk and Cost Assessments → Modeling, Analysis, Design of Driving Elements → Review and Iteration w/Industry Feedback → **Module Sizing, Cost, and Performance Models**

Runner Manufacturing, Structural Risk Assessments → Material and Process Downselection, Detailed Design → Coupon and Component Validation → **Validated Runner Design, Test Reports**

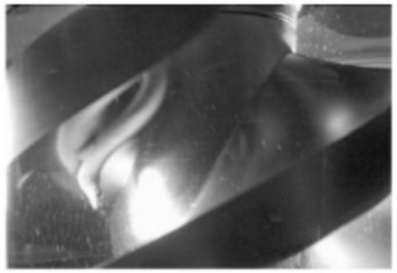
Fish Passage Roadmap of Validation Priorities → Test Scoping, Plans, Test Infrastructure → Test Execution and Data Analysis → **Peer Reviewed Published Fish Passage Datasets**

Stakeholder Engagements (Agencies, Customers)

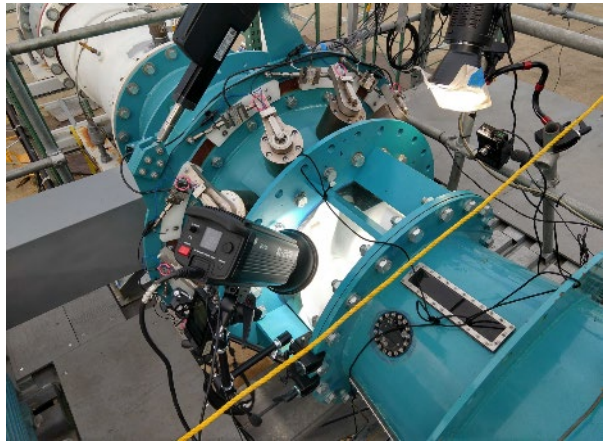
Eel passage testing

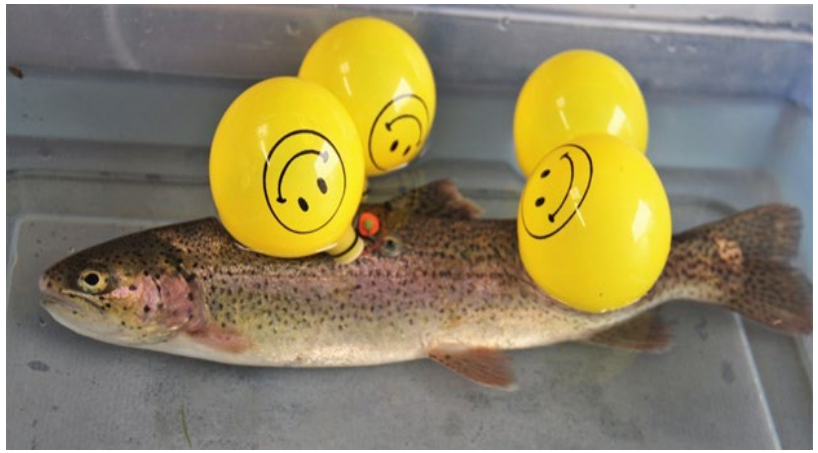
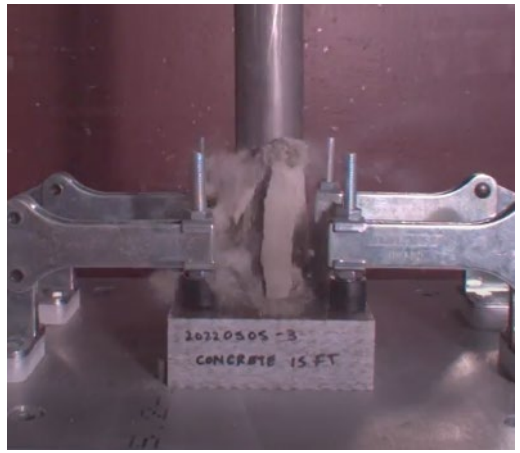
Project Approach: Visuals

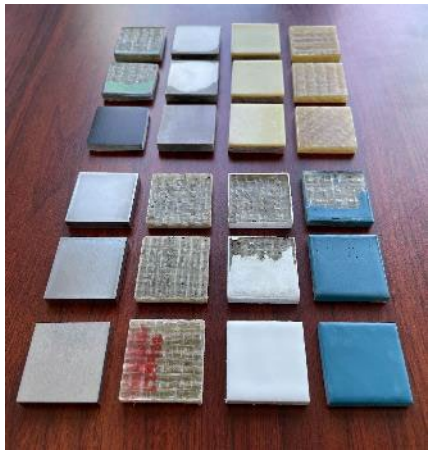








Project Objectives: Expected Outputs and Intended Outcomes

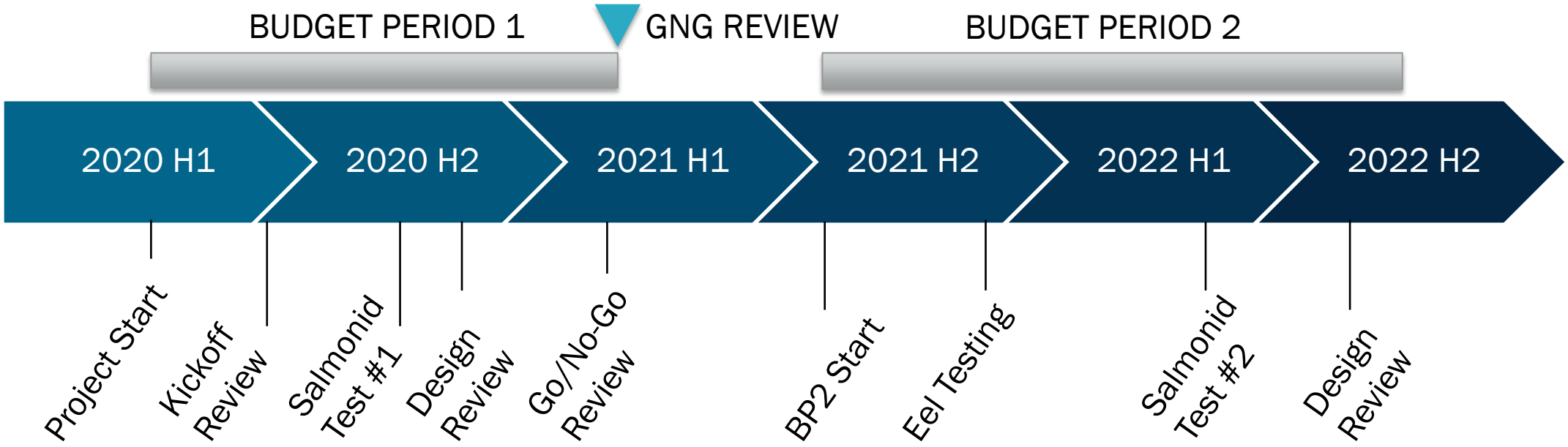
Outputs:

- Preliminary design of submersible fish-safe run-of-river generation modules including performance assessments and tradeoffs, COGS, installation, O&M models
- Detailed design of scalable runner design utilizing advanced manufacturing techniques to produce unique fish-safe geometry; accompanying assessments and reports of materials and analysis + manufacturing methods, down selection, and validation tests
- Peer reviewed publications of fish passage testing of key representative species (salmonids, American eel) demonstrating safety for proportionately large fish (~1/4 runner diameter) and eel (~1 runner diameter)

Outcomes:

- Enable greenfield plant designs and studies utilizing these submerged turbine + generator configurations
- Enable usage and acceptance of advanced manufacturing in the production of next-generation, fish-safe runners
- Awareness, quantification, and application of fish inclusion (through turbine downstream passage without conventional exclusion) as a viable design strategy backed by peer-reviewed publications
- Provide guidance and references for: improved run-of-river plant design, methods of analyzing fish safety and plant performance, modularity tradeoffs, and EDES updates

Project Timeline



Fiberglass test coupons

CONTINUOUS ACTIVITIES DURING PROJECT:

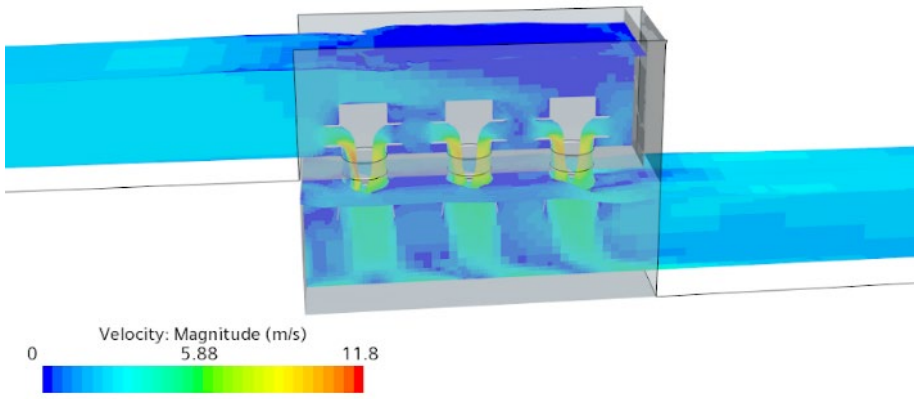
- Module and turbine design, sizing, costing
- Module performance analysis (CFD)
- Runner design and analysis
- Material and manufacturing assessments, coupon and component design
- Test planning, data analysis, report authoring (fish passage as well as runner material / structural)

American eel

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1M	$371K	$1.37M

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$0K	$388K	$658K	$1.05M



3-unit module CFD analysis

The only modifications to the original project budget allocations came from discussion and debrief with the Go / No-Go review team (DOE and external reviewers), resulting in a slight shift in BP2 focus onto extending the passage testing impacts as well as reducing focus on a full-scale runner build in lieu of more rigorous component level testing in parallel with module performance analysis. These adjustments were reallocations of the existing budget and did not increase the project total.

End-User Engagement and Dissemination

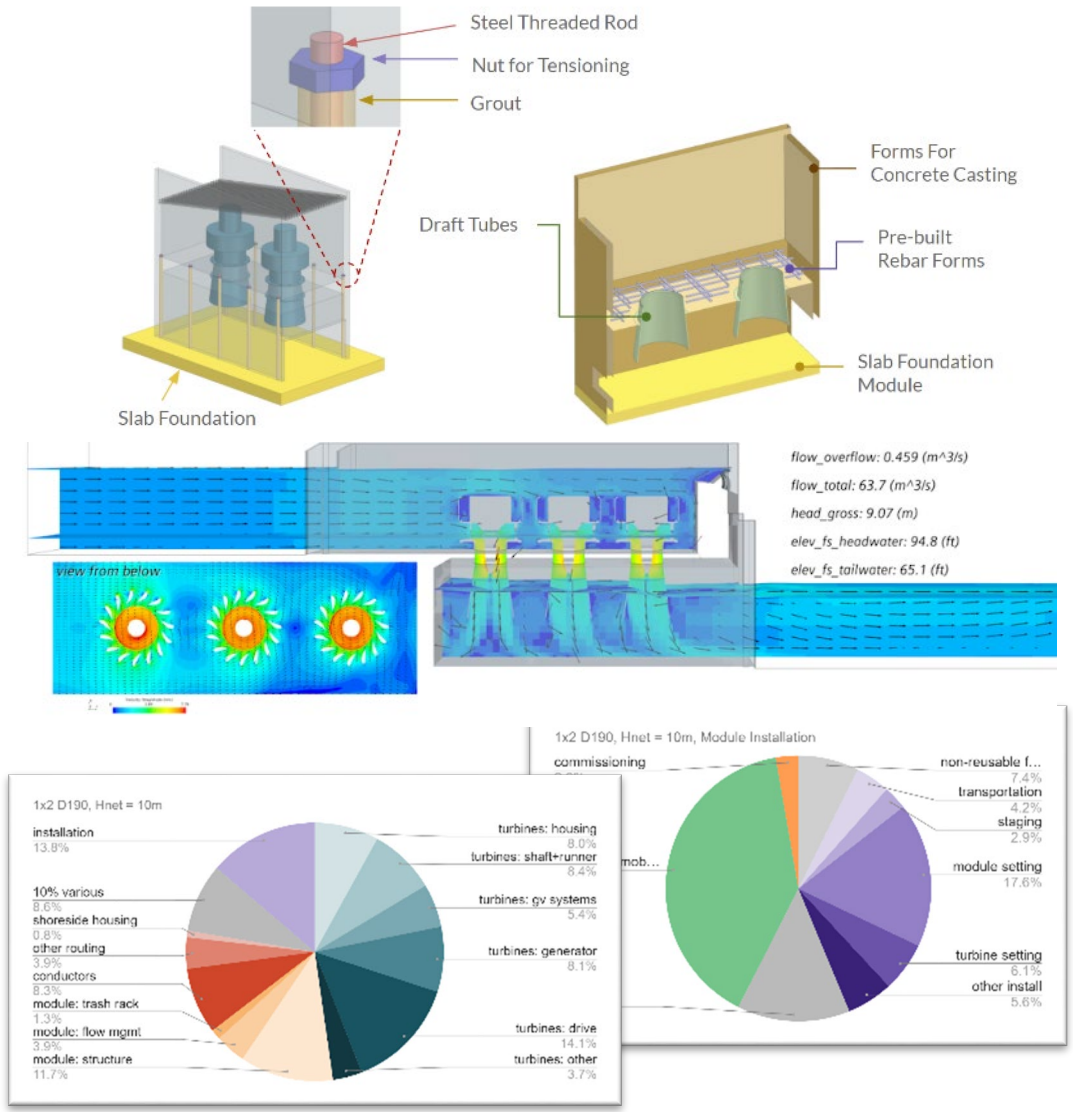
- Stakeholder Engagement
  - Primary stakeholders and end users are industry customers and regulators
  - Both seek validated plant design options for robust, efficient, economical systems that improve upon status quo (exclusion difficulties, high project civil costs, etc.)
  - Strategy has been early and frequent engagement on multiple fronts:
    - Natel's existing customer and industry network, along with ORNL's SMH team and other sources (conferences, publications etc) to understand viability and market needs
    - Experienced engineering firms such as Kleinschmidt Group to review requirements and designs, and recommend improvements
    - Engagement with regulatory agencies and fish passage experts to review passage test objectives, detailed test plans, and results

- Project Result Utilization / Dissemination
  - Results have and will be disseminated or utilized through a combination of peer reviewed journal publications, industry presentations, continued outreach, turbine product offerings, greenfield and restoration project design, and EDES / DOE feedback.

Performance: Accomplishments and Progress

Module Design Technical Accomplishments

- Conceptual design options **down-selected** into clear design approach with generation, flow control, debris management, fish and sediment passage, and interconnection functions detailed; Requirements, interfaces, use and load cases clearly defined
- Module bay **structural sizing** and cost modeling incorporating hydrostatic / hydrodynamic loading, reviewed by Kleinschmidt Group
- Key **turbine** functional elements detailed including intake gate, direct drive generator, shaft and bearings
- Performance and functionality optimization via **Computational Fluid Dynamics** (CFD) analysis
- Summary reports of module **installed cost** estimates and installation approaches



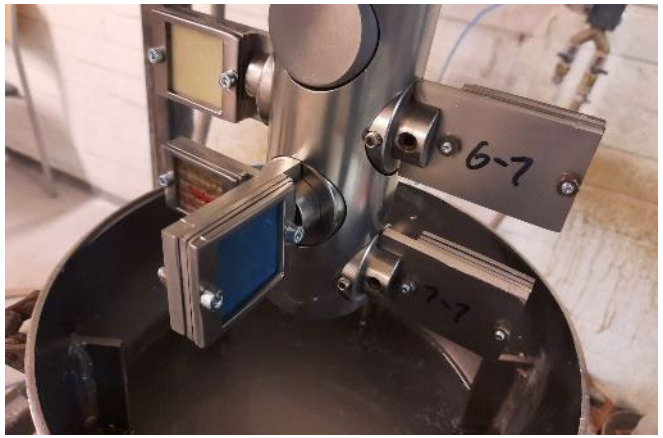
Top to bottom: module structural concepts, iterative CFD design, and cost model breakdowns

Performance: Accomplishments and Progress

Advanced Manufacturing Runner Design Technical Accomplishments

- Conceptual design and manufacturing options, including a range of materials and processes **down-selected; r**equirements, interfaces, load and analysis cases clearly defined
- Building on prior and contemporary work, critical technical and market acceptance challenges identified and targeted with a comprehensive material, coupon, and component **test program paired with finite element analysis**
- Focus on: blade to hub structural attachments; stiffness, strength, and fatigue; environmental degradation (thermal/freezing, erosion/abrasion, cavitation, impact); and manufacturing repeatability
- Results: best design approach and material selection that will meet or exceed lifetime expectations of traditional stainless runners

Impact test coupon evaluation



Slurry pot accelerated erosion testing

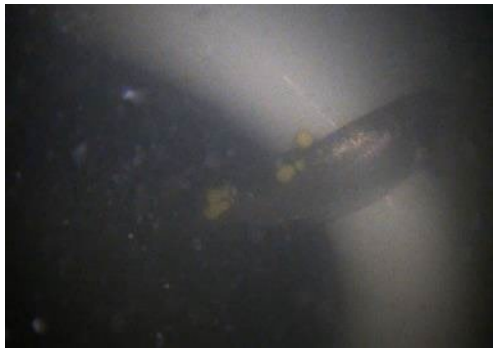
Performance: Accomplishments and Progress

Safe Fish Passage Studies Technical Accomplishments

- Successful execution of **three major groundbreaking studies** assessing safe fish passage through Natel turbines
- 2020: rainbow trout (**salmonid** representative) of 200-400mm length tested in a 1.9m diameter, 300kW Natel test facility (fish size up to 20% of runner diameter)
- 2021: **American Eel** of 350-650mm length tested in a 0.55m diameter, 100kW Natel test facility (eel size up to **120% of runner diameter**)
- 2022: larger rainbow trout up to 520mm length tested at the 300kW site (nearly **30% of runner diameter**)
- Studies confirm hypothesis: **no difference** in mortality between control and turbine passed fish. Individual pre- and post-test health assessments (immediate and 48 hrs.); highspeed passage video; matching sensor fish data collected
- All studies: currently or intended for **journal submission**

2020: large rainbow trout

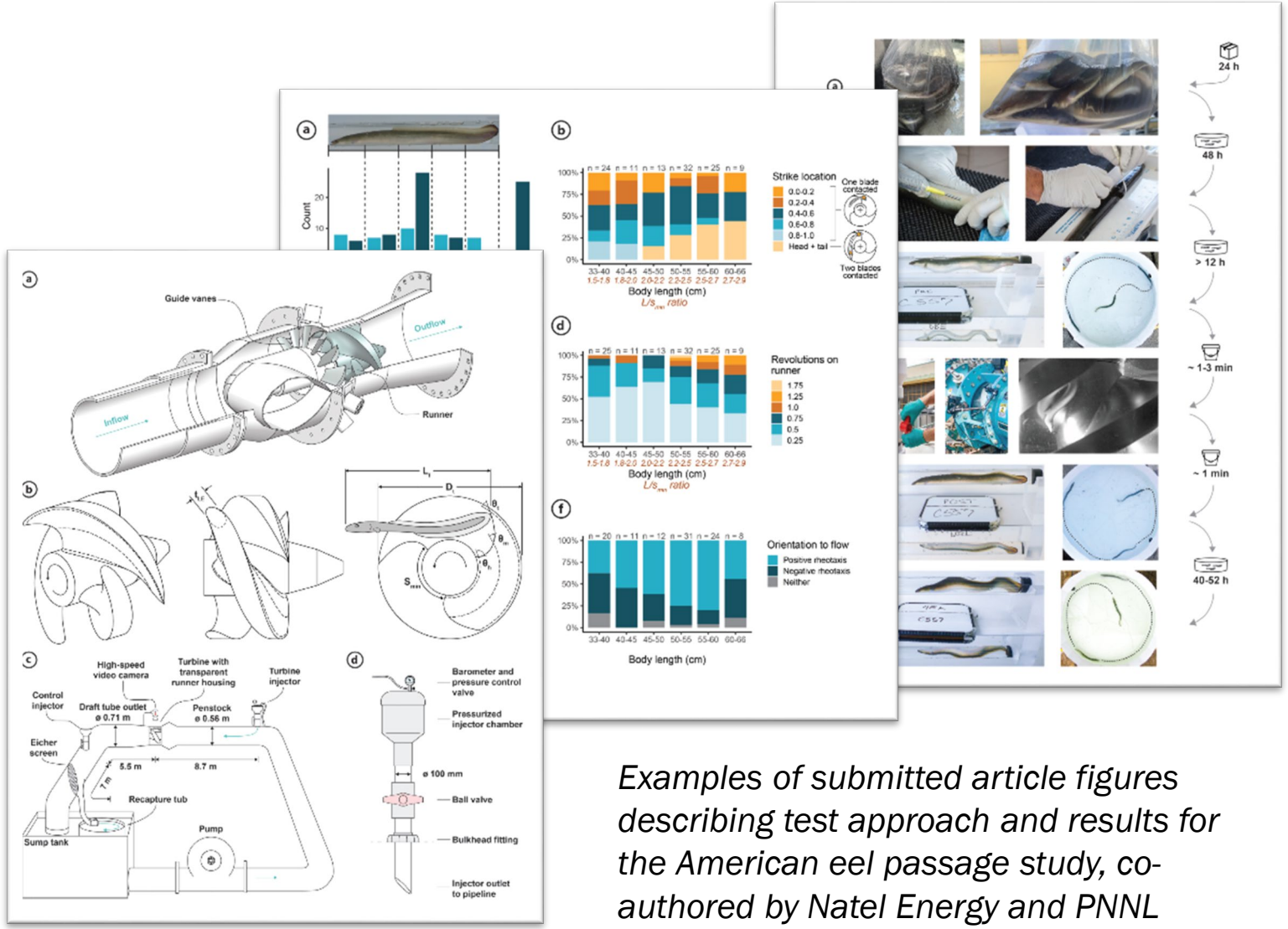
2021: American eel



2022: XL rainbow trout

Performance: Accomplishments and Progress (cont.)

- Summary of Recognition
  - Two peer reviewed journal articles expected (one submitted and in review, the other still in draft) for passage test results
  - Highlight in WPTO's 2020-2021 Accomplishments Report on the rainbow trout passage testing
  - Honorable Mention in Fast Company's World Changing Ideas 2022 list, awarded for the testing and test infrastructure developed for eel passage assessments
  - Invitation to participate in the next round of EDES updates



Examples of submitted article figures describing test approach and results for the American eel passage study, co-authored by Natel Energy and PNNL

Future Work

Remaining Project Work

- Runner leading edge structural testing
- Completion of testing reports
- Journal article submissions, reviews
- Updated cost, O&M assessments
- Design review and documentation

Efforts will wrap in Q3 2022 with publication timelines likely extending into 2023.

Natel Energy would like to thank our project team as well as our WPTO project staff for the collaboration and support in successfully completing this broad and impactful project!

Photo: Natel and PNNL test team on site for 2020 rainbow trout passage study

Q&A