# Appendix K
# Tetra Tech Bird Survey Report

# Spring – Fall 2010
# Avian and Bat Studies Report
# Lake Erie Wind Power Study




***Prepared for:***

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# EXECUTIVE SUMMARY

Tetra Tech, Inc. (Tetra Tech) was contracted by the Cuyahoga County Department of Development (CCDD) to conduct avian and bat studies for the Lake Erie Wind Power Project (the Project). The Project will consist of up to eight turbines to be located off the coast of Ohio, approximately 4 to 7 miles (mi) into Lake Erie, north of the City of Cleveland. The avian and bat Study Area consisted of habitat within 4 nautical mile (nm) radius circle centered on the City of Cleveland Water Intake Crib (Crib), as well as the adjacent shoreline south and east of the Crib (**Figure 1.1**). This report provides the results of the baseline ecological surveys conducted in the Study Area in 2010.

The goal of the 2010 survey effort was to document the species composition, overall occurrence patterns, phenology, and flight behavior of birds and bats within the Study Area. The results of the 2010 field survey provide baseline data that may be used for the preparation of a formal risk assessment and for comparison with post-construction surveys. Surveys completed as part of the 2010 biological survey program included a MERLIN avian radar survey, boat-based surveys, avian acoustic monitoring, and bat acoustic monitoring.

For the purposes of this study, the turbine used to determine the rotor swept zone (RSZ) was the largest offshore wind turbine currently in production, which is the Siemens SWT 6.0, 6 megawatt (MW) with a rotor diameter of up to 165 meters (m) (541 feet [ft]) and a hub height of up to 120 m (394 ft). The size of the turbines used for the Lake Erie Wind project has yet to be determined, since the project is in its inception. The RSZ used for this report assumed the largest possible turbine that could be deployed at the time of the reporting, which would presumably present the greatest risk to birds and bats, and presumably any smaller turbine would present less risk. The RSZ used was defined as 27 m (89 ft) to 202.5 m (664 ft) above mean low water level (AMWL). The use of the largest turbine dimensions enables a conservative approach to risk assessment and it is possible that smaller turbines will be used, thereby reducing potential risk to birds and bats.

## Radar Survey

A dual radar MERLIN Avian Radar System was deployed in the Study Area during the 2010 survey effort. See **Appendix A** for additional information about radar systems and **Appendix B** for a glossary of radar terms. The MERLIN system consisted of S-band horizontal scanning radar and X-band vertical scanning radar. The output of these radars was digitally transformed and assessed in the MERLIN software program. MERLIN software uses algorithms to track bird and bat targets in real time in the radar output. The system reduces “clutter” in the dataset by implementing a site specific filters and masks. Target flight heights and passage rates were obtained from the X-band vertical scanning radar output. Flight direction was obtained from the S-band horizontal scanning radar.

Radar data were collected onshore at the Cleveland Lakefront State Park March 31 – April 21, 2010 and later moved to the Crib (**Figure 2.1**). The radar operated at the Crib from May 1 - May 26, 2010, and August 16 - October 12, 2010. Of the total 120 available days during the spring and fall sampling periods, the radar collected data on 81 days (67.5% of available time).

A total of 642.9 hours of clear air (e.g. without precipitation) radar data was recorded during onshore and offshore operation in 2010, although the radar collected data over a much greater period in 2010. The onshore portion of avian radar monitoring yielded a total of 128.8 hours of data during periods of clear air. During spring radar operation at the Crib, 228.8 hours of clear air radar data were recorded, and 285.3 hours of clear air data were recorded in the fall. Only clear air radar data were used to calculate target passage rate(s) [TPR(s)], target flight direction, and target flight height. TPR was calculated for a 1 kilometer (km) front and was defined as targets per kilometer per hour of radar monitoring (t/km/hr). The 1 km front used to sample TPR and flight height within the vertical scanning radar coverage area was orientated perpendicular to the predicted migration direction, which was expected to be generally north to south, and south to north. Therefore the 1 km front used to calculate TPR was east to west across the vertical scanning radar's beam. The 1 km front was offset, and began 750 m from the radar and ended at 1750 m. We hoped to reduce the potential effects of the Crib's lighting system on flying organisms by offsetting the portion of the radar's output used to calculate TPR and flight heights out to 750 m from the radar.

Mean TPR across the spring onshore survey period was 52.7 t/km/hr. TPRs from the onshore survey period were variable across nights. Nightly TPR ranged from 0.4 t/km/hr (April 18) to 78.4 t/km/hr (April 14). The overall nightly onshore average TPR was 32.1 t/km/hr. Average nightly passage rates in the RSZ onshore were greater during the day than during the night (4.2 t/km/hour and 1.5 t/km/hr, respectively).

The offshore dataset from the MERLIN radar was more robust than the onshore dataset because of the longer duration of operation, we were therefore able to derive differentiated TPR and flight height metrics for four biological periods; dawn, day, dusk, and night. Mean TPR during offshore surveys was 722.4 t/km/hr in spring and 974.3 t/km/hr in fall. The daily spring offshore TPR for all biological periods (dawn, day, dusk, and night) combined ranged from 3.1 t/km/hr (May 5) to 3,931 t/km/hr (May 9). The fall offshore TPR, for all biological periods combined, ranged from 181.5 t/km/hr (September 23) to 4,459 t/km/hr (September 13).

During periods of the highest activity in spring (i.e. highest TPR) most targets flew below the RSZ during the dawn period. During the fall the highest TPRs were recorded at night, and targets flew generally above the RSZ. The table below provides TPRs, mean flight heights, and median flight heights for each biological period (dawn, dawn, dusk, and night) by season, during the offshore radar surveys.

| Biological Period | TPR Below RSZ | TPR Within RSZ | TPR Above RSZ | Overall TPR | Mean Flight Height (m) | Median Flight Height (m) | Flight Height Standard Deviation |
|---|---|---|---|---|---|---|---|
| **SPRING** | | | | | | | |
| Dawn | 959.0 | 22.6 | 9.7 | 991.3 | 16.5 | 9.0 | 45.6 |
| Day | 674.0 | 8.5 | 3.3 | 685.8 | 12.5 | 8.0 | 41.1 |
| Dusk | 801.7 | 6.9 | 1.6 | 810.2 | 11.7 | 9.6 | 15.2 |
| Night | 792.7 | 36.2 | 11.8 | 840.7 | 17.3 | 8.4 | 43.7 |
| **FALL** | | | | | | | |
| Dawn | 204.8 | 168.5 | 393.8 | 767.1 | 518.5 | 257.0 | 668.4 |
| Day | 205.7 | 265.7 | 389.2 | 860.6 | 279.6 | 116.9 | 446.7 |
| Dusk | 199.4 | 182.3 | 312.7 | 694.4 | 329.1 | 139.5 | 499.7 |
| Night | 126.3 | 638.5 | 929.3 | 1,694.1 | 466.4 | 243.1 | 548.5 |

## Boat Surveys and Radar Validation

During the spring and fall 2010 migration periods, boat-based visual observation surveys were conducted. These surveys provided species composition information on avifauna in the portion of the Study Area covered by the offshore radar. Surveys were conducted around dawn, dusk, and during the night using night vision equipment from a moving vessel. These surveys provided species composition (surveys conducted during the night provided only basic taxonomic information on the birds or bats observed), spatial and temporal distribution, relative abundance, and behavioral data within the Study Area during the spring and fall 2010 migration periods. Boat-based surveys provided opportunities to document the occurrence of state or federally listed rare, threatened, or endangered species, as well as to gather supplemental species information from the air space within the radar coverage area. Ten surveys were conducted: four in May, four in September, and two in October 2010.

Boast-based surveys were conducted along a single “saw tooth” transect that covered an 11.1 square km in the Study Area (**Figure 3.1**). This transect was generally within the coverage of the radar system and was centered on the Crib. Surveys conducted during the evening/night hours began approximately one-half hour before sunset and continued until the length of the survey transect was completed. Morning surveys began one-half hour before sunrise and continued until the entire transect was completed. All birds observed within a virtual circle with a diameter of 300 m ahead and perpendicular to the boat were recorded on standardized data sheets. Surveys were conducted while traveling at a constant speed between 8–12 knots and during optimal weather conditions (low wind speed and calm sea state). Birds were identified to species, when possible. Binoculars were used to identify birds during the early evening hours and night vision binoculars (ATN Night Shadow 3, American Technologies Network Corp.) after dark.

Avian species observed during the 2010 surveys consisted primarily of common species found in and around the greater Cleveland area. No state or federally listed rare, threatened, or endangered species were observed during the boat surveys. Observations during the spring surveys included four taxonomic groups: gulls (Laridae), cormorants (Phalacrocoracidae), ducks (Anatidae), and passerines (Passeriformes). Gulls were the most consistently observed species throughout the spring and fall surveys. During the spring surveys, a total of 456 bird observations were made, representing five species. Species observations during the fall surveys included three major taxonomic groups: gulls, cormorants, and ducks. During the fall a total of 2,958 observations were made, representing five species.

Flight heights varied across seasons. Combined data from spring and fall indicate that the majority of birds were observed flying below 10 m AMWL (63.3%), well below the RSZ of modern offshore wind turbines. A total of 973 birds were observed flying between 10 and 25 m AMWL (28.5%). A total of 170 birds were observed flying between 26 and 125 m AMWL (5.0%), which is within or just below the RSZ. Five birds were observed flying between 126 and 200 m AMWL and only one bird was observed flying above 200 m AMWL. A total of 102 birds (3.0%) were observed sitting on the water.

## Avian Acoustic Survey

Most North American songbirds migrate at night. Some nocturnal migrants emit flight calls during migration that provide information about the species of individuals flying over a given location. To provide insight into species composition of nocturnal migrants in the Study Area, an acoustic survey was conducted in conjunction with the MERLIN avian radar survey effort. The goals of the study were to determine avian use of air space directly above and adjacent to the radar system.

During the spring and fall, onshore and offshore, avian radar survey periods a Song Meter SM-1 (Wildlife Acoustics, Inc.) recorder was deployed near the MERLIN avian radar system. The maximum range of the microphone for some species was approximately 300 m vertically and 250 m horizontally, at 300 m. The Song Meter operated onshore during the radar deployment at the Cleveland Lakefront State Park and then operated offshore on the Crib when the radar was deployed there later in the spring. The Song Meter was deployed offshore on the Crib during the fall radar survey.

Avian acoustic monitoring during spring migration produced 49 nights of recordings. The Song Meter SM-1 recorder was deployed onshore from March 31 through April 20, 2010, and offshore from April 29 through May 26, 2010 (**Figure 2.1**). Recordings began at 45 minutes before sunset and continued uninterrupted until 45 minutes after sunrise. During the monitoring period 22 flight calls were recorded onshore and 73 flight calls were recorded offshore.

During the 2010 fall migration the Song Meter SM-1 recorder was located on the Crib from August 16 through October 12, 2010, but due to an equipment malfunction all usable avian acoustic data was lost. Onshore monitoring was not conducted during fall.

The spring 2010 avian acoustic monitoring survey recordings contained flight calls that were attributed to six species groups: blackbirds, thrushes, mimic-thrushes, finches, wood-warblers, and swallows. More flight calls were recorded offshore than onshore, however, the monitoring duration was greater offshore. Additionally, the offshore monitoring period was later into the migration season when, presumably, more individuals would be flying.

### Bat Acoustic Survey

Bat acoustic monitoring allows for continuous surveillance of bat activity. Bats emit ultrasonic echolocation calls during flight for both foraging and navigational purposes. A bat acoustic survey was conducted offshore at the Crib and at sites along the shoreline of Lake Erie during spring, summer, and fall 2010. Four detectors sampled bat activity within the offshore Study Area, and four detectors sampled along the shore of Lake Erie, in the Study Area (**Figure 5.1**). Offshore detectors were placed at different heights and sampled different directions around the Crib. Onshore detectors were placed at four different locations along the shoreline of Lake Erie, north and east of Cleveland city center.

To record in the airspace below and adjacent to the potential RSZ the offshore detectors at the Crib were installed at different heights. Two detectors were deployed in the Crib's meteorological measurement tower (met tower) guy wires at a height of approximately 50 m AMWL. One of the two detectors placed directly in the guy wires above the Crib sampled airspace to the east of the Crib, and the other to the west. Two additional detectors were placed on the railings of the Crib's crow's nest at approximately 35 m AMWL; one detector was oriented to survey airspace west of the Crib and one was oriented to sample north of the Crib.

During spring, one onshore detector was placed at the 55th Street Marina within the Cleveland Lakefront State Park at the radar location, two detectors were placed at Burke Lakefront Airport, and one detector was placed at Whiskey Island State Park. During the summer/fall survey, the detector at the radar was moved to the Burke Lakefront Airport; all other onshore detector locations were the same as those used in the spring survey. To ensure that the greatest period of bat activity was surveyed, the detectors were programmed to begin recording approximately 45 minutes before sunset and stop recording approximately 45 minutes after sunrise each day.

The 2010 bat acoustic study demonstrated that migrating bats, including eastern red bat (Lasiurus borealis), hoary bat (Lasiurus cinereus), and silver-haired bat (Lasionycteris noctivagans) use the Lake Erie shoreline, and to a lesser extent the offshore Crib area. Additionally, the offshore Study Area and shoreline are used by non-migratory and migratory species during the summer residency period.

During spring monitoring, onshore detectors recorded the highest rates of bat activity in late April and early May, and the highest overall activity was recorded on the night of May 1, 2010. During spring, offshore detectors recorded the most bat activity in mid-May, and the highest activity rate during spring was recorded on the night of May 21, 2010. Offshore detectors recorded low rates of bat activity during late July and early August. At the onshore detector locations, the greatest activity rate for the summer/fall monitoring period was recorded on the night of August 2, 2010. Peaks in recorded summer/fall activity at offshore detectors occurred in mid-to late August. During the summer/fall period offshore, the highest activity rate was recorded on the night of August 30, 2010.

During the 2010 bat acoustic surveys onshore detectors operated for a combined 244 detector-nights and offshore detectors operated for a combined 232 detector-nights. Overall, the onshore detectors recorded a total of 1,209 call sequences, compared to 82 call sequences recorded offshore. The index of activity (IA) is the number of 1-minute intervals with bat activity per detector-night multiplied by 100. The IA was 70.1 for the onshore detectors pooled and 23.3 for the offshore detectors pooled.

The small numbers of call sequences recorded at the offshore detectors is similar to results of acoustic studies conducted in Rhode Island Sound, RI (Tetra Tech Wildlife Biologist, Aaron Svedlow personal observation) and with observations made at existing offshore wind facilities in southern Scandinavia.

Three species—little brown bat (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*), and tri-colored bat (*Perimyotis subflavus*)—recorded during the 2010 acoustic monitoring surveys are listed as Species of Concern by the Ohio Department of Natural Resources.

### Conclusions

The survey techniques employed during 2010 were intended to be complementary and, in particular, the results of the radar and acoustic surveys allow for a comprehensive understanding of migration patterns over the Study Area during the spring and fall.

As predicted in the 2008 Avian Risk Assessment for the Project (Guarnaccia and Kerlinger 2008), species richness in the Study Area was low. Of the 3,414 birds observed during the spring and fall 2010 boat-based visual surveys the majority of observations were gulls. An extensive aerial study conducted by the Ohio Department of Natural Resources (ODNR) on bird distribution in Ohio's portion of Lake Erie also documented a majority of gulls during surveys conducted on or near the same dates in May, 2010. Results from the ODNR study demonstrated that high densities of birds observed offshore over the open lake consisted almost entirely of gulls congregating around commercial fishing vessels. This would suggest, as suspected, that the majority of biological targets recorded by the radar during the day, and possibly during dusk and dawn, were likely gulls. Flight heights were predominantly below the RSZ, although on nights with high passage rates flight heights trended higher. Diurnal avian species diversity, as quantified during daytime visual surveys was deemed to be low although portions of the migration period, especially early and late fall, were not surveyed. Bat activity levels were substantially higher onshore than offshore, although the Crib detectors recorded greater than expected bat activity. It is not improbable that the Crib or lights mounted on the Crib act as attractions for some species, especially gulls, cormorants, night migrating birds and bats, as well as insects.

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# 1.0 INTRODUCTION

The Great Lakes Energy Development Task Force (Task Force) initiative chartered by the Cuyahoga County Board of Commissioners is proposing to develop a pilot commercial offshore wind energy facility in the waters of Lake Erie near Cleveland, Cuyahoga County, Ohio. This project is referred to as the Lake Erie Wind Power Project (Project). The proposed pilot project will consist of up to 8 turbines of a size yet to be determined in the vicinity north of the City of Cleveland Water Intake Crib (Crib), see **Figure 1.1** – Study Area Map and Crib Location.

Tetra Tech, Inc. (Tetra Tech) was contracted by the Cuyahoga County Department of Development (CCDD) to conduct Avian and Bat Studies for the Lake Erie Wind Power Project, to be located approximately 4 to 7 miles (mi) from shore in the waters of Lake Erie and north of the City of Cleveland, Ohio. Tetra Tech conducted field studies in 2010, and prepared this Avian and Bat Studies Report in accordance with the Cuyahoga County Request for Proposal (RFP) #DIV-10-16039, the scope of services identified in the Tetra Tech Proposal dated February 18, 2010, and contract (CE1000241-01) authorized by the Cuyahoga County Board of Commissioners on March 18, 2010. Field survey methodologies were developed in accordance with the Cuyahoga County RFP, and were discussed with the U.S. Fish and Wildlife Service (USFWS).

This report provides quantitative information regarding the number and type of birds and bats that are present in the Lake Erie Wind Project Study Area. Additionally, this report provides the avian and bat assessment methods used to gather data (radar, boat-based, and acoustic monitoring surveys), results, tables, figures, and supporting information.

## 1.1 Study Background and Purpose

A Great Lakes Wind Energy Center Feasibility Study (GLWECFS) for the proposed Project was prepared for the Task Force in 2008 (Guarnaccia and Kerlinger 2008) and included an assessment of risk to the avian and bat community posed by the proposed Project. This preliminary assessment was based on a review of existing data and literature and regional Next Generation Radar (NEXRAD) analysis (GeoMarine, Inc. 2008). The Task Force, in consultation with the Ohio Department of Natural Resources (ODNR) and USFWS determined that additional site-specific surveys and supplemental data were needed to more fully evaluate the avian and bat communities in the general area of the proposed wind energy project (Study Area).

In spring 2010, Cuyahoga County contracted Tetra Tech to initiate a program of onsite avian and bat surveys. These included an avian radar study, a boat-based visual / infrared-night vision (IR) survey, avian and bat acoustic monitoring. Based on recommendations by ODNR and USFWS, studies were performed in the Project Area (as identified in the GLWECFS) and a 4 nautical miles (nm) radius centered on the Crib (Study Area) was the focus of the onsite avian and bat surveys (see **Figure 1.1**).

The purpose of these studies was to attempt to further document bird and bat use of the project site and surrounding area including species composition, density, flight height, flight direction, passage rates, activity levels, temporal distribution patterns, and correlations with climatic or other factors.

## 1.2 Study Area Description

The proposed Study Area for these studies is located in the waters of Lake Erie and includes a 4 nm radius centered on the Crib, which is located approximately 3.3 mile offshore and north of downtown Cleveland and the city's harbors (see **Figure 1.1**).

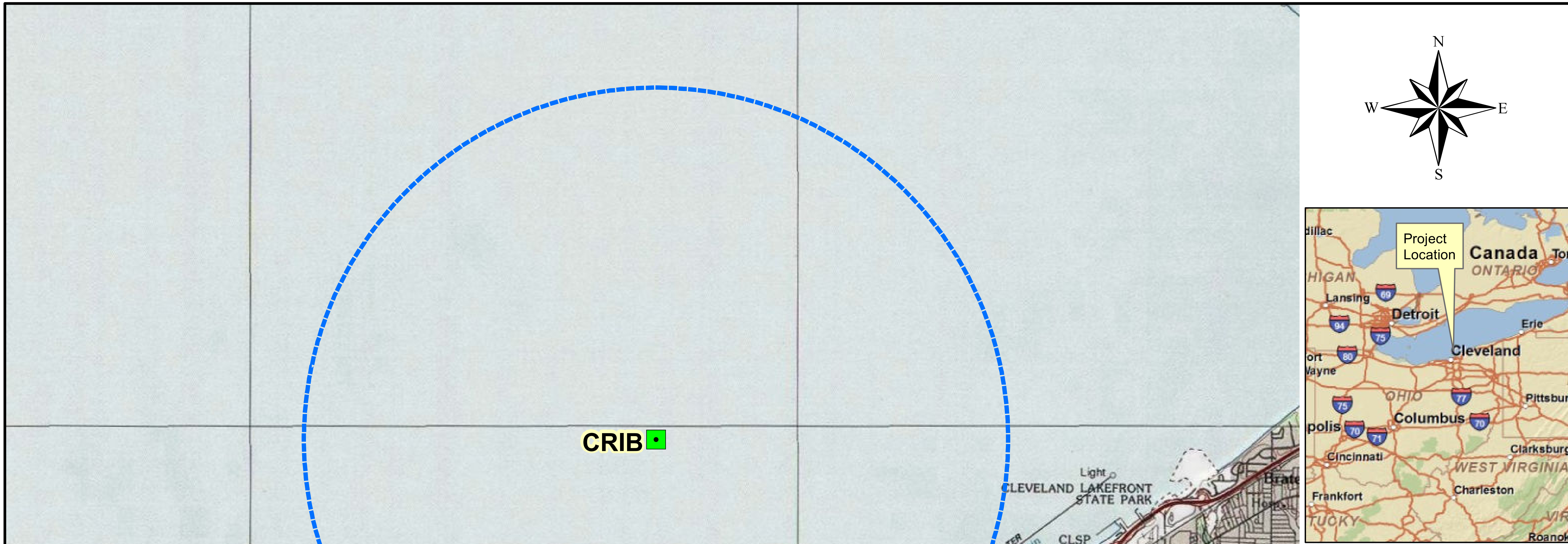
Lake Erie is characterized by shallow, warm, and nutrient-rich waters. It is the shallowest of the Great Lakes, with an average depth of 62 feet (ft). It is also the warmest and most biologically productive, supporting a diversity of fish such as perch, smallmouth bass (*Micropterus dolomieu*), white bass (*Morone chrysops*), walleye (*Sander vitreus*), and freshwater drum (*Aplodinotus grunniens*). Prevailing winds are usually from west to east, creating large, short-term fluctuations in water levels at the western and eastern ends; the greatest recorded being more than 16 ft (Great Lakes Information Network [GLIN] 2009). Lake habitats include vegetated/rocky/sand shoreline, shallow waters containing submerged vegetation, and open waters with benthic substrate. The offshore waters, protected harbors, and shoreline provide habitat for birds such as gulls, terns, waterfowl, and passerines. The shoreline also provides migratory stopover habitat for birds before and after crossing Lake Erie (Diehl et al., 2003), and roosting and foraging habitat for bats during migration and the summer months.

Land use adjacent (south and east) to the Study Area is primarily urban commercial and residential development (see **Figure 1.1**). State parks are scattered along the Cleveland area shoreline where sand beaches and harbors provide recreational opportunities. Forested, shrubland, and grassland habitat exists in small, fragmented areas associated with the state parks, Burke Lakefront Airport, and some residential areas.

## 1.3 Avian and Bat Studies – Overview

In March of 2010 Tetra Tech initiated a survey program to gather site-specific bird and bat data in the Study Area during spring, summer, and fall 2010. Study methodologies were based primarily on the Cuyahoga County RFP, as well as Tetra Tech's experience with similar studies. The methods employed were consistent with survey techniques for other offshore wind projects, as well as with recommendations from the USFWS and ODNR for collecting pre-construction baseline bird and bat data. Surveys were designed to provide data on avian and bat migration patterns as well as information on species that use the proposed Study Area during the spring, summer, and fall migration periods. Surveys completed as part of the program included a radar survey, boat-based visual surveys in the Study Area, avian acoustic surveys, and bat acoustic monitoring.

Radar surveys were conducted onshore and offshore in 2010 (see **Figure 2.1**). The dual X-band and S-band radar was initially deployed onshore at the Cleveland Lake Front State Park (East 55$^{th}$ Street Marina) during early spring, and was then moved onto the Crib location offshore for spring and fall, 2010. Boat-based visual observations surveys were also performed and provided information on species composition in the Study Area. Boat surveys were conducted along a single "saw tooth" transect that covered 11.1 square km of the Study Area and was generally within the coverage area of the radar system. Visual observations were aided by binoculars and Infrared (IR) night vision goggles. Bird and bat acoustic monitoring provided information on species composition, and spatial and temporal distribution patterns of avifauna and bats in the Study Area. Avian acoustic monitoring equipment was used to record nocturnal passerine migrants moving above the avian radar system. Bat acoustic monitoring equipment was used to record bat activity onshore and offshore from April through November 2010.




Legend

- Crib Location
- 4-Mile Radius Study Area Boundary

0 3,000 6,000 Feet

SOURCE: MODIFIED FROM USGS.

LAKE ERIE WIND PROJECT
CUYAHOGA COUNTY, OHIO

FIGURE 1.1
STUDY AREA MAP AND CRIB LOCATION

TETRA TECH

Date: 5/9/2011 User: joel.peters Path: S:\CADD\S\1391\mxd\CuyahogaCounty_1-0.mxd


Legend

Avian Radar

4 Mile Buffer

0 3,000 6,000 Feet

SOURCE: MODIFIED FROM USGS.

LAKE ERIE WIND PROJECT
CUYAHOGA COUNTY, OHIO

FIGURE 2.1
STUDY AREA AVIAN
RADAR LOCATIONS

TETRA TECH

Date: 10/18/2011 User: joel.peters Path: S:\CADD\S\1391\mxd\CuyahogaCounty_2-1.mxd

# 2.0 RADAR SURVEY

Tetra Tech conducted a radar survey at the Study Area to characterize use of the site by migrating birds and bats (see **Figure 2.1**). The MERLIN Avian Radar System collected data on bird and bat movements and migration using both vertical and horizontal marine surveillance radar (see **Appendix A** for additional information about radar systems and **Appendix B** for a glossary of radar terms). Initially the radar system was deployed on the Lake Erie shoreline southeast of the proposed Study Area at the Cleveland Lake Front State Park (East 55th Street Marina). During the spring migration period the radar operated onshore from March 31, 2010 to April 21, 2010 (see **Figure 2.2**). The radar was then moved to the Crib and operated offshore from May 1 to May 25, 2010 (see **Figure 2.3**). During the fall migration period the radar operated on the Crib from August 16 through October 12, 2010.

The objective of the radar survey was to collect radar data on biological target activity and movements in the Study Area, with the goal of assessing baseline activity in order to help estimate mortality risk to birds and bats from the proposed wind project.

**Figure 2.2** MERLIN Avian Radar at the onshore location

**Figure 2.3** MERLIN Avian Radar at the offshore location

## 2.1 Methods

The MERLIN Avian Radar System collected data on birds and bat targets (the term *biological targets* is also used interchangeably, as we assume that little to no information on aerial invertebrates was recorded) using vertical and horizontal marine radars. The objective of the radar survey was to collect data in the proposed Study Area, with a focus on providing data useful for assessing potential mortality risks to birds and bats from the proposed wind energy Project. This section presents a summary of the avian radar data collected during the spring and fall 2010 migration seasons.

For the purposes of this study, the turbine used to determine the rotor swept zone (RSZ) was the largest offshore wind turbine currently in production, which is the Siemens SWT 6.0, 6 megawatt (MW). This turbine has a rotor diameter of 165 meters (m) (541 ft) and a hub height of 120 m (394 ft). RSZ was defined as 27 m (89 ft) to 202.5 m (664 ft) above mean low water level (AMWL). We used the current largest available turbine for RSZ risk calculations, based on projected heights of potential turbines, at the time of this report. We understand that GE is likely to produce an offshore turbine comparable to the Siemens SWT 6.0 and that new generations of offshore turbines will be trending even larger.

Avian radar surveys were conducted at 2 locations during the spring 2010 migration period (see **Figure 2.1**). The initial deployment was onshore at the Cleveland Lake Front State Park from March 31 to April 21, 2010. During the onshore deployment the avian radar system operated for a period of 20 days (24 hours per day) and was setup to survey airspace at a range of 3 nm, in horizontal surveillance mode. To provide coverage of open water in the Study Area the horizontal radar was offset from center. The vertical radar was optimized to survey airspace out to a range of 1.5 nm northwest of the radar location.

The shoreline radar location did not provide optimal coverage of the offshore portion of the Study Area; radar energy returns from wave action near shore reduced the radars ability to track targets from the onshore location. Once logistical and powering issues associated with moving the radar to the Crib were resolved the radar was moved offshore.

The radar was transported by barge to the Crib on April 29, 2010. The system remained on the Crib until May 26, 2010 and was operational there for a total of 17 days, of which 11 days were suitable for analysis. The radar was removed from the Crib for the summer and re-deployed prior to collecting offshore fall migration data on August 16, 2010. During spring operations at the Crib the radar recorded 13 days of data useable for analysis; 46 days of useable radar data were recorded offshore in fall 2010. The horizontally-scanning radar (HSR) offset was removed for operations offshore. The vertical-scanning radar (VSR) was orientated to survey airspace parallel to the shoreline of Lake Erie (i.e., east to west), and therefore perpendicular to the predicted migration patterns.

The onshore radar survey provided information about biological target movement through the Study Area and adjacent shoreline. However, the Crib location provided a more effective platform for surveying the offshore portion of the Study Area. There were two advantages to placing the avian radar system offshore: first, the effectiveness of the radar to sample open airspace within and adjacent to the potential project location, and secondly, the ability to more accurately assess the migration of passerines. The shoreline placement of the avian radar system was a less desirable location to sample avian migration in the Study Area because of the reduced effectiveness of the radar when adjacent to physical barriers, such as breakwaters and shorelines, which block portions of the radar energy. Additionally, by operating the radar onshore only a portion of the avian community present within the proposed Study Area was being sampled. The effectiveness of the radar at recording data on biological targets above and immediately adjacent to the Study Area was increased by operating the radar at the Crib location. At the Crib there were fewer physical barriers to prevent the transmission of the radar's energy into clear air space. The radar was capable of capturing more accurate information on the utilization of the Study Area by biological targets by operating in clear airspace.

The primary purpose of the radar survey was to record passage rates and flight heights of biological targets within the Study Area. However, the radar does not discriminate between "targets", as such all targets are referred to as (as previously mentioned) biological targets. It is not possible to differentiate between bats or birds, nor is it possible to determine species from the radar data. It is probable that some targets tracked by the radar were bats, but there is no way of really knowing the proportion of bat and avian targets. It is also probable that some targets were insects. Although the radar does record size classes these size classes are primarily for internal processing purposes and provide the radar's tracking system one of many metrics on which to base its "decision" of which targets to track and which to ignore. For example it is important for the radar to be able to differentiate between a flock of geese and a small airplane; therefore it must have a metric that provides information on relative "size" and shape of the object creating the radar return. Essentially all objects which create a return are evaluated on size and speed (as well as many other metrics) and the Merlin system's algorithms then classify the radar return as a either biological target or not. The most accurate and conservative terminology for the radar's output is "biological targets," however, it is very likely that the vast majority of said targets are indeed birds, therefore it is acceptable to discuss patterns, such as nocturnal migration, based on the radar data.

Nocturnal avian migrants may be at risk from offshore wind energy development due to collisions. The results of the portion of the radar surveys performed along the shoreline were relevant and valid; however, they may not be representative of the migration patterns occurring within the proposed Project Area. Additionally, the known prevalence of gull species and resident terrestrial avian species along the shoreline may have skewed the overall passage rates from the shore based radar location, resulting in a potentially faulty understanding of avian activity within the proposed Study Area. Although the sophisticated settings of the MERLIN system reduced the possibility of skewed data and false positives, the system may not have been completely sampling the population of interest as effectively as possible while onshore. False "positives" may also be caused by the presence of large numbers of insects that sometimes cannot be separated from bird and bat echoes on the radar.

### 2.1.1 Radar Equipment & Data Collection

#### MERLIN Avian Radar System

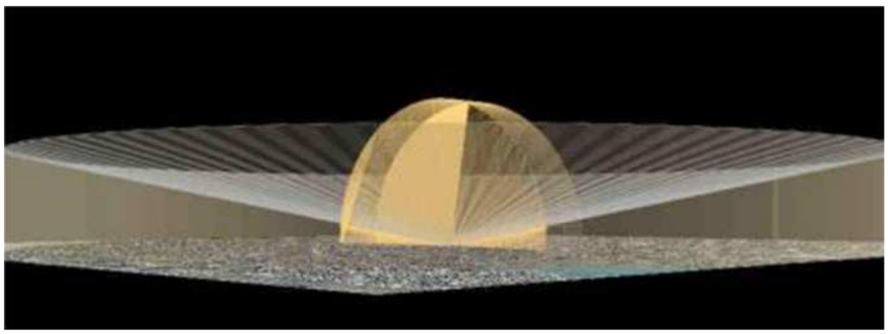
The MERLIN Avian Radar System is an advanced, automated radar system originally developed for, and currently used by, the United States Air Force and National Aeronautics and Space Administration (NASA) for remote detection and tracking of potentially hazardous bird activity on and around airfields and launch facilities in support of aviation and flight safety (bird-aircraft strike avoidance). The MERLIN system is a fully self-contained ornithological radar system developed and manufactured by DeTect, Inc. (Panama City, Florida), specifically for bird detection and tracking. Since 2003, the MERLIN technology has also been used for the collection of pre-construction survey data, risk modeling, and post-construction monitoring at proposed wind projects in the United States, England, Scotland, The Netherlands, Poland, Norway, and New Zealand. Agency and research users of MERLIN include the USFWS, U.S. Environmental Protection Agency, U.S. Geological Survey, various state natural resource agencies, the United Kingdom Central Science Lab (CSL, the UK environmental agency), and various U.S. and international universities. See **Appendix A** for additional information about radar systems and **Appendix B** for a glossary of radar terms. To date, radar has not been demonstrated to be a reliable or valid predictor of risk to birds or bats; however radar data are valuable as a baseline of nocturnal migration. Additional validation studies are needed before it is reasonable to rely on radar data as a means of assessing risks at prospective wind energy facilities.

The MERLIN system used for this Study had dual marine radar sensors: a 10-kilowat (kW) power, X-band frequency with 3 centimeter (cm) wavelength, VSR sensor, and a 30-kW power, S-band with 10 cm wavelength, HSR sensor. Remote system monitoring through the Internet (remote data viewing in real time) was provided by a remote data uplink (cell phone based wireless internet), which allowed access to recorded data and system administration. A Tetra Tech team of biologists performed the initial set-up, after which the system was remotely monitored via the data uplink/internet connections for the remaining data collection periods in spring and fall.

#### Vertical Scanning Radar Operation

The VSR, or X-band radar, operates in the vertical (y-z) plane transmitting a wedge-shaped beam from horizon-to-horizon using the vertical scanning technique (Harmata et al., 1999) (**Appendix B** provides a glossary of commonly used radar terms). In this configuration the radar is turned on its side so it scans a vertical slice through the atmosphere, out to 1.5 nm (2,778 m). The MERLIN software detects and tracks targets that pass through or along the vertical beam, recording relative target size, speed, and altitude attributes, as well as other characteristics. Relative target sizes are determined by the radar's tracking system; this metric is used primarily as a way for the radar to assure that non-biological targets are not being tracked. Due to the variability in size of avian and bat targets and the change in relative size as perceived by the radar with distance from the radar, size classes do not correspond to species or species groups. This radar transmits a 22°, fan-shaped beam (see **Figure 2.4**) at a scan rate of ~2.5 seconds/scan, and can reliably detect small, bird-sized targets as far as 1.5 nm from the radar. The VSR in this configuration outputs the lowest power density, but provides high spatial resolution data with low side lobe returns to provide optimal detection of bird targets as they pass through the Study Area. As the X-band is a short wavelength radar (3 cm), it is susceptible to interference from precipitation, and data collection is suspended during rain events, although not when virga (rain that does not reach the ground) occurs. The VSR data are used to determine target altitudes and is the primary dataset used to determine TPRs through the RSZs for mortality risk assessments.

**Figure 2.4** Illustration of beam coverage of the HSR and the VSR



### Horizontal Scanning Radar Operation

The HSR, or S-band radar, operated in the horizontal (x-y) plane transmitting a 25°, wedge-shaped beam relatively perpendicular to the VSR (see **Figure 2.4**). The HSR for this survey was configured to operate with a short pulse (0.08 microseconds or µs) but transmits at a longer wavelength (10 cm) of energy than the VSR. The S-band has the advantage of greater detection range and less signal attenuation (interference) from surrounding vegetation (typically referred to as ground clutter) and weather. It is also less sensitive to insect contamination. Ground clutter interference is additionally reduced by applying the MERLIN software clutter suppression algorithms that improve detection of small (bird-sized) targets in high clutter environments. The HSR scans 360° in the horizontal plane at a scan rate of ~2.5 seconds/scan and a range setting of 2.0 nm radius (for this survey), detecting and tracking targets moving around the survey site. The HSR in this configuration outputs the lowest power density available to the radar, but provides highest possible spatial (range) resolution data with low side lobe returns to provide optimal detection of bird targets as they move across the study site. The HSR data are used to determine directional movement of targets over or through the Study Area.

### Radar Data Collection, Processing and Analysis

The MERLIN Avian Radar System uses modern, marine-grade radar signal processing technology to collect, process, and store 12-bit digitized radar data from both the VSR and HSR. Target data from both radars are processed in real-time by the MERLIN software at the radar with all data recorded to compact, internal system databases for target and track processing, analysis, and reporting. All VSR and HSR target data and system metadata were written to internal system databases, and all radar data were processed at the radar in real-time by MERLIN system software. Database analysis of the radar data was conducted in Tetra Tech's Data Lab in Portland, Maine. The Data Lab uses Microsoft Windows© based computer systems, networks, and structured query language (SQL) servers for database processing and analysis. This database analysis was conducted by Tetra Tech, radar ornithologists, and biologists.

### MERLIN Avian Radar Processing Software

The MERLIN Avian Radar processing software uses automated clutter suppression in conjunction with biological target detection, tracking, and data recording to identify and track biological targets (birds and bats) in the survey area. The software also identifies noise (undesired signals such as ground clutter and interference) within a given radar environment and applies a statistical approach to suppressing the noise while still allowing targets within the noise to be detected, tracked, and recorded. This maximizes the probability of detecting moving targets in high clutter environments (such as over vegetation). The application of constant false alarm rate (CFAR) algorithms and ground clutter mapping techniques are also included in the MERLIN software and provide automated, high resolution data while minimizing the amount of display lost to ground clutter.

The software allows the user to select settings specific to the conditions and objectives of each study. These settings include minimum and maximum target size (based on target pixel area), minimum and maximum target speed, and minimum reflectivity (a measure of target intensity). By using techniques common in image processing, the MERLIN software also extracts values other than the area or number of pixels. As an example, the length and width, roundness and elongation of a target are extracted and recorded. These are the same parameters an expert observer of a radar display would use to separate a fast moving aircraft from a large skein of geese. In this way parameters are available to classify targets in the same manner a human radar ornithologist applies when interpreting the screen data, but with the MERLIN software this is accomplished with the precision and consistency of a computer program.

The detection and tracking algorithms in the MERLIN software locate sequences of biological targets in the raw radar data that fit together into a linear sequence over time as the radar scans (each radar scan updates approximately every 2.5 seconds). When a target meeting the target definition of a bird is tracked for a minimum of three sequential scans, it is verified as a bird/bat target by the system, enumerated, and recorded to the system database. Targets continue to track as long as it is detected within three of the last four scans. The system can also detect and track other types of biological targets such as insects, but through optimization of the operational settings in the software, visual ground-truthing, and application of custom database queries, the inclusion of non-bird/bat targets was minimized from the survey counts.

It must also be noted that an individual radar echo does not necessarily represent an individual bird or bat, as individuals moving in and out of the radar beam (e.g., circling) would be "counted" by the radar system multiple times. Similarly, a target that is tracked but drops out of the radar line-of-sight (e.g., drops below a tree or brush line) is recorded as a "new" target once it "reappears" and is tracked again (within the MERLIN system, each target is assigned a unique, 64-digit identification number, which facilitates analysis of extended surveys). Therefore, an individual radar echo is referred to as a biological "target" in this study, and when counted together they represent an index of bird/bat activity or exposure level for any given period of time, and not necessarily a count of individuals.

### 2.1.2 Data Analysis

#### Radar Data

Radar data were analyzed for the both the spring and fall sampling period of 2010. Tetra Tech biologists set up and maintained the MERLIN avian radar system, which ran automatically and was remotely monitored daily for the remaining data collection period. Data were processed using standard and custom database queries on a SQL server data network by Tetra Tech wildlife biologists in Portland, Maine. In order to filter out false tracks in both the horizontal and vertical data (e.g., insects, ground clutter, and interference), targets with only one entry in the database were eliminated from the database. The MERLIN software was set to truncate the minimum target-tracking area to 8 pixels to reduce, but not eliminate the possibility of tracking insects.

#### Vertical Radar Data – Target Counts and Altitudes

As targets passed along or through the VSR beam, the altitude of the target was recorded with each scan (rotation) of the radar (approximately every 2.5 seconds), and the average altitude of each target AMWL was generated. In order to standardize target heights so they would be comparable, 5.4 m was subtracted from all target heights, after which all targets with negative target heights were eliminated from the data. Adjusting target heights based on their location over the water and the elevation at that location would have prevented the elimination of these targets, but would not have accounted for biases from differences in detection probabilities and would have also distorted the area sampled; invalidating the 1-km front used for target passage rate (TPR) measurements.

These adjusted target heights were used to derive mean and median target heights, as well as to group targets into one of three categories: below RSZ, within RSZ, or above RSZ to a maximum height of 2,772.6 m (1.5 nm or 2,778 m minus 5.4 m) adjusted AMWL. Some migrating birds fly even higher than this altitude, but these were not detected in this radar study. The turbine dimensions used for the altitude analyses included a RSZ of 27 to 202.5 m AMWL.

The VSR data queries were standardized to a 1-km front per hour, generally the industry standard for most migration surveys, wind energy avian studies, and risk analyses. For this report, TPR are further defined as the number of targets detected within 1 km starting at 250 m from the radar and out to 1,250 m, for a total frontal width of 1 km during a 1-hour period. Passage rates were standardized using the number of minutes with radar data within a given time period (minus any time with rain) and collated for each night (dusk, 45 minutes before sunset to dawn, 45 minutes after sunrise) and day (remaining time period) as well as the entire season. The average TPR (below, within, and above the RSZ, as well as total) and mean and median target heights were calculated for both days and nights during this survey. TPRs and average target heights were also calculated hourly. TPRs in 50-m increments of altitude up to 2,772.6 m are also displayed.

#### Horizontal Radar Data – Target Directions

The horizontal radar data collected was used to develop information on the movement of targets throughout the Study Area. As targets were detected on the HSR, their bearings were recorded on each scan (rotation) of the radar (approximately every 2.5 seconds). The average bearing of each target was then generated as the target passed through the HSR beam. The horizontal radar data were queried and the average target directions were generated for each night (45 minutes before sunset to 45 minutes after sunrise) and day (remaining time period), and the overall distribution plotted for all nights and days using Oriana version 3.21 (Kovach Computing Services) by averaging the bearing of each target to develop a frequency table of target numbers occurring in 45° increments (8 groups centered on north, northeast, east, southeast, south, southwest, west, and northwest). This provided a directional assessment of the target movements throughout the survey area.

#### Weather Data

Weather data were collected from a meteorological tower (met tower) at the Crib (Mattheisen 2011). Data were provided to Tetra Tech by Great Lakes Wind  Recordings of wind speed [meters / second (m/s)] at 60 m, wind direction at 60 m, and temperature (°C) were recorded every 10 minutes and used to derive daily averages. Precipitation data were derived from the recorded vertical radar data.

## 2.2 Results

The following section will discuss the results of the onshore and offshore radar surveys.

### 2.2.1 Onshore Radar Data Results

The MERLIN Avian Radar System operated onshore at the Cleveland Lake Front State Park (East 55$^{th}$ Street Marina) from March 31 to April 30, 2010 (see **Figure 2.1**). A total of 128.8 total hours of onshore radar data were recorded during the onshore sampling period, out of a total of 712 available hours between March 31 and April 30. The onshore radar survey recorded substantial period of rain and wave clutter, resulting in only about 20% of available, clear air, radar data available for analysis. Wave clutter was less of a problem at the offshore Crib site; however there were still periods of rain.

#### Vertical Radar

Data collected from the VSR were used to quantify target movements during the onshore portion of the radar study. Data are presented as total number of targets per kilometer per hour (t/km/hr). This rate is also used when quantifying targets above (up to 2,772.6 m adjusted AMWL), below, and at the height of the RSZ for the 2010 sampling period (**Appendix C** provides multiple tables with daily TPR from the spring and fall 2010 survey periods onshore and offshore).

#### Targets Passage Rates Over Time

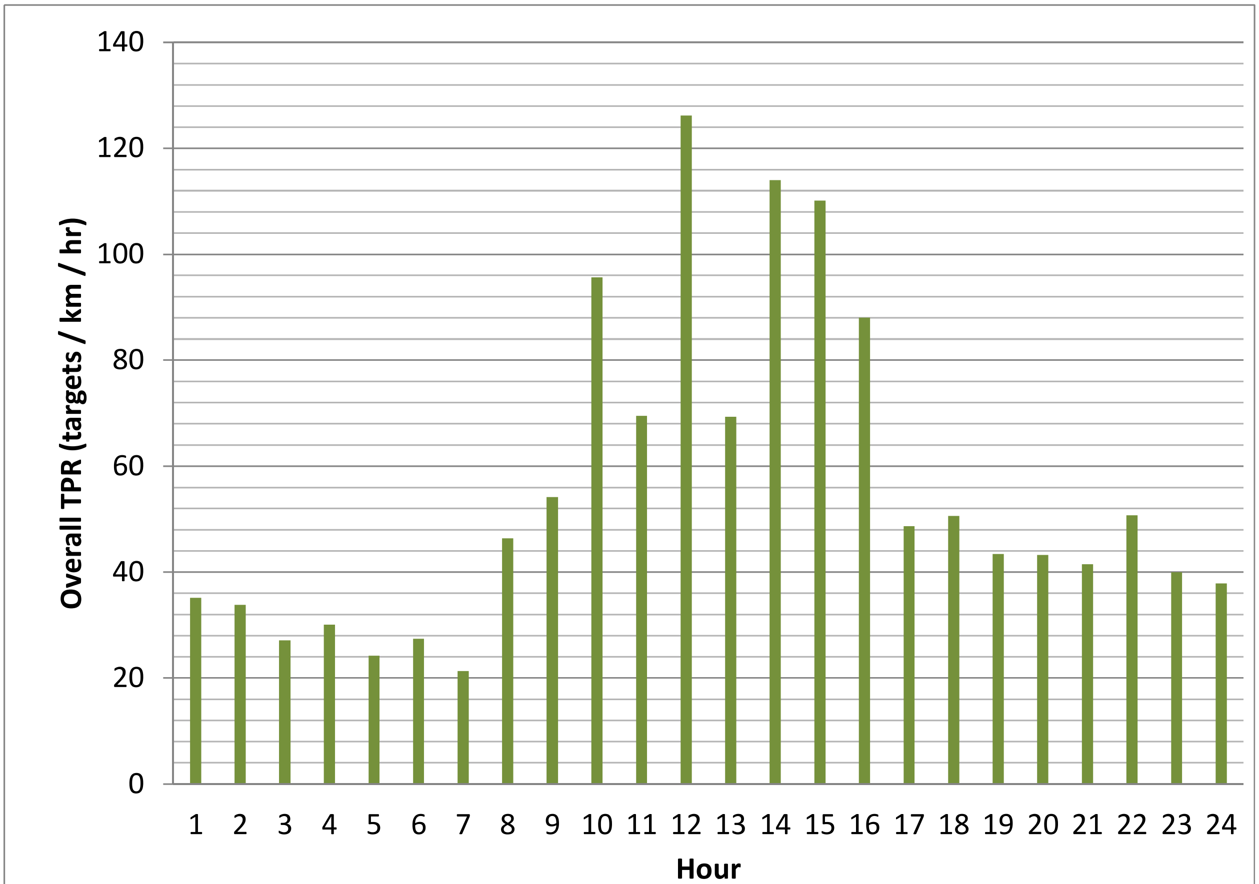
TPRs from the onshore survey period were highly variable (see **Figure 2.5**). Nightly TPRs ranged from 0.4 t/km/hr (April 18) to 78.4 t/km/hr (April 14). The overall nightly average TPR was 32.1 t/km/hr during the spring season.  Average nightly passage rates in the RSZ were greater during the day, than during the night: 4.2 t/km/hr and 1.5 t/km/hr, respectively (see **Figure 2.5**).

It was apparent that nightly TPRs were as variable as daytime passage rates, and peak nighttime passage rates were often followed by high passage rates during the day (see **Figure 2.6**).

Hourly passage rates were highly variable during the onshore radar deployment period (see **Figure 2.5**). Throughout the onshore deployment period, recorded passage rates were greatest during the early hours of night (hours 21–24, i.e., 9 pm–12 am).

The average mean nightly target height was 382.84 m AMWL. The average nightly flight height was 433.26 m. Nightly average flight heights ranged from 28.3 to 965.1 m. (All mean and median target height values can be found in **Appendix C**).

**Figure 2.5** Hourly activity (average TPRs) from onshore, spring 2010




## Altitudinal Distribution of Targets

Target counts below, within, and above the RSZ (27 to 202.5 m AMWL) are presented in **Figures 2.7**. Target counts are not passage rates, but represent the actual number of targets (n = 6,495 onshore in spring), tracked by the radar system, and are not rates of activity. Of all the targets that were detected by the vertical radar during the onshore sampling period, 91.2% were above the RSZ, 7.8% were within the RSZ, and 1.0% below the RSZ (see **Table 2.1** and **Table 2.2, Figure 2.7**). Nightly target counts within the RSZ ranged from 0 to 40 % of all targets, with an average of 1.7 % of tracked biological targets within RSZ (All counts and passage rates can be found in the tables included in **Appendix C**).

**Figure 2.6** Onshore TPRs during the spring 2010 sampling period

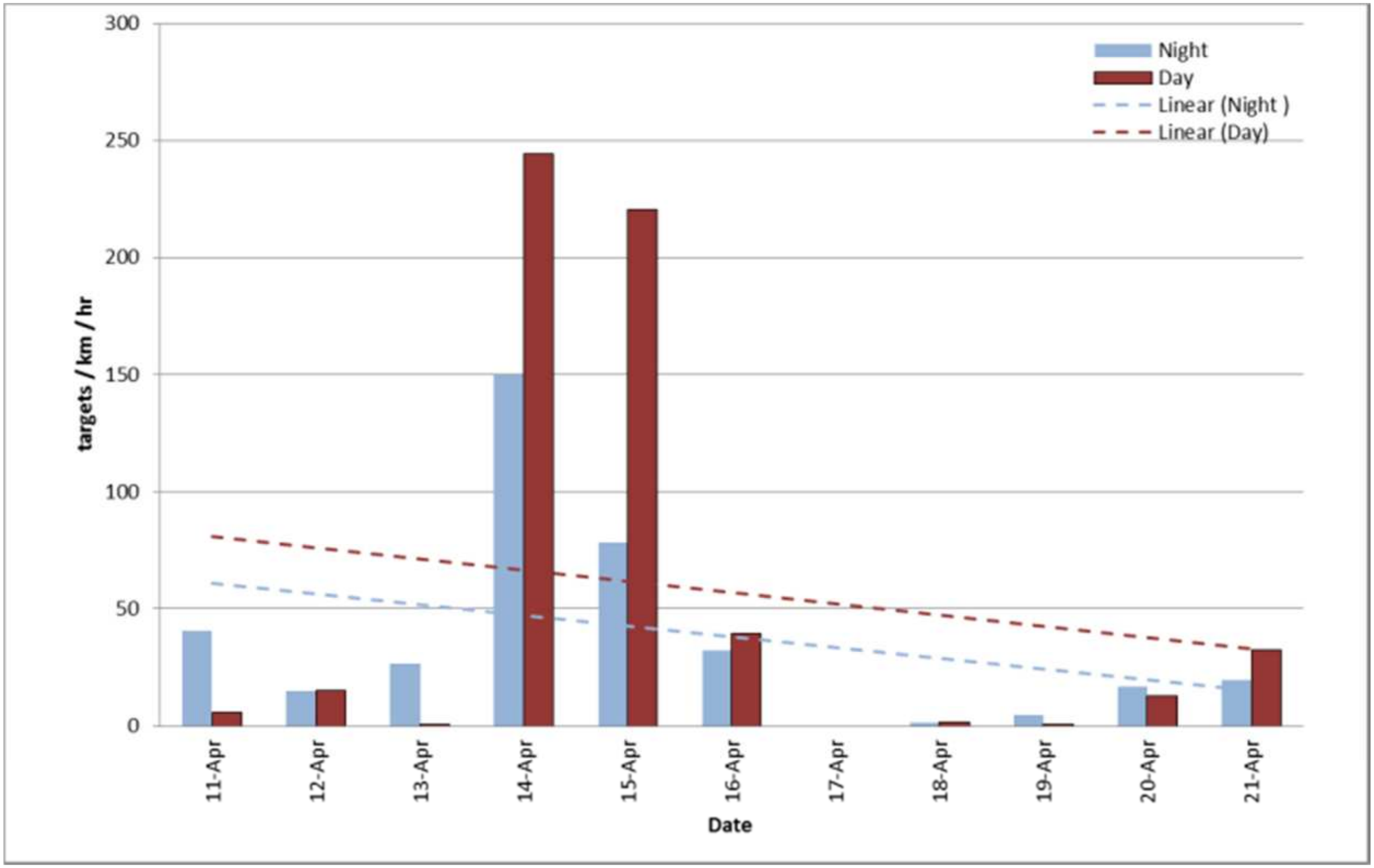


**Table 2.1** Onshore TPR spring parameters

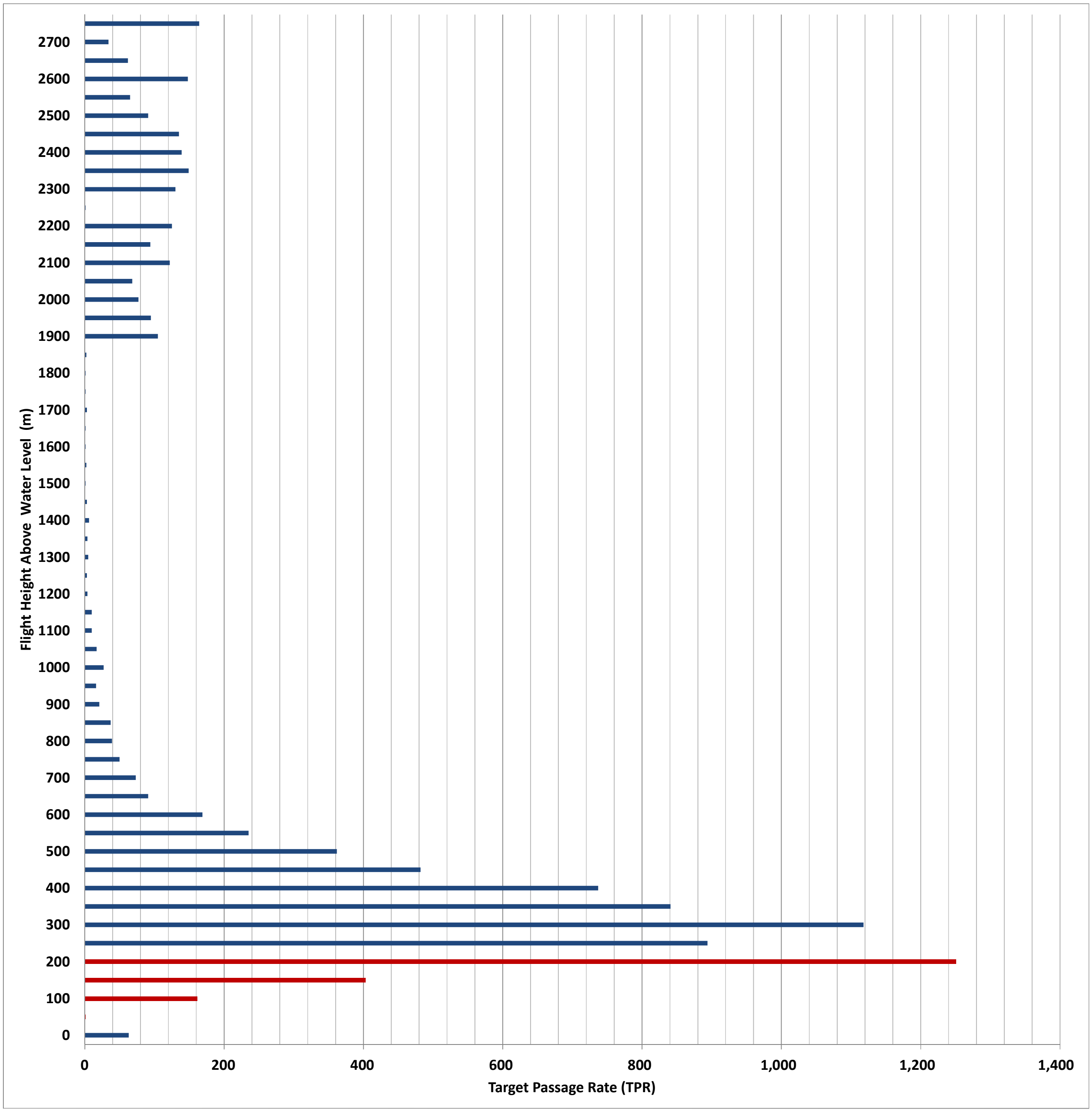
| TPR Parameter | PERIOD | |
|---|---|---|
| | SPRING | |
| | NIGHT | DAY |
| TPR Range ( t / km / hr) | 0.4 - 78.4 | 0.8 - 244.3 |
| Overall Mean ( t / km / hr) | 32 | 71 |
| TPR below RSZ ( t / km / hr) | 0.03 | 3.6 |
| TPR within RSZ ( t / km / hr) | 1.5 | 4.2 |
| TPR above RSZ ( t / km / hr) | 30.6 | 48.1 |

Onshore spring average target flight heights varied, ranging between 18.32 m AMWL (April 30) and 398.9 m AMWL (April 21). On average flight heights were highest during the evening hours especially from 9:00 pm to 12:00 am.

**Table 2.2** Onshore target counts below, within, and above the RSZ

| Target Count | PERIOD | |
|---|---|---|
| | SPRING | |
| | NIGHT | DAY |
| % of Target Count Below RSZ | 0.94% | 1.46% |
| % of Target Count Within RSZ | 7.85% | 8.59% |
| % of Target Count Above RSZ | 91.21% | 89.95% |

**Figure 2.7** Number of targets occurring onshore, spring 2010




Note: Red indicates rotor swept heights.

## Horizontal Radar

The HSR was used to determine directional movements of targets during days and nights of the 2010 sampling period. Statistical program Oriana version 4 (© 2011 by Kovach Computing Services) was used to determine circular summary statistics.

### Target Directions

The average flight direction of all targets in spring during the night was north to northeast. During the onshore survey period when nights were grouped by average target direction, TPRs were the greatest during nights when target movements were towards the north and northeast.

## 2.2.2 Offshore Radar Data Results

The MERLIN Avian Radar System operated offshore at the Crib (see **Figure 1.1**) during the 2010 sampling period, from May 1 to May 26, 2010, and again from August 16 to October 12, 2010. During the fall the radar operated for a much longer period than it did in the spring. However, because of poor weather conditions in the fall a similar number of hours with clear air were available for both seasons (see **Table 2.3**). Poor weather conditions in the fall included; rain, heavy fog, and periods of very windy conditions which created a level of clutter on the lake's surface that exceed the clutter suppression capabilities of the radar.

**Table 2.3** Offshore radar hours summary - spring and fall 2010

| MERLIN Crib Data Collection | Spring (hours) | Fall (hours) | Overall |
|---|---|---|---|
| Time radar collected data | 309.4 | 1,039.8 | 1,349.2 |
| Radar data with rain | 80.5 | 754.6 | 835.1 |
| Useable radar data (clear air) | 228.8 | 285.3 | 514.1 |

### Vertical Radar

Data collected from the VSR were used to quantify target movements through the Study Area. Data are presented as targets per km per hr (t/km/hr). This rate is also used when quantifying targets above (up to 2,772.6 m adjusted height AMWL), below, and at the height of the RSZ for the 2010 sampling period (Tables in **Appendix C** provide all daily TPR from the spring and fall 2010 survey periods onshore and offshore).

### Targets Passage Rates Over Time

Offshore TPRs varied throughout the spring 2010 sampling period (see **Table 2.4**). The overall TPR for offshore was 722.4 t/km/hr in the spring survey and 974.3 t/km/hr in the fall survey. The daily spring offshore TPR for each all biological periods (dawn, day, dusk, and night) combined ranged from 3.1 t/km/hr on May 5, 2010 to 3,931 t/km/hr on May 9, 2010. The fall offshore TPR ranged from 181.5 t/km/hr on September 23, 2010 to 4,459 t/km/hr on September 13, 2010 (see **Table 2.4**).

### Spring

During the spring, TPR were highest overall during dawn, and lowest during the day. TPR in the RSZ during spring was highest at night (36.2 t/km/hr), although TPRs in the RSZ were substantially less than TPRs below the RSZ. Overall TPR peaked on May 9, 2010 during the spring, TPR within the RSZ trended differently than overall TPR and peaked on May 11, 2010 (see **Figures 2.9 and 2.13**).

### Fall

TPRs varied between fall and spring. Overall TPR for the fall was highest at night, and was substantially higher overall than in spring (see **Table 2.4**). The TPR within the RSZ was greatest during the night (638.5 t/km/hr), although the activity in the RSZ at night was still lower than activity above the RSZ (929.3 t/km/hr).

Mean target flight heights during the fall were substantially higher than during the spring (see **Table 2.4**). Overall TPR in fall peaked on September 13, 2010 (see **Figures 2.10 and 2.14**). Unlike in spring, overall TPR and TPR within the RSZ trended together, and the peak TPR within the RSZ was recorded on September 12, 2010.

### Hourly

Overall TPR was highest during the night. The aggregate (spring and fall) peak hourly TPR was during 21:00, followed by 23:00 and 19:00. TPR was lowest during the day, especially 9:00 to 15:00. TPR within the RSZ was generally higher at night, although TPR within the RSZ was never greater than TPR above the RSZ during periods of high activity (see **Figure 2.11**).

**Table 2.4** Offshore TPRs during each biological period and by season of 2010

| Biological Period | TPR Below RSZ | TPR Within RSZ | TPR Above RSZ | Overall TPR | Mean Flight Height (m) | Median Flight Height (m) | Flight Height Standard Deviation |
|---|---|---|---|---|---|---|---|
| **SPRING** | | | | | | | |
| Dawn | 959.0 | 22.6 | 9.7 | 991.3 | 16.5 | 9.0 | 45.6 |
| Day | 674.0 | 8.5 | 3.3 | 685.8 | 12.5 | 8.0 | 41.1 |
| Dusk | 801.7 | 6.9 | 1.6 | 810.2 | 11.7 | 9.6 | 15.2 |
| Night | 792.7 | 36.2 | 11.8 | 840.7 | 17.3 | 8.4 | 43.7 |
| **FALL** | | | | | | | |
| Dawn | 204.8 | 168.5 | 393.8 | 767.1 | 518.5 | 257.0 | 668.4 |
| Day | 205.7 | 265.7 | 389.2 | 860.6 | 279.6 | 116.9 | 446.7 |
| Dusk | 199.4 | 182.3 | 312.7 | 694.4 | 329.1 | 139.5 | 499.7 |
| Night | 126.3 | 638.5 | 929.3 | 1,694.1 | 466.4 | 243.1 | 548.5 |

**Figure 2.9** Overall offshore TPR and TPR within RSZ during spring 2010

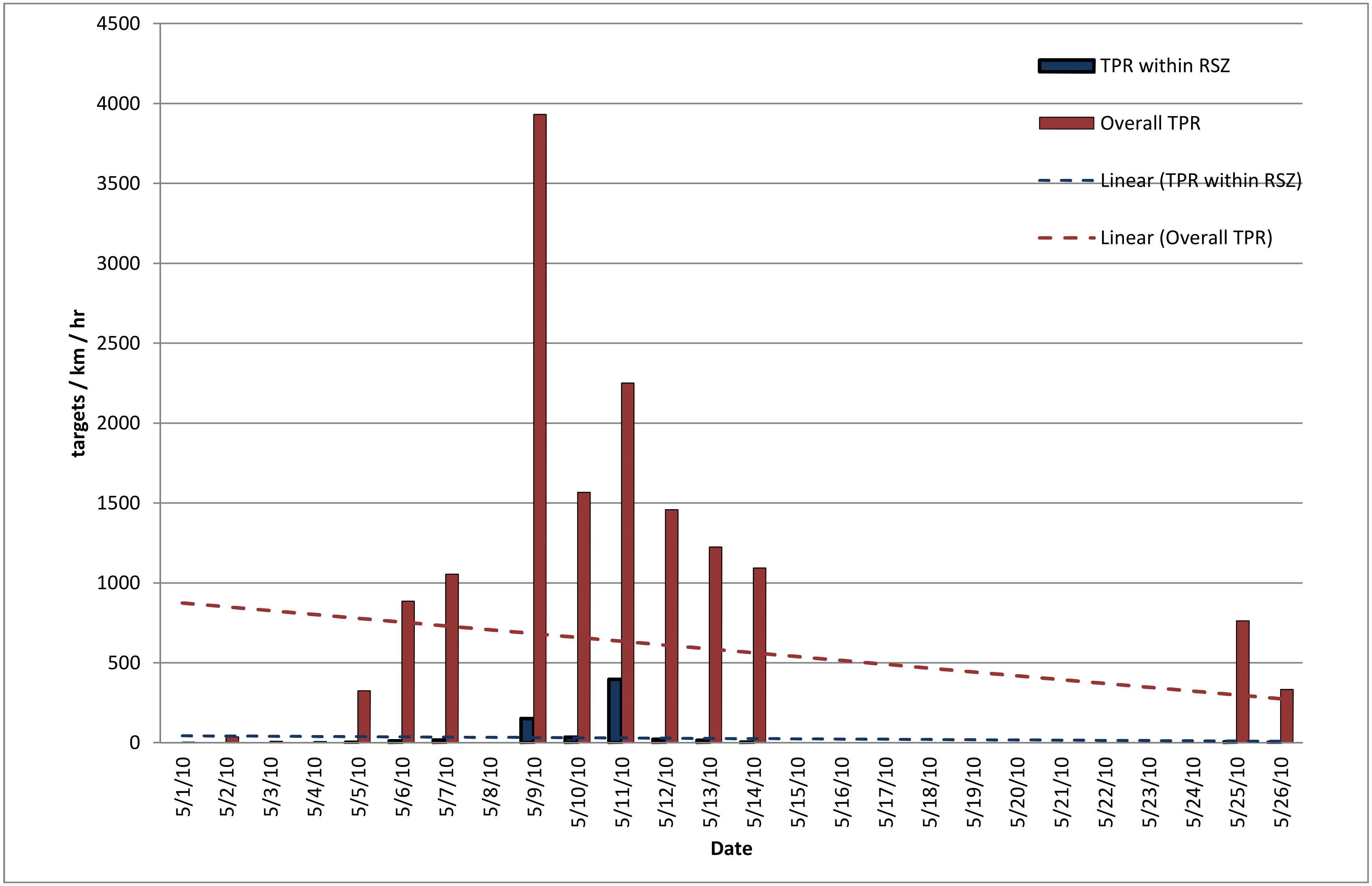


**Figure 2.10** Overall offshore TPR and TPR within RSZ during fall

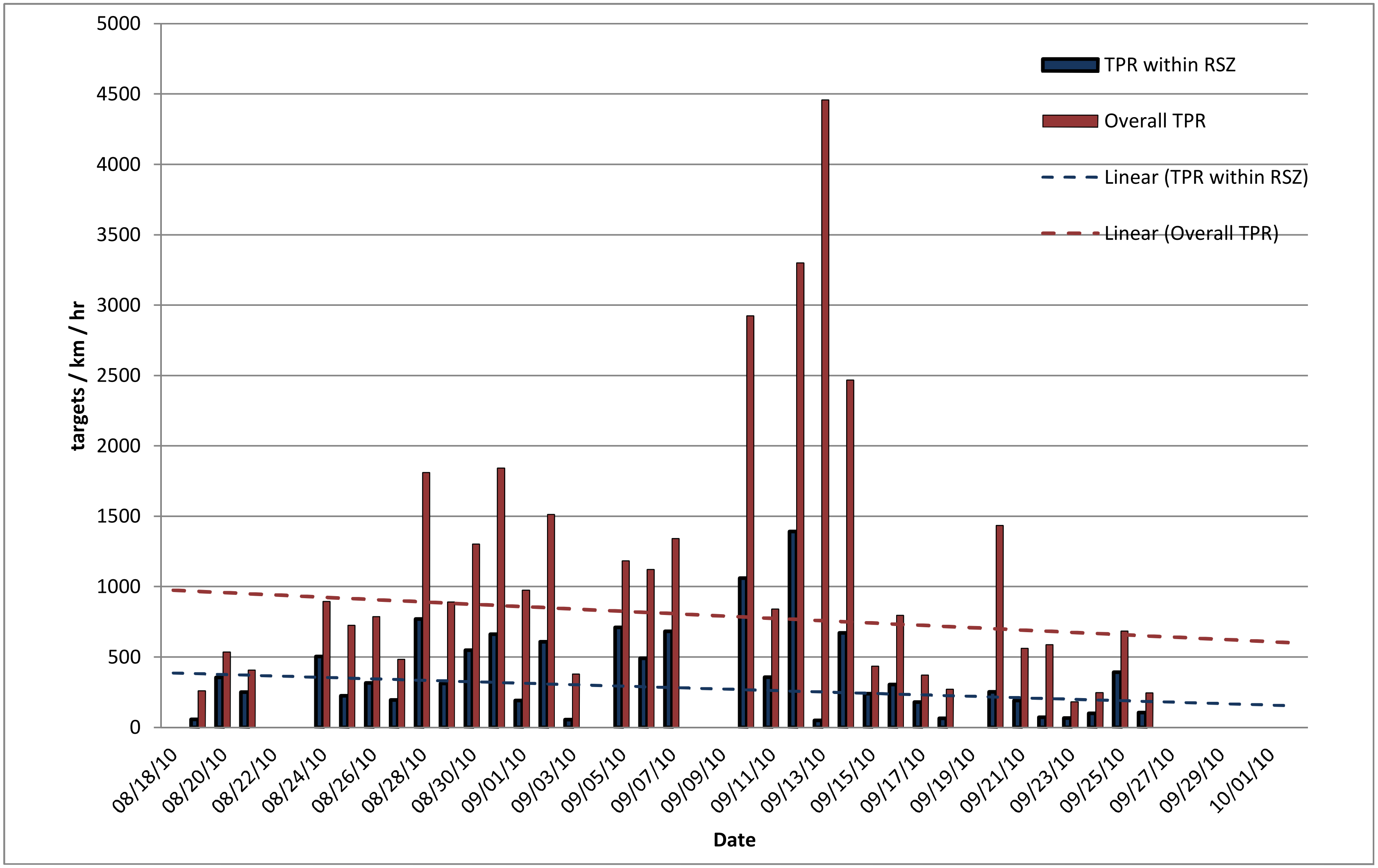
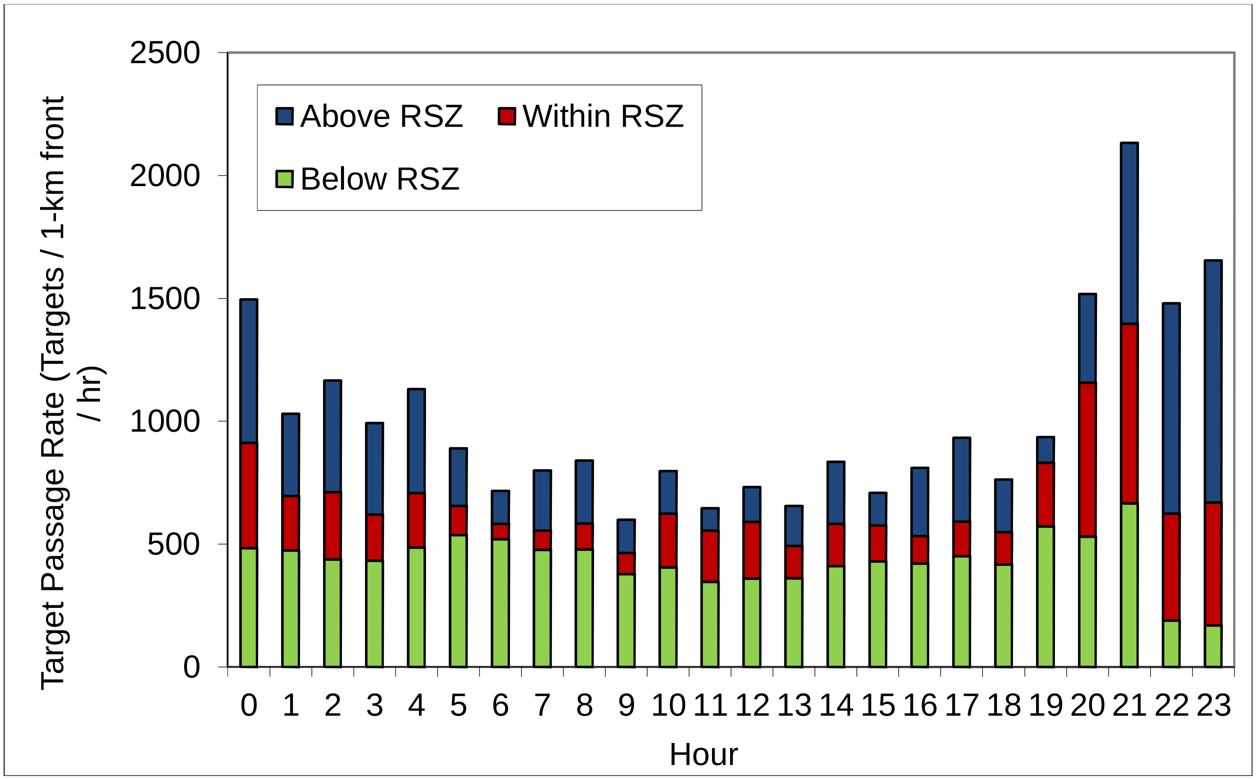


**Figure 2.11** Offshore hourly activity and TPR below, within, and above the RSZ during spring 2010



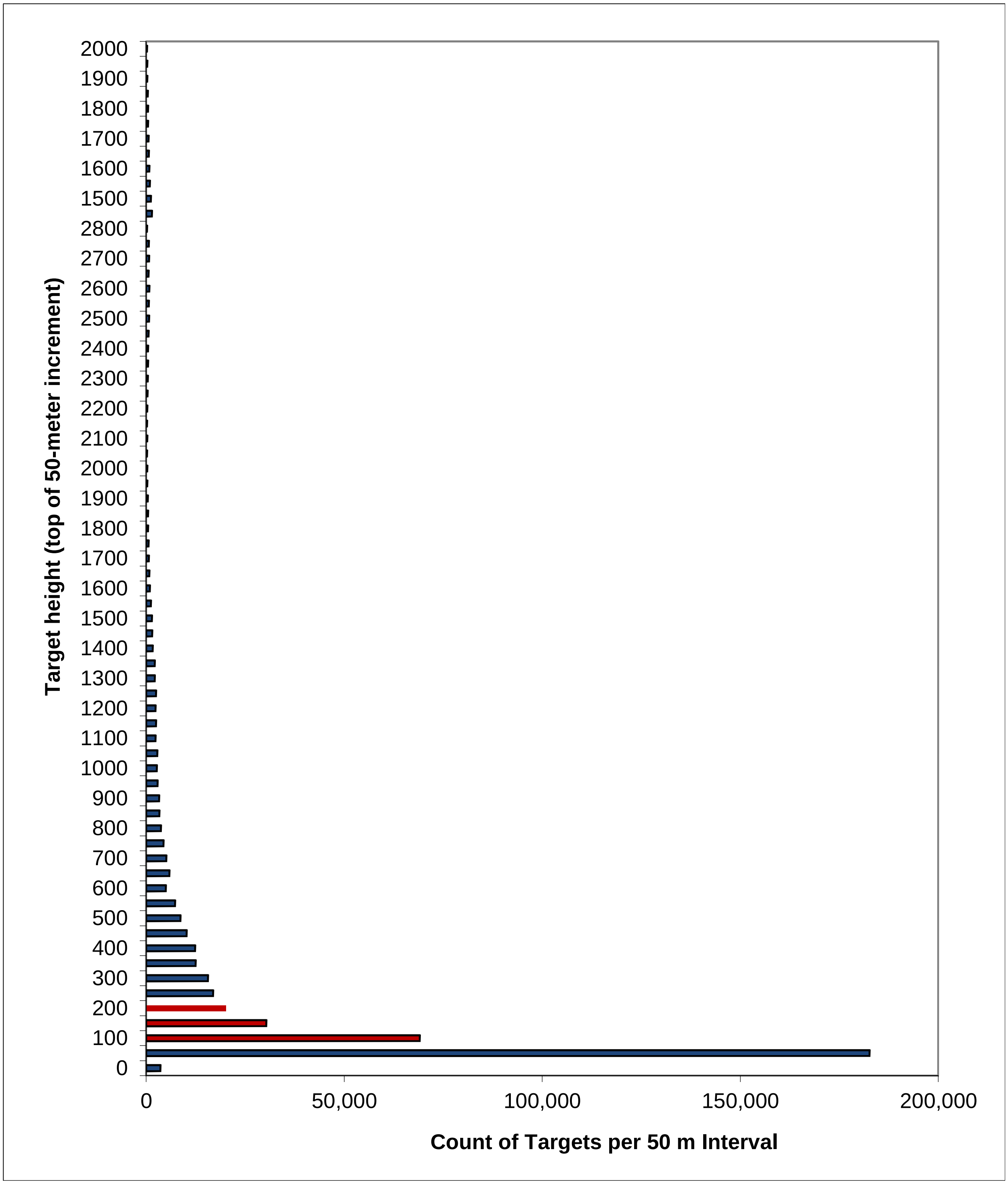

### Altitudinal Distribution of Targets

Passage rates below, within, and above the RSZ were variable across seasons and between day and night (see **Figure 2.11** and **Table 2.4**). Average target flight heights were highest in the fall during the dawn period (518.5 m AMWL) and lowest during spring at dusk (11.7 m AMWL). The percentage of targets counted below, within, and above the RSZ followed a similar trend as average flight height. Spring targets flew primarily below the RSZ, whereas fall targets flew primarily above the RSZ. In general flight heights were higher during periods of increased TPR. For example the highest TPRs were recorded during dawn and at night in fall, periods when TPR above the RSZ was greater than TPR within or below the RSZ; the average flight height during these periods was 518.5 m AMWL and 466.4 m AMWL, respectively.

**Table 2.4** Percentage of offshore target counts below, within, and above the RSZ – spring/fall 2010

| Period | % of Target Count Below RSZ | % of Target Count Within RSZ | % of Target Count Above RSZ |
|---|---|---|---|
| SPRING | | | |
| **Overall** | 96.55% | 2.60% | 0.85% |
| FALL | | | |
| **Overall** | 15.19% | 34.88% | 49.93% |

**Figure 2.12** Number of offshore targets, spring and fall 2010




Note: Red indicates approaching or within rotor swept heights.

Pooled target counts from spring and fall within 50 m increments are presented in **Figure 2.12**. The vast majority of targets flew well below the RSZ, presumably near the surface of the lake. Targets were identified within and above the RSZ. During periods of peak activity in spring most targets flew well below RSZ, although there was also increased activity within, and above the RSZ (see **Figure 2.13**). Target flight activity and flight heights were more variable in the fall. During periods of high activity in the fall, TPR was much greater above RSZ than within (**Figure 2.14**). Peak TPRs were recorded during mid-September (September 10 – September 14, 2010), and the majority of targets were identified above RSZ (**Figure 2.14)**. This seems to indicate that during periods of high activity (which presumably correlates with heavy migration) targets flew more frequently above the RSZ than within or below.

### Horizontal Radar

The HSR was used to determine directional movements of targets during days and nights of the 2010 sampling period. Statistical program Oriana version 4 (© 2011 by Kovach Computing Services) was used to determine circular summary statistics.

**Figure 2.13** Overall spring offshore TPR by date and in relation to the RSZ

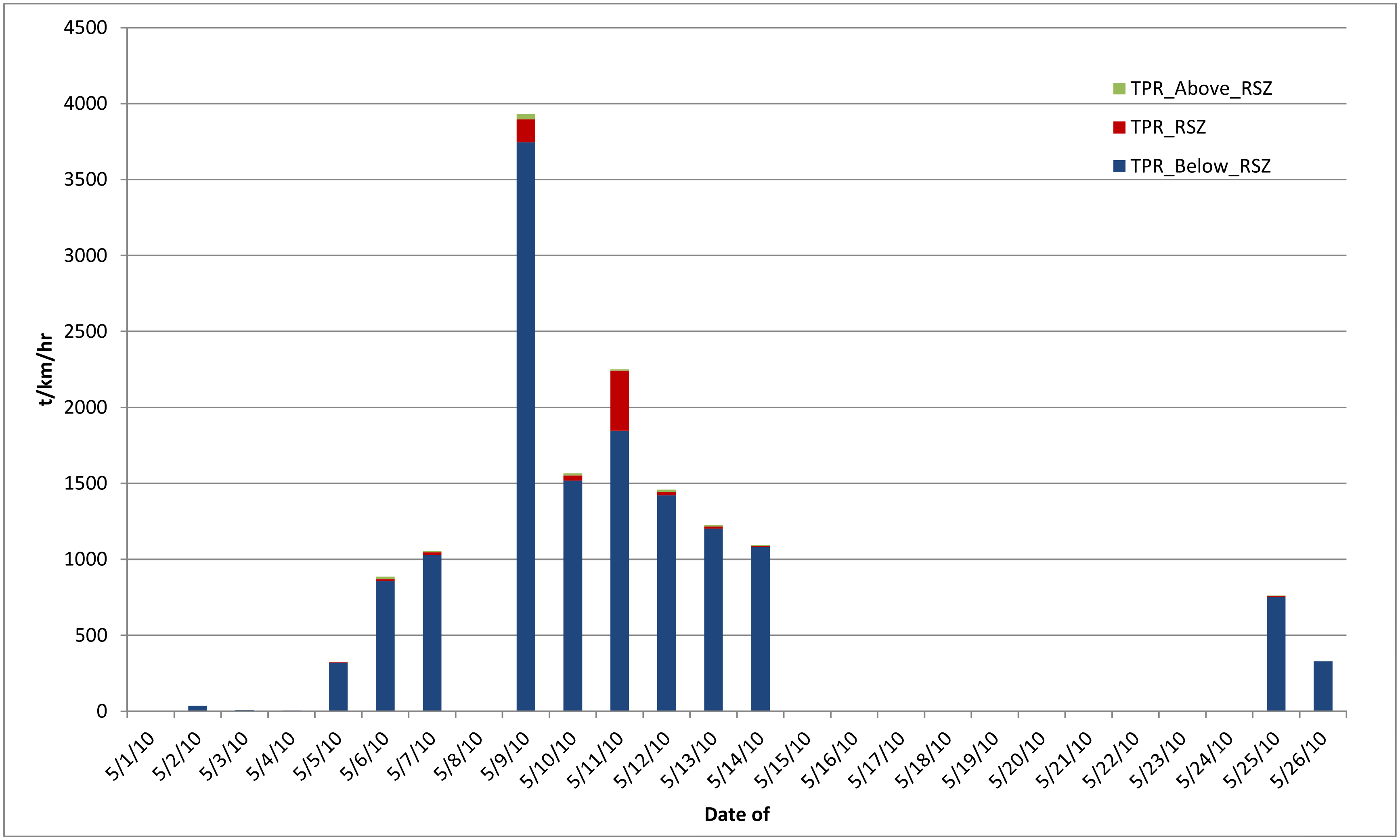
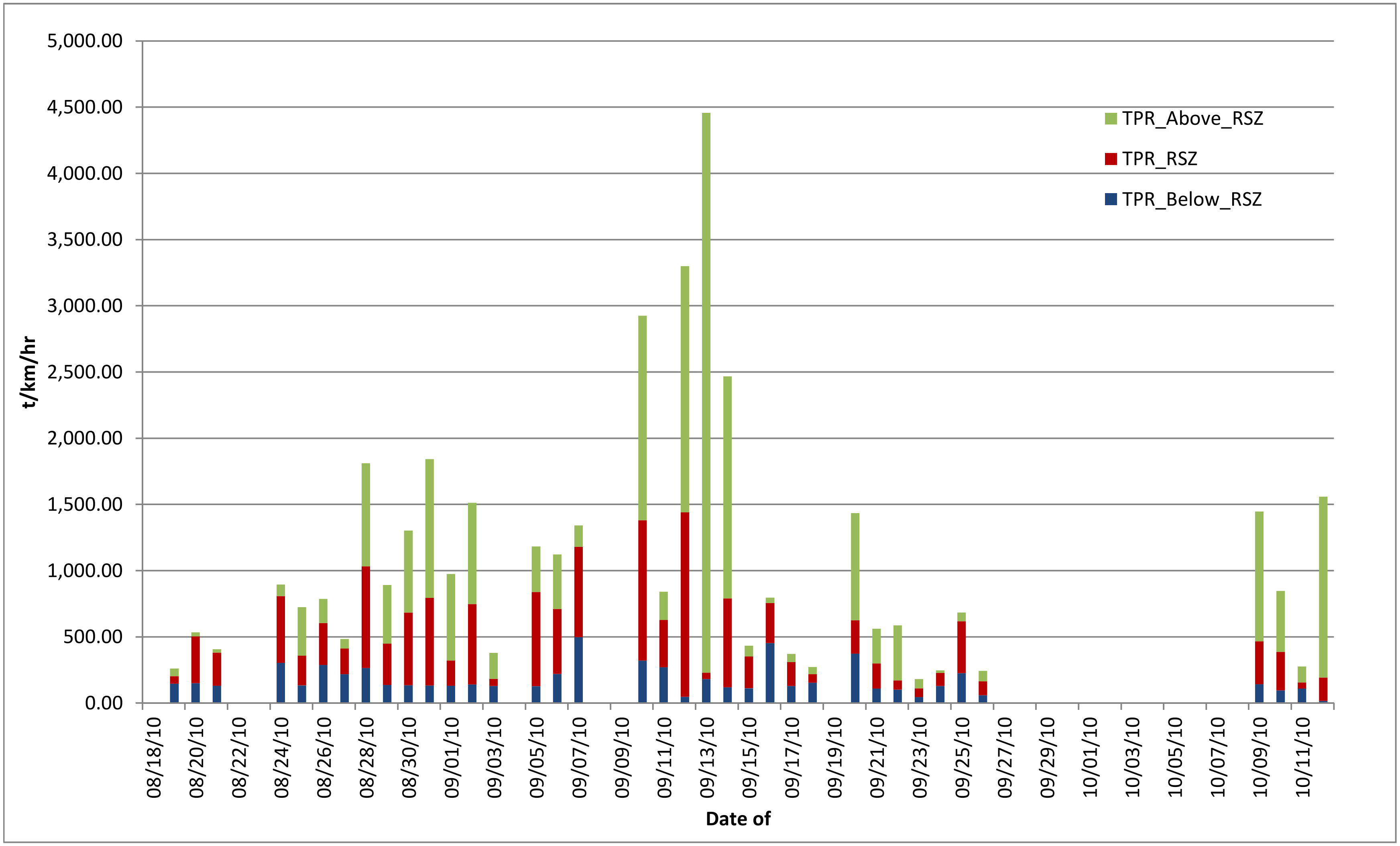


**Figure 2.14** Overall fall offshore TPR by date in relation to the RSZ



### Target Directions

The average flight direction of all targets in spring during the night was 6.7° ± 110° (**Figure 2.17**). During fall the average flight direction of targets was 208.8° ± 143° (approximately southwest) (**Figure 2.18**). On nights with high TPR, targets generally flew north or northwest in the spring, and south or southeast in the fall. However, there was a large degree of variability in the data for both seasons. Fall orientation did not appear to be as consistent as during spring, as is evident from the lack of a distinct directionality in fall (**Figure 2.18**).

**Figure 2.15** Distribution of offshore nightly target movement direction, spring 2010

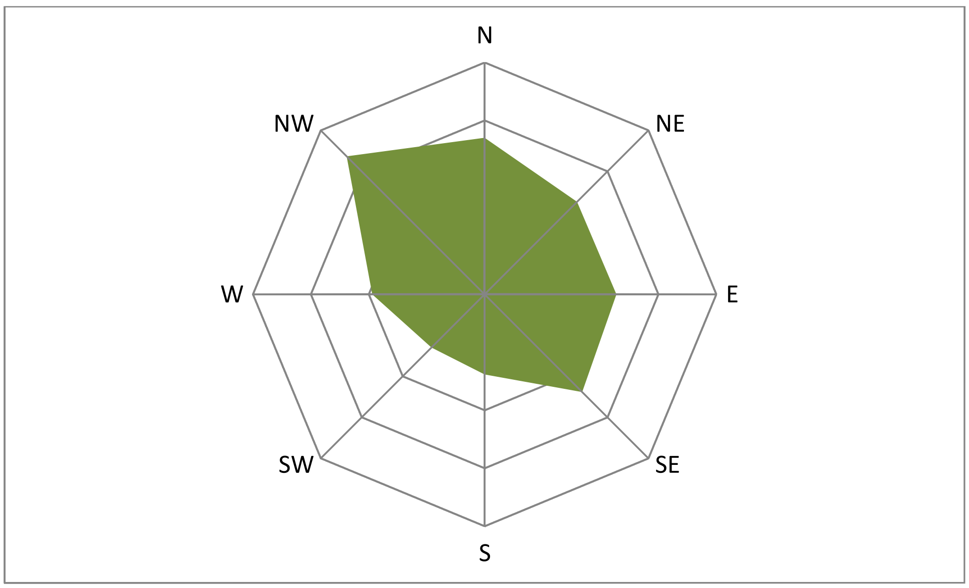
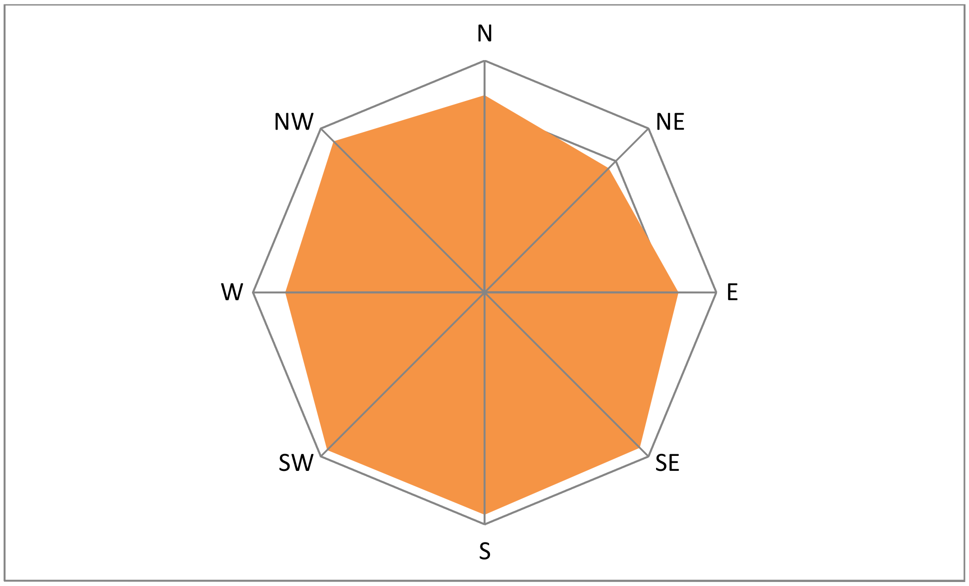
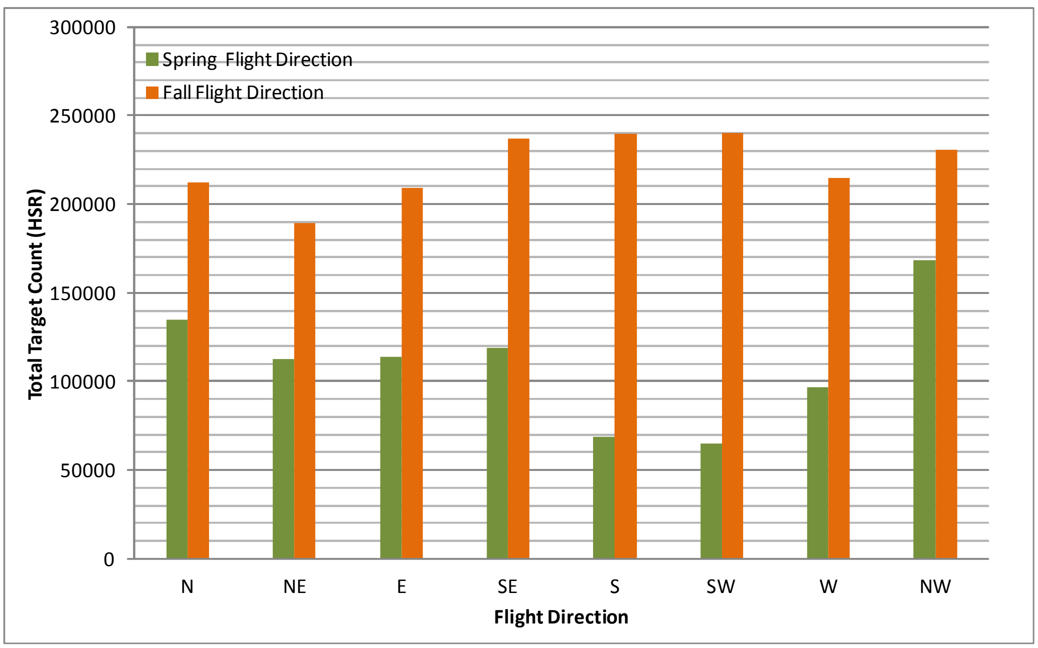


**Figure 2.16** Distribution of offshore nightly target movement direction, fall 2010




During spring when nights were grouped by average target direction, TPRs were the greatest during nights when target movements were towards the north and northwest. During the fall, the majority of targets moved towards the south, southwest, and southeast, however, directionality was less concentrated than during the spring (**Figure 2.18** and **2.19**).

**Figure 2.17** Distribution of average offshore nightly target movement direction, spring and fall 2010



## 2.3 Discussion

The 2010 radar survey collected biological target data on resident and migrant birds, bats, and, possibly insects, during spring and fall migration. The objective was to sample bird and bat passage rates, flight heights, and migration phenology, although unlikely, some targets may have been insects. The 1 km front of the radar coverage area sampled for the analysis was chosen to minimize the possibility of counting insect targets.

Passage rates onshore were lower than those recorded offshore. The mean nightly TPR for the spring onshore survey period was 32.1 t/km/hr as compared to 722.4 t/km/hr in spring and 974.3 t/km/hr in fall offshore. This difference in nightly passage rates is likely a function of the survey timing, the radar's ability to sample uncluttered airspace and the types of avian species occurring near each of the onshore and offshore locations. The onshore portion of the spring 2010 survey effort was done earlier in the migration season than the offshore radar surveys, so it is likely that the earlier onshore survey did not capture peak migration over the Lake Erie shoreline. The offshore survey was during what may be considered peak passerine migration for the region, from late April until the middle of May (Guarnaccia and Kerlinger 2008). Another possible cause for the higher observed passage rates offshore is the presence of bird targets attracted to the Crib. During visual surveys (Section 3.0), cormorant and gull species were observed roosting on the Crib. This increase in avian activity around the Crib may have contributed to the increase in recorded TPR offshore during daylight hours. Additionally, the night lighting on the crib may have attracted nocturnal migrants, insects, and possibly bats.

TPR within the RSZ at night was substantially lower during the spring than during fall. Overall TPR across biological periods (dawn, dusk, day, or night) was lowest during the day in spring, and at dusk in fall. TPR was generally highest below RSZ in spring and above RSZ in fall.

It is expected that the large number of gulls and cormorants offshore, as confirmed by the visual surveys, were responsible for the much of the activity during the day and likely at dawn and dusk. The results of the boat-based surveys indicated that gulls were the most frequently encountered species flying at heights within the RSZ. The results of the spring passive avian acoustic monitoring survey seem to indicate that passerines were either not present during migration over the Crib, or were flying above the receptive range of the microphones, which correlates approximately to the upper boundary of the RSZ. It is suspected that any passerine targets detected during the radar surveys were flying well above, or near the upper portions of the RSZ. However, it is evident from the fall TPRs that nocturnal migration was occurring, and at high rates, offshore, although most of these nocturnal migrants flew above the RSZ, as was evident from the mean altitudes that exceeded 300 m regularly during the night.

Mean TPR during the combined 2010 sampling period at the offshore location at the Crib varied widely, ranging from 0.4 to 3 to 4,459 t/km/hr per 24 hour period. Peak activity in spring was recorded on May 9, 2010, and peak activity in fall on September 13, 2010. Hourly TPR during spring onshore was generally greatest during the day (peak TPR was recorded during 12:00); however, hourly TPR during the offshore surveys was greatest at night from 20:00 to 0:00. The onshore portion of the spring survey was early in the migration season, and nocturnal passerine (primarily neo-tropical) migrants may not have reached northern Ohio until after the radar began collecting data at the offshore location. It is apparent from the fall radar survey results, as has been shown by GeoMarine Inc. (2008) and Diehl et al. (2003) for the Great Lakes, that there is substantial nocturnal migration over Lake Erie, primarily in mid-September, and at heights above the RSZ (mean night time flight height in fall offshore was 466.4 m AMWL).

During both spring and fall offshore, mean target heights were generally greater during nights than days, although mean flight heights during fall at dawn were greater than at night. Median flight heights trended a little differently; greatest median flight height was during dusk in spring, and dawn during fall. High-altitude nocturnal migration and low-altitude, local movements during daytime, are likely explanations for some of the temporal difference in target heights, as well as the TPRs.

As expected during spring migration, the majorities of average nightly target movements were to the north and averaged 6.7° (north-northeast). Also as might be expected during fall migration, the majority of nightly target movements was to the south and averaged 208° (southwest), although flight directions were more variable in fall than spring. There was also substantial variation among the directions of targets recorded, including targets moving in directions inappropriate for migration. It is not known if this variation was correlated with wind direction.

During spring 2010, TPRs were greatest on nights when target movements averaged north. The prominent northerly movement is not surprising during a spring migration time period. There were very few patterns between weather and target rates, or flight heights in fall offshore. There was a correlation between average nightly temperature and TPR below and within the RSZ ($r$ = -0.72 and -0.51, respectively). This correlation suggests that as temperature increases the TPR below and within the RSZ decreases. There was no apparent association between any fall target metric and weather conditions.

# 3.0 BOAT-BASED SURVEY

This section explains the methods and results of the spring and fall 2010 offshore visual observation boat-based surveys. The goal of the visual observation surveys was to collect data on species composition, spatial and temporal distribution, relative abundance, and behavior of avifauna within the Study Area during the spring and fall 2010 migration period. This information is relevant as both a standalone data set, as well as a supplement to the avian radar surveys data. The visual observation surveys also provided opportunities to document any occurrence of state or federally listed rare, threatened or endangered species in the Study Area (see **Figure 3.1**)

## 3.1 Methods

During the spring and fall 2010 migration periods, boat-based visual observations were conducted in early morning, early evening, and night. Surveys were conducted along a single “saw tooth” transect that covered a large portion of the Study Area within the radar coverage area, and was centered on the Crib (see **Figure 3.1**). The survey transect was approximately 37 km (20 nm) in length and contained a total of 21 points spaced at even intervals [1.85 km (1 nm) apart]. Transect section point 1 was located north of the Crib, and the farthest from shore, point 21 was located south of the Crib and closest to the Cleveland shoreline. To provide spatial information on species occurrence the points were combined into two categories: points 1 to 11 and points 12 to 21. These categories correspond to the north portion of the survey area (points 1–11), and the south portion of the survey area (12–21). Surveys conducted during the evening/night hours began approximately ½ hour before sunset and continued until the length of the survey transect was completed. Morning surveys began ½ hour before sunrise and continued until the entire transect was completed. Spring surveys were conducted aboard a 78 foot tug boat and fall surveys were conducted aboard a 28 foot boat, both surveys traveled the same route at the same speeds, and provided similar observation platforms. The survey vessels traveled at a constant speed between 8 to 12 knots, and generally surveyed during optimal weather (low wind speed, high mean nightly temperature, and calm sea state). The starting location along the survey transect (i.e., north or south starting point) was alternated to avoid potential biases related to survey timing and species activity patterns.

All birds seen or heard within a 300 m radius ahead and perpendicular to the boat were recorded on standardized data sheets. Birds were identified to species when possible, using binoculars and a field guide (Sibley 2000). Binoculars were used to identify birds during the early evening hours and IR night vision binoculars (ATN Night Shadow 3, American Technologies Network Corp.) were used after complete civil twilight. Other data recorded included abundance, flight height, distance from the boat, and behavior (foraging, direct flight, sitting on the water, and boat following). The vertical flight elevation above the water was recorded in the following categories: <10 m, 10 to 25 m, 26 to 125 m, 126 to 200 m, >200 m (Paton et al., 2009).

Data were then entered into a Microsoft Excel database at the conclusion of each survey. The mean abundance (MA) of birds per sample point was calculated based on the total number of for all surveys combined, divided by the total number of times all points were sampled. Individual observations were linked to the survey point passed prior to the bird's observation..

## 3.2 Results

The following section presents a summary of the offshore avian boat-based survey results.

### 3.2.1 Weather

The mean temperature during the 2010 spring offshore avian boat-based surveys was 71.3°F (21.8°C), and ranged from 65°F to 75°F (18.3°C to 23.8°C). Wind speeds during surveys were generally moderate and ranged from 1 to 10 miles per hour (mph) or 0.44 to 4.47 meters per second (m/s). Weather conditions during surveys were highly variable including rain, partly cloudy, to mostly clear.

The mean temperature during the 2010 fall offshore avian surveys was 65.5°F (18.6°C), with a low of 43°F and a high of 85°F (6.1°C and 29.4°C, respectively). Wind speed during surveys was generally moderate with a survey period range of 0 to 17 mph (0.00 to 7.60 m/s). Atmospheric conditions were variable including fog, partly cloudy, and clear.

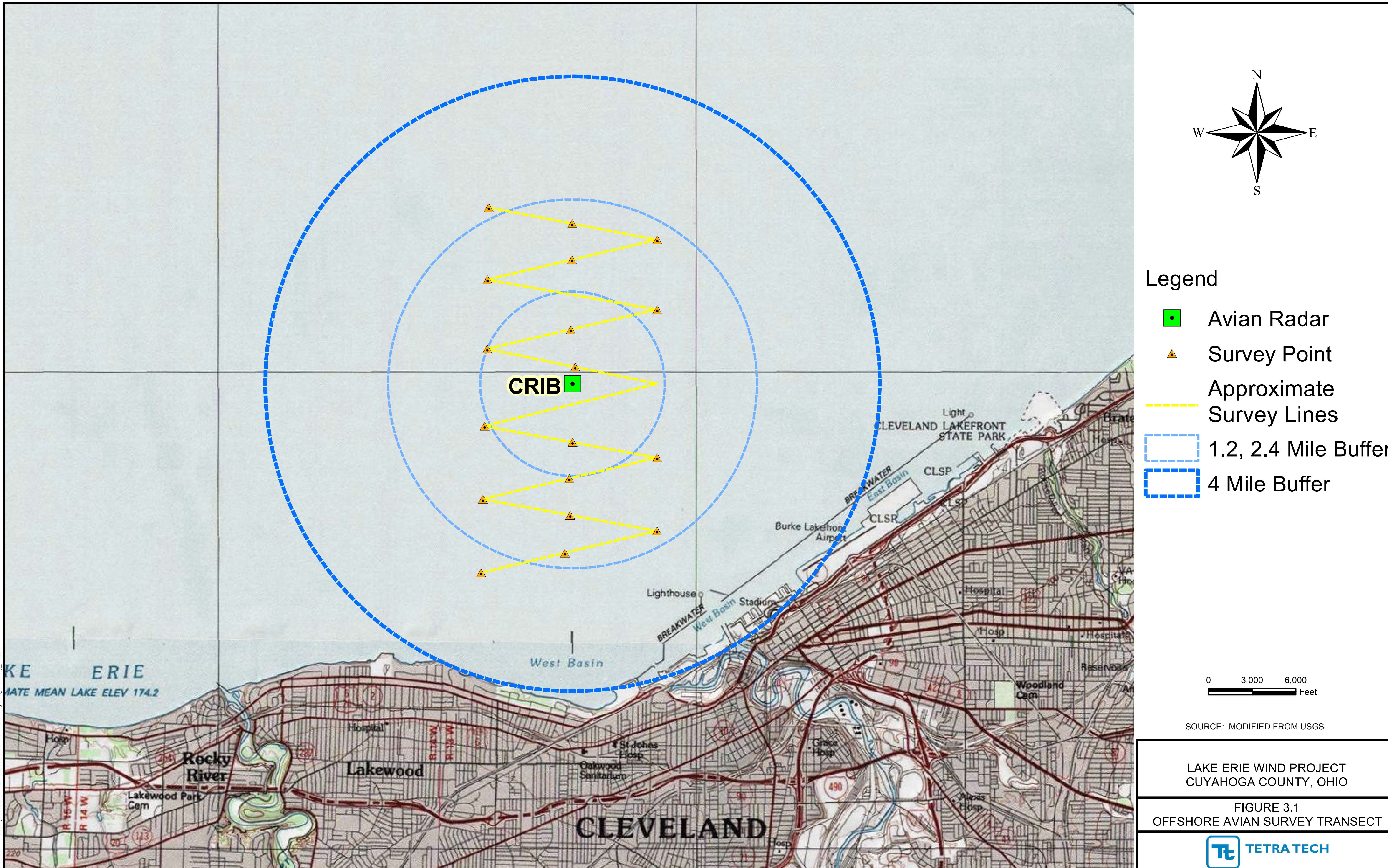
### 3.2.2 Spring 2010 Observation Totals and Abundance

Offshore avian surveys were conducted on 4 evenings during the month of May 2010 (May 5, 13, 20, and 24, 2010). A total of 68 points were surveyed during this period which resulted in a total of 7.3 hours of offshore avian observations for the spring surveys combined. Inclement weather during the first survey (May 5, 2010), interfered with the completion of all 21 survey points. A total of 456 individual birds were observed during spring surveys representing 5 species, not including unidentified *Larus* gulls and other unidentified birds (see **Table 3.1**). The 4 major taxonomic groups represented included gulls, cormorants, ducks, and passerines. The majority (96.7%) of sightings were gulls ($n$ = 441). Cormorants ($n$ = 8), ducks ($n$ = 2), and passerines ($n$ = 1) were observed infrequently. No state or federally listed endangered or threatened species were observed during the spring surveys.

Species composition was not complex and both composition and the number of birds observed during each transect sample were similar among the May surveys. Average relative abundance of birds per sample point was 6.71 birds per point-surveyed. Ring-billed gull (*Larus delawarensis*) and herring gull

(*Larus argentatus*) had a comparatively high average number of observations per sample point; 2.94 and 2.51 birds per point-surveyed, respectively. Unidentified *Larus* gulls were observed often and the average number of observations per sample point was 2.51 birds. Double-crested cormorant (*Phalacrocorax auritus*) and a small number of unidentified birds, ducks, and sparrow species were observed (see **Table 3.1**).

Birds were observed flying, foraging, and sitting on the water (see **Table 3.2**). The majority (84.1%) of birds were observed in direct flight. Birds were also seen actively foraging (10.9%) and resting on the water (2.2%). A total of 12 gulls were observed to have been following the survey vessel (2.6%), although for only a brief period of time. Most gull observations consisted of adults (*n* = 231; 51%), followed by unknown/unidentifiable age birds (*n* = 192; 41%). A small number (*n* = 33; 7%) of observations were of immature ring-billed and herring gulls.




LAKE ERIE WIND PROJECT
CUYAHOGA COUNTY, OHIO

FIGURE 3.1
OFFSHORE AVIAN SURVEY TRANSECT

TETRA TECH

**Table 3.1** Offshore species totals and average abundance per transect area, spring 2010

| Spring 2010 | | Transect Area | | |
|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **North** | **South** | **Total** |
| Double-crested Cormorant | *Phalacrocorax auritus* | 1 | 7 | 8 |
| Herring Gull | *Larus argentatus* | 37 | 33 | 70 |
| Ring-billed Gull | *Larus delawarensis* | 89 | 111 | 200 |
| Unidentified bird | Aves | 4 | 0 | 4 |
| Unidentified duck | Anatidae | 0 | 2 | 2 |
| Unidentified Larus gull | *Larus* spp. | 67 | 104 | 171 |
| Unidentified sparrow | Emberizidae | 1 | 0 | 1 |
| | **TOTAL** | **199** | **257** | **456** |

**Table 3.2** Offshore avian behavior by species, spring 2010

| Spring 2010 | | | | | | |
|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **Direct Flight** | **Foraging** | **Resting on Water** | **Following Vessel** | **Total*** |
| Double-crested cormorant | *Phalacrocorax auritus* | 8 | 0 | 0 | 0 | 8 |
| Herring gull | *Larus argentatus* | 47 | 14 | 1 | 8 | 70 |
| Ring-billed gull | *Larus delawarensis* | 163 | 24 | 4 | 3 | 194 |
| Unidentified bird | Aves | 4 | 0 | 0 | 0 | 4 |
| Unidentified duck | Anatidae | 2 | 0 | 0 | 0 | 2 |
| Unidentified Larus gull | *Larus* spp. | 153 | 11 | 5 | 1 | 170 |
| Unidentified sparrow | Emberizidae | 1 | 0 | 0 | 0 | 1 |
| **Total** | | **378** | **49** | **10** | **12** | **449** |
| **Percentage** | | **84.2%** | **10.9%** | **2.2%** | **2.7%** | |

*Behavior data were not obtained for a total of 7 individual birds; therefore they were excluded from the analysis.

Incidental bird observations were recorded while in the vicinity of the Study Area. Additional waterfowl, passerine, and raptor species observed along the shoreline at the Cleveland Lakefront State Park headquarters and 55th Street Marina, Burke Lakefront Airport, Port Authority harbor, and Whiskey Island include: American coot (*Fulica americana*), American robin (*Turdus migratorius*), barn swallow (*Hirundo rustica*), belted kingfisher (*Megaceryle alcyon*), blue-winged teal (*Anas discors*), Bonaparte's gull (*Chroicocephalus philadelphia*), Canada goose (*Branta canadensis*), canvasback (*Aythya valisineria*), Cooper's hawk (*Accipiter cooperii*), eastern phoebe (*Sayornis phoebe*), European starling (*Sturnus vulgaris*), greater scaup (*Aythya marila*), green heron (*Butorides virescens*), killdeer (*Charadrius vociferous*), mallard (*Anas platyrhynchos*), northern mockingbird (*Mimus polyglottos*), red-breasted merganser (*Mergus serrator*), red-tailed hawk (*Buteo jamaicensis*), red-winged blackbird (*Agelaius phoeniceus*), song sparrow (*Melospiza melodia*), and turkey vulture (*Cathartes aura*). Most of these species were encountered infrequently; however Canada goose, European starling, and northern mockingbird were frequently encountered.

### 3.2.3 Spring 2010 Temporal Distribution

Based on the recorded counts of individual species observed, species composition in the Study Area did not appear to change substantially over the course of the spring survey period. As can be seen from the data, observations of gulls were dominant and generally consistent throughout the survey period. Herring gull abundance did not vary greatly between weeks. Ring-billed gull observations peaked during the May 20, 2010 survey, but were otherwise consistent across survey dates. Many gulls were unidentifiable because of unpredictable boat movements, as well as when visibility was poor or due to inadequate light conditions. Additionally, exact species identification is difficult or impossible, even while using IR night vision binoculars after dark. Unidentified *Larus* gull observations increased between weeks, though this may be due in part to varying survey conditions.

The only observations of double-crested cormorants occurred on May 5, 2010 and May 20, 2010. A few observations of unidentified ducks, and bird species occurred on May 20, 2010, and a single observation of an unidentified sparrow occurred on May 13, 2010. These data suggest that the avian community in the Study Area consists primarily of gulls during spring migration.

### 3.2.4 Spring 2010 Spatial Distribution

Species composition did not differ substantially between the north (points 1 to 11) and south (points 12 to 21) portions of the Study Area. Although a higher count of individuals was observed in the south portion, with a total of 257 birds, compared to a total of 199 individuals observed in the northern portion. Proportionately, 56.4% of all birds were observed in the south of the Crib, while 43.6% were observed in the north of the Crib (**Figure 3.1**).

Distribution of herring gulls did not differ greatly between the north and south portions: 53% occurred in the north portion and 47% occurred in the south portion. Ring-billed gulls, unidentified gulls, and double-crested cormorants were observed more frequently in the south portion of the survey area; 55.5%, 61%, and 88.5% of observations of these species occurring in the south, respectively. These data demonstrate that birds appear to be evenly distributed throughout the Study Area.

The single sparrow observation occurred in the north area; the bird was heading in a southeast direction. The unidentified duck observations occurred in the south portion of the survey area closer to the harbor. The unidentified bird species occurred in the north portion of the survey area on May 20, 2010 and may be representative of birds flying too high for detection during the boat-based surveys.

Flight heights were variable during the spring surveys (see **Table 3.3**). The majority of birds were observed flying generally below the RSZ, between 10 and 25 m (58%), 31% were observed flying at heights generally within the RSZ. Only 2% of the observations were of birds flying at heights generally above RSZ. Few birds (1.5%) were observed sitting on the water. Overall, these data suggest that approximately one-third of observed bird, which consisted primarily of gulls, were flying within the RSZ.

**Table 3.3** Offshore avian flight heights by species, spring 2010

| Spring 2010 | | Flight Height | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **< 10 m** | **10-25 m** | **26-125 m** | **126-200 m** | **> 200 m** | **On Water** | **Total** |
| Double-crested cormorant | *Phalacrocorax auritus* | 0 | 7 | 1 | 0 | 0 | 0 | 8 |
| Herring gull | *Larus argentatus* | 20 | 31 | 19 | 0 | 0 | 0 | 70 |
| Ring-billed gull | *Larus delawarensis* | 41 | 96 | 57 | 0 | 0 | 6 | 200 |
| Unidentified bird | Aves | 0 | 0 | 0 | 0 | 4 | 0 | 4 |
| Unidentified duck | Anatidae | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| Unidentified Larus gull | *Larus* spp. | 19 | 85 | 64 | 2 | 0 | 1 | 171 |
| Unidentified sparrow | Emberizidae | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **Total** | | **80** | **219** | **142** | **4** | **4** | **7** | **456** |
| **Percentage** | | **17.5** | **48** | **31.1** | **0.8** | **0.8** | **1.5** | |

### 3.2.5 Fall 2010 Observation Totals and Abundance

During the fall 2010 survey period 4 offshore avian surveys were conducted in September 2010 and 2 surveys were conducted in October 2010 for a total of 6 separate transect surveys (September 13, 23, 29, 30, and October 13 and 25, 2010). During the fall 4 surveys were conducted in the evening and 2 surveys (September 30 and October 13, 2010) were conducted in the morning. A total of 126 points were surveyed during this period which resulted in a total of 12.6 hours of offshore avian observation for all fall surveys combined. A total of 2,958 individual birds were observed representing 5 species, not including unidentified *Larus* gulls and unidentified ducks (see **Table 3.4**). Species observations included only 3 taxonomic groups; gulls, cormorants, and ducks. The majority (83%) of all individuals observed were gulls ($n$ = 2,451 birds observed) followed by cormorants ($n$ = 503). Ducks were observed on only a few occasions ($n$ = 4). No state or federally listed endangered or threatened species were observed during the fall survey period.

Species composition was not complex and both composition and the number of birds observed during each transect sampling event was generally consistent throughout the fall survey period (see **Table 3.4**). The mean (average) relative abundance was 23.48 birds per point surveyed. Ring-billed gull had the highest mean abundance of observations per sample point at 9.63 birds per point-surveyed, followed by Bonaparte's gull (MA = 5.80 birds per point-surveyed). The next highest was double-crested cormorant with an average of 3.99 observations per sample point. Unidentified *Larus* gulls averaged 2.51 birds per point surveyed and herring gulls averaged 1.51 birds per point-surveyed.

Behavioral observations during the offshore avian surveys consisted of birds flying, foraging, sitting on the water, and sitting on the Crib (see **Table 3.5**). The majority (53.7%) of birds were observed actively foraging. Many birds were observed in direct flight (22.9%) and resting on the Crib (13.5%). Fewer birds were observed resting on the water (3.2%). A total of 200 gulls were observed following boats, including the survey vessel (6.8%).

Incidental bird observations were recorded while in the vicinity of the Study Area. Additional waterfowl and passerine species were observed at Burke Lakefront Airport, 55$^{th}$ Street Marina and on the Crib during scheduled radar maintenance include: American coot, mallard, Caspian tern (*Hydroprogne caspia*), and blue-gray gnatcatcher (*Polioptila caerulea*). The blue-gray gnatcatcher was observed resting on the Crib during the late evening hours of September 29, 2010 and was the only migrant passerine documented in the Study Area during fall 2010. Caspian terns were observed frequently during October at the Burke Lakefront Airport and once in the harbor at 55th Street Marina on October 25, 2010, but not during in the Study Area.

**Table 3.4** Offshore species totals and average abundance by transect area, fall 2010

| Fall 2010 | | Transect Area | | |
|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **North** | **South** | **Total** |
| Blue-winged teal | *Anas discors* | 3 | 0 | 3 |
| Bonaparte's gull | *Larus philadelphia* | 728 | 3 | 731 |
| Double-crested cormorant | *Phalacrocorax auritus* | 468 | 35 | 503 |
| Herring gull | *Larus argentatus* | 100 | 90 | 190 |
| Ring-billed gull | *Larus delawarensis* | 878 | 336 | 1214 |
| Unidentified duck | Anatidae | 1 | 0 | 1 |
| Unidentified Larus gull | *Larus* species | 168 | 148 | 316 |
| | **Total** | **2346** | **612** | **2958** |

**Table 3.5** Offshore avian behavior by species, fall 2010

| Fall 2010 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **Direct Flight** | **Foraging** | **Resting on Water** | **Resting on Crib** | **Following Vessel** | **Total** |
| Blue-winged teal | *Anas discors* | 3 | 0 | 0 | 0 | 0 | 3 |
| Bonaparte's gull | *Larus philadelphia* | 0 | 684 | 0 | 0 | 47 | 731 |
| Double-crested cormorant | *Phalacrocorax auritus* | 85 | 10 | 8 | 400 | 0 | 503 |
| Herring gull | *Larus argentatus* | 134 | 36 | 2 | 0 | 18 | 190 |
| Ring-billed gull | *Larus delawarensis* | 231 | 777 | 77 | 0 | 129 | 1214 |
| Unidentified duck | Anatidae | 0 | 0 | 1 | 0 | 0 | 1 |
| Unidentified Larus gull | *Larus* species | 223 | 80 | 7 | 0 | 6 | 316 |
| **Total** | | **676** | **1587** | **95** | **400** | **200** | **2958** |
| **Percentage** | | **22.9%** | **53.7%** | **3.2%** | **13.5%** | **6.8%** | |

### 3.2.6 Fall 2010 Temporal Distribution

Based on the recorded data of observed species, the composition of avifauna in the Study Area did not change substantially during the fall survey period. Observations consisted primarily of gulls throughout the survey period. The relative abundance of herring gulls varied slightly between surveys with the greatest number recorded during the first survey on September 13, 2010 and the second highest number recorded during the October 13, 2010 survey. Ring-billed gull observations increased between surveys and peaked during the October 25, 2010 survey. Bonaparte's gulls were observed in large numbers, but only during the October 25, 2010 survey. Many gulls were unidentifiable during periods of poor visibility, unpredictable boat movements, and inadequate light conditions. Additionally, species identification is difficult when using IR night vision binoculars after nautical twilight. Unidentified *Larus* gull observations increased each week during the fall surveys, though this may be due, in part, to varying survey conditions. The highest observation counts of double-crested cormorants occurred on September 13, 2010 and October 13, 2010 although a small number of individuals were also observed on September 29 and 30, 2010.

On October 13, 2010, 3 blue-winged teals were observed and an unidentified duck was observed on September 30, 2010. These limited observations do not provide sufficient information for temporal distribution analysis of waterfowl.

### 3.2.7 Fall 2010 Spatial Distribution

During the fall surveys overall species composition did not differ greatly between the north (points 1 to 11) and south (points 12 to 21) portions of the Study Area. Although the few duck observations occurred in the north area with no observations of ducks in the south area. The higher count of individuals was observed in the north area with a total of 2,346 birds, compared to 612 individuals observed in the south area. Proportionately, 79.3% of birds were observed in the north area while 20.7% were observed in the south area. These data suggest that the majority of birds observed during the fall were found in the north portion of the Study Area.

Distribution of herring gulls did not differ greatly between the north and south portions; 53% of herring gull observations occurred in the north portion and 47% occurred in the south portion. Bonaparte's gulls, ring-billed gulls, unidentified gulls, and double-crested cormorants were observed more frequently in the north portion of the survey area with 99.5%, 72.3%, 53.2%, and 93% of observations of these species occurring in the north, respectively.

Flight heights were variable during the fall surveys, although 95.7 % of observed birds flew below the RSZ (see **Table 3.6**). The majority of birds were observed flying below 10 m (70.3%), substantially below the RSZ. A total of 752 birds were observed flying between 10 and 25 m (25.4%), below the RSZ. A total of 29 birds were observed flying within RSZ (1.0 %), and a total of 95 birds (3.2%) were observed sitting on the water.

**Table 3.6** Offshore avian flight heights by species, fall 2010

| Fall 2010 | | Flight Height | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Common Name | Scientific Name | < 10 m | 10-25 m | 26-125 m | 126-200 m | > 200 m | On Water | Total |
| Blue-winged teal | *Anas discors* | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| Bonaparte's gull | *Larus philadelphia* | 727 | 4 | 0 | 0 | 0 | 0 | 731 |
| Double-crested cormorant | *Phalacrocorax auritus* | 448 | 46 | 1 | 0 | 0 | 8 | 503 |
| Herring gull | *Larus argentatus* | 71 | 100 | 17 | 0 | 0 | 2 | 190 |
| Ring-billed gull | *Larus delawarensis* | 748 | 384 | 5 | 0 | 0 | 77 | 1214 |
| Unidentified duck | Anatidae | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Unidentified Larus gull | *Larus* species | 83 | 220 | 5 | 1 | 0 | 7 | 316 |
| **Total** | | **2080** | **752** | **28** | **1** | **0** | **95** | **2958** |
| **Percentage** | | **70.3%** | **25.4%** | **0.9%** | **0.0%** | **0.0%** | **3.2%** | |

### 3.2.8 Spring & Fall 2010 Combined Temporal Distribution

Avian species composition in the Study Area did not change substantially over the entire survey period (spring and fall combined). Observations of gulls were consistent throughout the entire survey period. Herring gull abundance varied between seasons with the greatest number recorded during the fall survey. Ring-billed gull observations were greater during the fall surveys. Bonaparte's gull was only observed during the fall. Observations of unidentified *Larus* gulls were also greater during the fall surveys. The highest number of observations of double-crested cormorants also occurred during the fall surveys. Passerines were only observed during the spring surveys. The limited observations of ducks during the spring and fall surveys do not provide sufficient information for temporal distribution analysis.

### 3.2.9 Spring & Fall 2010 Combined Spatial Distribution

During the spring and fall surveys overall species composition did not differ greatly between the north (points 1 to 11) and south (points 12 to 21) portions of the Study Area. Although the few duck observations during the spring occurred in the south area and the few duck observations during the fall occurred in the north area. The only observations of passerines occurred in the north portion of the Study Area. The overall higher count of individuals was observed in the north area with a total of 2,545 birds, compared to a total of 869 individuals observed in the south area. Proportionately, 231.4 birds per point were observed in the north area, and 87 birds per point were observed in the south area.

Overall distribution of herring gulls did not differ greatly between the north and south portions; 53% of herring gull observations occurred in the north portion and 47% occurred in the south portion. Bonaparte's gulls, ring-billed gulls, and double-crested cormorants were observed more frequently in the north portion of the survey area with 99.5%, 68%, and 92% of observations of these species occurring in the north, respectively. In the south, observation rates of Bonaparte's gulls were 0.3%, ring-billed gulls 44.7 birds per point, and double-crested cormorants 4.2 birds per point. Unidentified *Larus* gulls were observed only slightly more frequently in the south portion with 25.2 birds per point compared to 21.4 birds per point in the north portion.

To compare spatial variability we calculated an observation rate for each section of the survey transect. This rate was calculated by comparing the total number of observed individuals at each point by the total number of times the point was surveyed. The distribution of individuals throughout the study area and the rate at which they were observed provides an estimate of bird density relative to distance from shore. Transect section point 1 was located north of the Crib, and the farthest from shore, point 21 was located south of the Crib and closest to the Cleveland shoreline (see **Figure 3.1**). The greatest density of birds was observed near the Crib, at transect points 4, 9, 5, and 6, the Crib was located near transect point 8 (**Figure 3.2).** Overall density did not vary greatly from north to south, although there were lower observation rates as the distance from the Crib increased (**Figure 3.2**). The huge prevalence of gulls and cormorant in the data set and the known propensity of these species (especially cormorant) to perch on structures over or adjacent to open water was likely the cause of higher densities adjacent to the Crib (**Figure 3.3**).

**Figure 3.2** Observation rate per transect survey point location, spring and fall 2010

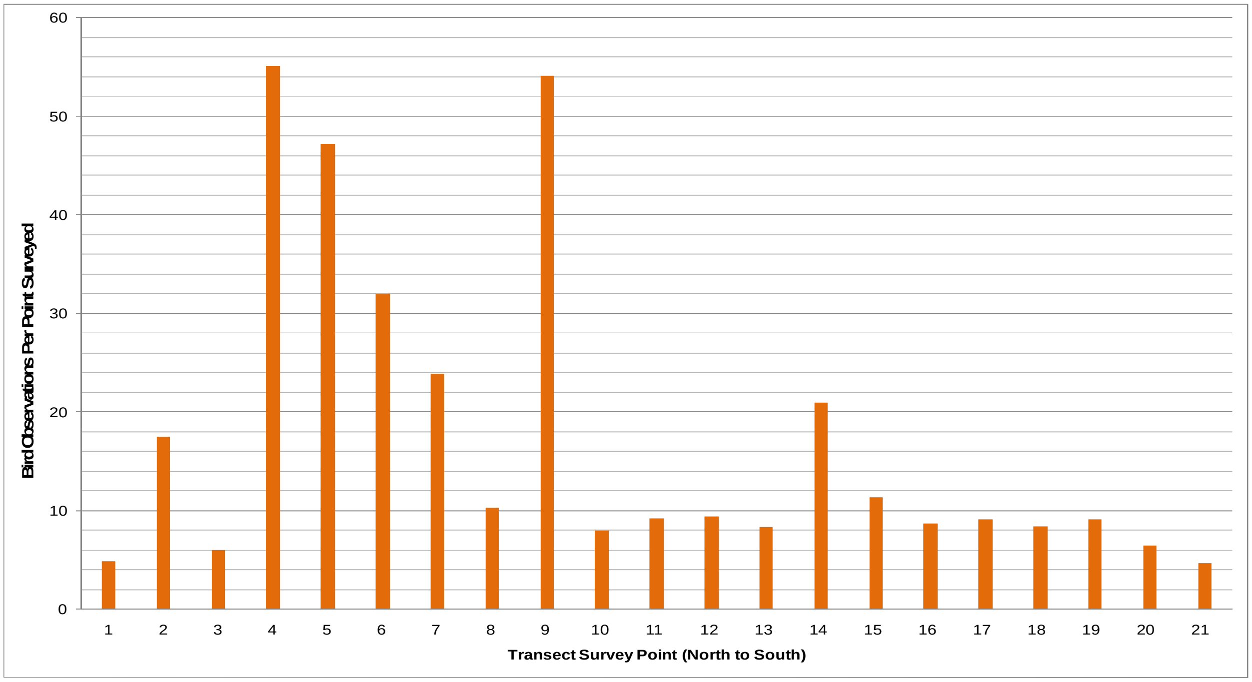
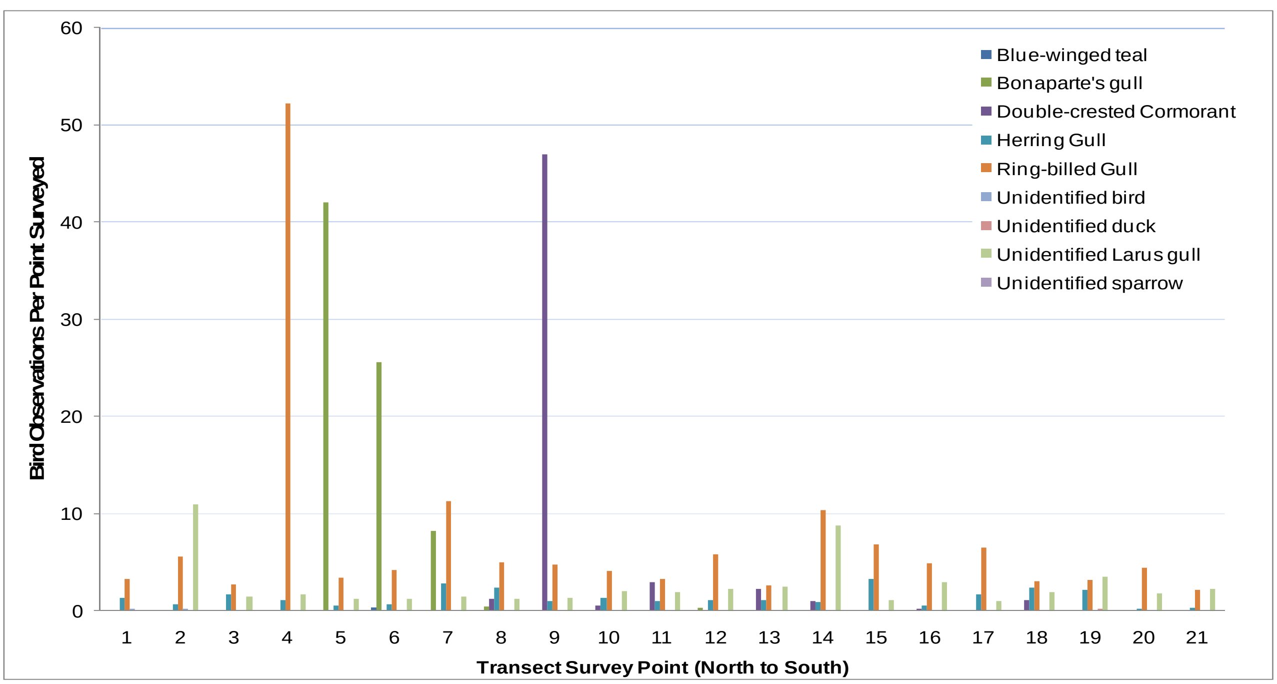



**Figure 3.3** Species observation rate per transect survey point location, spring and fall 2010




Flight heights were variable across survey dates, although birds generally flew below or above the RSZ (see **Table 3.7**). Overall, 91.8% of all observations made during the spring and fall surveys, were of individuals flying below RSZ. Very few birds were observed flying above the approximate RSZ, or within. Although it is probable that there was some observer bias towards low flying birds, as birds moving at higher altitude are often more difficult to see. A total of 102 birds (3.0%) were observed sitting on the water.

**Table 3.7** Offshore avian flight heights by species, spring and fall 2010

| Spring and Fall 2010 | | Flight Height | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Common Name** | **Scientific Name** | **< 10 m** | **10-25 m** | **26-125 m** | **126-200 m** | **> 200 m** | **On Water** | **Total** |
| Blue-winged teal | *Anas discors* | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| Bonaparte's gull | *Larus philadelphia* | 727 | 4 | 0 | 0 | 0 | 0 | 731 |
| Double-crested cormorant | *Phalacrocorax auritus* | 448 | 53 | 2 | 0 | 0 | 8 | 511 |
| Herring gull | *Larus argentatus* | 91 | 131 | 36 | 0 | 0 | 2 | 260 |
| Ring-billed gull | *Larus delawarensis* | 789 | 480 | 62 | 0 | 0 | 83 | 1414 |
| Unidentified bird | Aves | 0 | 0 | 0 | 0 | 4 | 0 | 4 |
| Unidentified duck | Anatidae | 0 | 0 | 0 | 2 | 0 | 1 | 3 |
| Unidentified Larus gull | *Larus* spp. | 102 | 305 | 69 | 3 | 0 | 8 | 487 |
| Unidentified sparrow | Emberizidae | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **Total** | | **2160** | **973** | **170** | **5** | **4** | **102** | **3414** |
| **Percentage** | | **63.3%** | **28.5%** | **5.0%** | **0.1%** | **0.1%** | **3.0%** | |

An observation rate was calculated for each individual transect survey point. This observation rate was then plotted for each flight height bin against survey transect point locations both for gull species combined, and for non-gull species combined (see **Figures 3.4** and **3.5**, respectively). For gull species, flight heights were generally lower near the Crib (points 4–9), and higher north and south of the Crib (**Figure 3.4**). Flight height for non-gull species, which consisted primarily of cormorants, seemed to be highly correlated with the Crib (**Figure 3.5**). Flight heights were lowest adjacent to the Crib.

**Figure 3.4** Gull observation rate per transect survey point for flight height, spring and fall 2010

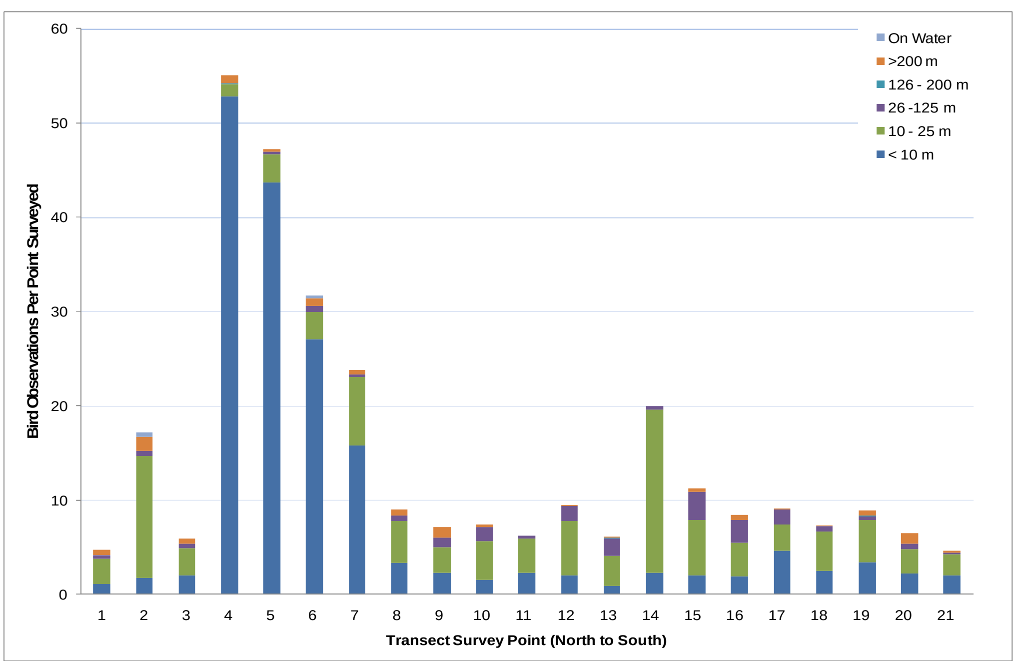
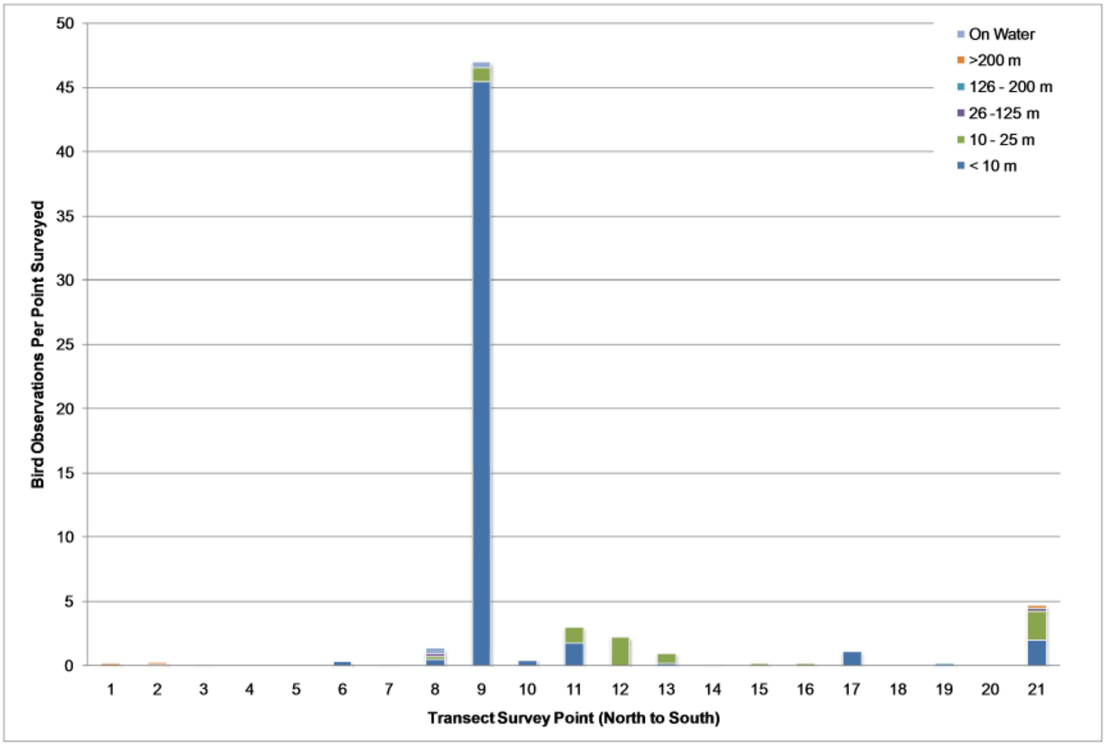


**Figure 3.5** Non-gull observation rate per transect survey point for flight height, spring and fall 2010




## 3.3 Discussion

Species composition documented during the 2010 surveys was minimal, consisting primarily of common and abundant species around Lake Erie (Peterjohn and Rice 1991, Sibley 2000, Peterjohn 2001, Cornell Lab of Ornithology 2009, Ohio Bird Records Committee 2009). No state or federally listed rare, threatened or endangered species were observed (Ohio Department of Natural Resources 2009).

During the spring and fall surveys, observations of waterfowl and passerines were infrequent. No shorebird or raptors were observed during the surveys. Species composition and relative abundance was generally consistent across surveys. Because the spring surveys were conducted only during May, there was no boat-based survey data for early spring migrants, such as red-breasted merganser. That surveys were not conducted earlier in spring may account for minimal species richness observed.

Herring and ring-billed gulls are common year-round residents and therefore the observed abundance pattern in the Study Area, with these birds accounting for a majority of bird sightings, was expected. Individual ring-billed gulls that migrate during spring to the southern Great Lakes typically arrive in mid-to-late March and some may move north as late as mid-May (Ryder 1993). The greater number of ring-billed gulls observed during fall surveys may be attributed to slow fall migration causing individuals to be widespread in September and October (Ryder 1993). During a study of wintering gulls on southeastern Lake Erie, Chapman and Parker (1985) found ring-billed gulls to be the most frequently observed species. Pieroti and Good (1994) observed that most herring gull adults remained near breeding grounds year-round and those that did not disperse left in August and return to breeding colonies in April.

Due to the prevalence of ring-billed and herring gulls in the Study Area, it is likely that many of the unidentified *Larus* gulls were one of these species. Unidentified birds consisted mostly of individuals observed during low light conditions or flying high AMWL. Also, birds seen with the IR night vision binoculars were identified to a general taxonomic group but species identification was difficult.

Though incidental observations of birds in the vicinity of the Study Area were not included in the results of the standardized surveys, they provide insight on the avian community in the general area. Large concentrations of double-crested cormorants were observed incidental to transect surveys close to shore in the harbor and close to the Cleveland area shorelines in late March and early April, 2010. In May 2010, the overall number of cormorants gradually declined and by May 24, 2010, no cormorants were seen in the harbor prior to conducting the transect survey. There were relatively few double-crested cormorants observed during spring surveys. The majority of cormorant observations occurred during fall surveys. Double-crested cormorants migrate through the Lake Erie Study Area, and breed along the northern shores of Lake Erie in Canada, although there is a resident population Ohio (USDA 2006). Large numbers breed on the Lake Erie Islands, located approximately 85 km (53 miles), west of the Study Area (USDA 2006). This suggests that the cormorants use the Cleveland area harbors and protected shorelines as stopover habitat during migration. The lower numbers of cormorants observed during spring surveys could be attributed to birds flying directly from wintering areas to breeding areas. While the higher numbers observed during fall surveys could be attributed to cormorants dispersing from nesting grounds to post-breeding foraging areas. Use of waters close to shore by cormorants appears to be related to the greater abundance of food in shallow waters and ease of finding prey in those waters. Farther offshore, forage is distributed over a wider area and deeper waters preclude foraging near the lake bottom. The greater abundance of prey species near shore also explains the presence of many other species of waterfowl and other birds observed incidentally near the shoreline.

Other winter resident or migrant waterfowl (e.g., canvasback, American coot, red-breasted merganser) were observed incidentally in harbor areas earlier in the spring season (late March/early April) and later in the fall season (late October) but were not seen on the survey transect. Waterfowl may have already migrated through the area when the spring surveys were initiated. Alternatively, it is possible that waterfowl are generally less abundant during spring migration because of colder lake water temperatures, than during fall migration, when lake waters retain heat late into the season. It is known that concentrations of most waterfowl species peak on Lake Erie during March to early April (Prince et al., 1992) with fall migration spanning a three to four month period where different species show peaks in abundance at different times late into the fall migration season (Ewert et al., 2006). Foraging habitat for most of these birds is close to shore, as opposed to farther from shore where most of the transects were conducted.

The single observation of a passerine during the spring survey was of an unidentified sparrow traveling south in direct flight at 20:27 on May 13, 2010. Song sparrows had been observed resting or occurring on the Crib on two previous occasions (March 31 and during the last week of April, 2010); these incidental observations represent additional records of sparrows within the Study Area. The incidental observation of the blue-gray gnatcatcher resting on the Crib on September 29 demonstrates that passerines migrate out over the lake, which has been demonstrated by Diehl (Diehl et al., 2003) for the Great Lakes and Gauthreaux (1971) for the Gulf of Mexico). As have other researchers, Gauthreaux reported that migrants crossing the Gulf of Mexico flew at more than 300 m above the water during night and climbed to nearly 1,000 m during daytime. The northern populations of blue-gray gnatcatcher are long distant migrants known to cross open water such as the Gulf of Mexico (Ellison 1992).

Most behavioral observations recorded during the surveys were of birds actively foraging and of birds in direct flight. Far fewer birds were documented sitting on the water or on the Crib structure during the offshore surveys. This suggests that birds observed in the Study Area were foraging, traveling to roosting areas, or migrating to breeding grounds. Foraging behavior was exhibited by a large percentage of observed birds. Flocks of gulls respond to prey availability at or near the surface, and the feeding behavior of an individual may attract other birds (Stapanian and Waite 2003). This feeding behavior may not have been observed during the spring if birds were flying more directly to breeding areas or if bait fish were not active near the lake surface because of cold water. This might minimize the use of lake waters away from the shoreline, where water temperature does not rise as quickly as near the shoreline earlier in the spring.

Combined data from spring and fall, demonstrated that there was greater relative abundance in the north portion of the Study Area. However, during the spring surveys more birds were observed in the south portion of the Study Area while during fall surveys more birds were observed in the north portion. It is possible that the different distribution pattern observed in the spring was caused by a slightly different suite of species in the area and their associated habitat preferences. Species associated with shoreline habitat (i.e., ring-billed gulls, ducks) may be more likely to occur in the southern portion of the Study Area due to the proximity of land. This explains the greater number of incidental observations and their seeming greater use of waters closer to shore.

Higher relative abundance observed during the fall in the north portion of the Study Area may be attributable to post-breeding dispersal. Other factors contributing to changes in relative abundance may be associated with fluxes in the temporal and spatial availability of food resources. Prey availability can be dependent on many factors such as water temperature, turbidity, clarity, climate, benthic conditions, and interspecific predator-prey interactions (Gopalan et al., 1998, Ludsin et al., 2001). The water bird density study of western Lake Erie conducted by Stapanian and Waite (2003) demonstrated overall lower densities of birds in open water further offshore compared to adjacent near-shore water. Cormorants and herring gulls were the most frequently observed species offshore. Data from the Stapanian and Waite (2003) study showed an increase in species density over time that was attributed to the influx of fall and winter residents such as Bonaparte's gulls, and an increase in use of offshore waters by post-breeding herring gulls and ring-billed gulls, this is consistent with trends observed in the 2010 surveys in the Study Area.

# 4.0 AVIAN ACOUSTIC SURVEYS

Though some birds are diurnal migrants, most migrate at night (Kerlinger 2009). The largest group of nocturnal avian migrants includes the passerines. Approximately, 200 species of the 700+ species of North American birds are known to give calls during night migration, with approximately 150 (~75%) of these being distinctive enough to identify with certainty (Evans 2000). Perhaps one-half of night migrating passerines vocalize during night flights. It is thought that calling may help birds maintain organization and spacing to minimize collisions with each other, as well as other objects (Evans 1999). These flight calls are more simplistic than territorial songs, and usually consist of a single “chip” note. These “chip” notes are often species specific, and when compared to known flight call libraries, family, genus and even species level identifications are sometimes possible (Evans 1994, Evans 1999).

Using a specially designed microphone, flight calls were recorded during the spring and fall 2010 migration periods in the Study Area. The acoustic survey was conducted in conjunction with the MERLIN avian radar study. This was done in the air space directly above and adjacent to the radar system and sample migrant species moving through the radar sampled air space.

## 4.1 Methods

Avian acoustic monitoring equipment was deployed within the Study Area during the 2010 spring and fall migration periods. The acoustic survey was performed in conjunction with the MERLIN avian radar survey effort. During the spring and fall avian radar surveys a Song Meter SM-1 (Wildlife Acoustics, Inc.) recorder was deployed on the front of the radar system. The Song Meter operated onshore during the radar deployment at the Cleveland Lakefront State Park from March 31 to April 20, 2010. The Song Meter then operated offshore on the Cleveland Water Intake Crib from April 29 to May 26, 2010 when the radar was re-deployed there. The Song Meter was deployed offshore on the Crib during the fall radar survey, but malfunctioned.

The Song Meter unit began recording 45 minutes before sunset and continued until 45 minutes after sunrise, every night of the survey, regardless of weather. The Song Meter SM-1 drew power directly from the avian radar system and was used to record nocturnal flight calls for about twelve hours per night. The system recorded in WAC audio file format at a sampling rate of 16,000 hertz (Hz), mono. Song Meters record a full spectrum of sound frequencies from 1 to 10 kilohertz (kHz), which is the frequency band of most avian flight calls in eastern North America. The Song Meter was connected to a sound pressure zone microphone similar to those described by Evans (1999). The microphone unit was placed inside a 40 cm diameter PVC resin cylindrical container, lined with acoustic insulating foam to reduce ambient noise, and covered with a thin muslin screen to prevent debris from affecting the microphone. The maximum range of the microphone for most nocturnal migrant species is approximately 300 m vertically and less than 250 m horizontally (Evans 1999), although calls of species (e.g., warblers, kinglets) with higher frequency are not likely to be heard at these distances. Ambient noise (waves, etc.), wind noise, and other atmospheric conditions (including relative humidity) affect the range of the microphone.

### 4.1.1 Data Analysis

Data collected during the surveys was recorded in compressed WAC file format and converted into WAV files using Wildlife Acoustic Inc. WAC to WAV file conversion software. Files were then scanned through a series of recognizers in Song Scope Version 3.3 (Wildlife Acoustics Inc.). Recognizers were trained on known reference call libraries gathered from the Cornell Lab of Ornithology's MacAulay Library and from Evans and O'Brien (2002). All recordings were scanned against Song Scope recognizers, which were trained on all avian species regularly occurring east of the Mississippi River. All recognizers provided cross-training matches greater than 72%, with standard deviation values of less than 8%. These libraries were used to train Song Scope recognizers to scan for similar sounds within the files recorded in the Study Area. The recognizers identified calls that had a 70% match with those of the reference call recognizers. Flight calls, which were scanned and recognized by the trained Song Scope filters, were then visually reviewed to assure similarities between recorded flight calls and reference flight calls. Additionally, some calls were also analyzed in Glass O'Fire (Old Bird, Inc.) to allow for spectrogram images to be viewed in a way that was consistent with reference spectrograms from Evans and O'Brien (2002). All recorded flight calls were identified to species group level.

## 4.2 Results

The following section summarizes the results of the avian acoustic survey.

### 4.2.1 Spring Results

Avian acoustic monitoring was conducted during the 2010 spring migration period on 49 nights. The Song Meter SM-1 recorder was deployed onshore March 31 - April 20, 2010 at the Cleveland Lakefront State Park (East 55th Marina); while offshore monitoring on the Crib was conducted April 29 - May 26, 2010 (see **Table 4.1**). During the monitoring period 22 flight calls were recorded onshore and 73 flight calls recorded offshore.

**Table 4.1** Summary of avian acoustic effort and results, spring 2010

| Avian Acoustics | | | | | |
|---|---|---|---|---|---|
| **Location** | **Operation Period** | **Nights of Operation** | **Total # of Flight Calls Recorded** | **Nightly Flight Call Rate** | **Species Groups Recorded** |
| **Onshore** | March 31 - April 20, | 21 | 22 | 1.0 | 5 |
| **Offshore** | April 29- May 26, | 28 | 73 | 2.6 | 5 |

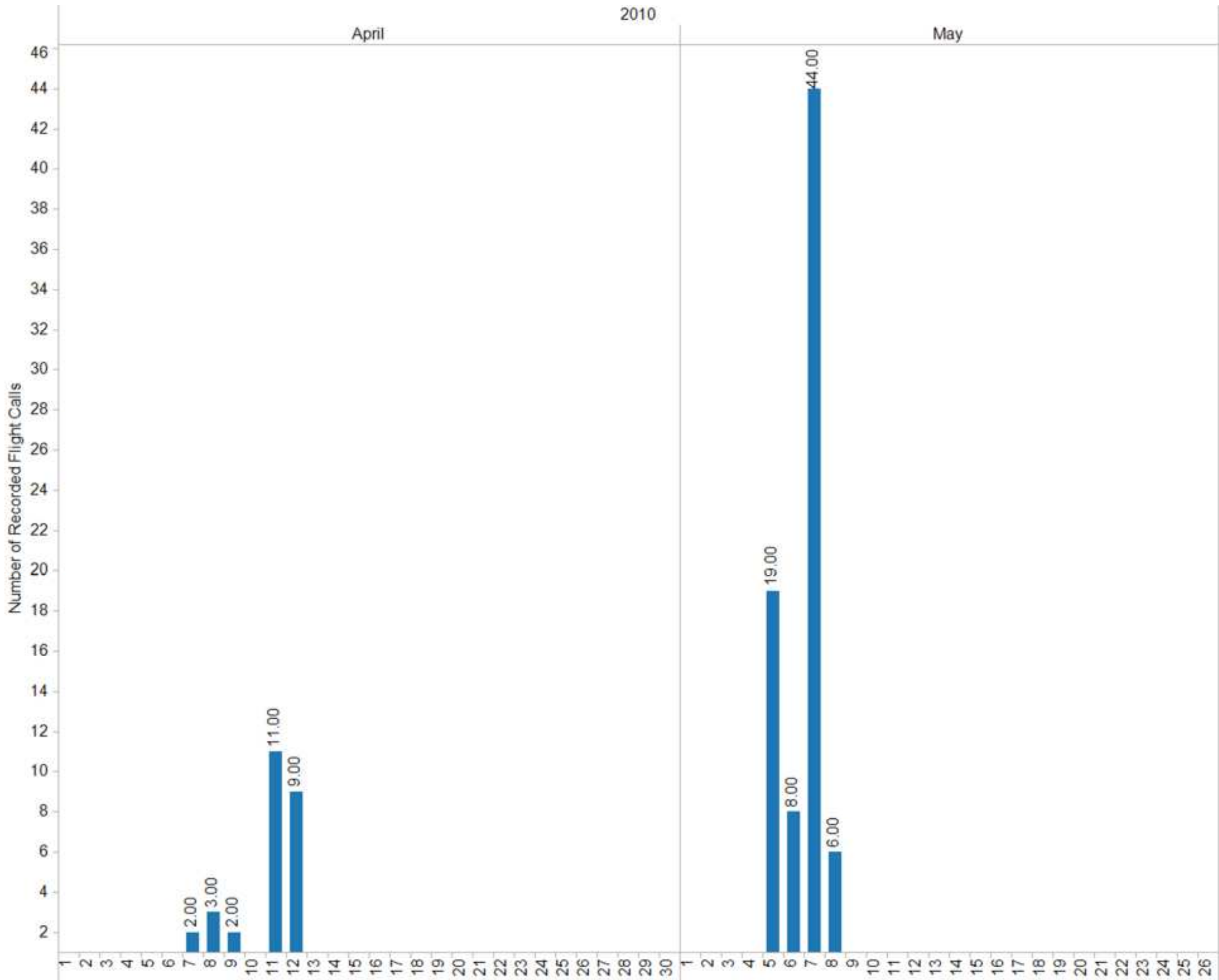
All recordings were analyzed with Song Scope Version 3.3, which identified a total of 6 species groups with a confidence level of greater than 70%. Identified groups include; blackbirds (Icteridae), finches and allies (Fringillidae and Cardinalidae), mimic-thrushes (Mimidae), swallows and martins (Hirundinidae), thrushes (Turdidae), and wood-warblers (Parulidae) (see **Table 4.2**).

The number of flight calls recorded per night varied during the 2 month monitoring period, with all calls recorded during a week-long period April 7–12, 2010 and a 4 day period from May 5–8, 2010. Flight call recording rates peaked offshore on May 7, 2010, with 44 flight calls recorded (**Figure 4.1**).

**Table 4.2** Identified bird groups and call counts, spring 2010

| Species Group | Onshore (March 31 - April 20) | Offshore (April 29 - May 26) |
|---|---|---|
| Blackbird Species Group | 2 | 47 |
| Finch Species Group | 0 | 11 |
| Mimic-thrush Species Group | 5 | 0 |
| Swallow Species Group. | 2 | 1 |
| Thrush Species Group | 2 | 8 |
| Wood-warbler Species Group | 11 | 6 |
| Total | 22 | 73 |

**Figure 4.1** Total flight calls recorded per night, spring 2010




### 4.2.2 Fall 2010 Results

Acoustic monitoring equipment was deployed offshore during the 2010 fall migration period on 44 nights. The Song Meter SM-1 recorder was located on the offshore Crib from August 16 through October 12, 2010. Onshore monitoring was not conducted during the 2010 fall survey period. Recordings were programmed to begin 45 minutes before sunset and continue uninterrupted until 45 minutes after sunrise. No offshore flight calls were recorded due to multiple power loss events associated with the avian radar unit shutting down during the fall season, this resulted in the loss of all usable avian acoustic data for this period.

## 4.3 Discussion

The spring 2010 avian acoustic monitoring recorded a limited number of flight calls attributed to six species groups. More flight calls were recorded offshore than onshore. However, the offshore monitoring period was later in the migration season, a time when more individuals would likely be flying. Based on radar data reviewed by Guarnaccia and Kerlinger (2008) for a 5-year period, spring migration near Cleveland typically increases in late April and peaks in mid-May.

Species groups recorded along the Lake Erie shoreline and at the Crib during spring monitoring were common migrants which typically occur in Ohio (Ohio Bird Records Committee 2009). Blackbirds, thrushes, mimic-thrushes, finches, wood-warblers and swallows, would be expected to occur during migration over the Crib. The only species group that may have been foraging over the open water, and possibly not migrating, were swallows (Garrison 1999). Species that are known to migrate during the day, such as swallows, martins, and some blackbirds, were recorded during the crepuscular monitoring period; 45 minutes before sunset and or the 45 minutes after sunrise.

Recorded calls were compared to calls of all species likely to occur in the area. Due to some inter-specific overlap between flight call parameters a species group level classification provides the most conservative cladistic approach to analysis. The 'blackbird' call recognizer included reference calls of all species known to occur east of the Mississippi River in the genera; *Icterus, Dolichonyx, Sturnella, Agelaius, Molothrus,* and *Quiscalus*. However, the only species in this group known to migrate at night are bobolink (*Dolichonyx oryzivorus*), orchard oriole (*Icterus spurius*), and Baltimore oriole (*Icterus galbula*). Bobolinks also migrate in daytime. The 'finches and allies' call recognizer contained reference calls of all eastern species in the genera; *Piranga, Cardinalis, Spiza, Pheusticus, Passerina, Coccotharaustes, Carduelis, Carpodacus, Pinicola,* and *Loxia.* The 'mimic-thrush' call recognizer included reference calls from the genera *Mimus, Dumetella,* and *Toxostoma.* The 'swallows and martins' call recognizer contained reference calls from the genera; *Hirundo, Petrochelidon, Stelgidopteryx, Riparia, Tachycineta,* and *Progne.* The 'wood-warbler' call recognizer contained reference calls for all of the North American *Parulidae* species occurring east of the Mississippi River, including all species in the genera: *Dendroica*, *Vermivora*, *Parula*, *Mniotilta*, *Setophaga, Protonotaria, Helmitheros, Geothlypis, Oporornis, Seiurus, Limnothlypis, Wilsonia,* and *Icteria*.

Though acoustic monitoring equipment was deployed during the 2010 fall migration period, multiple power loss events associated with the radar unit shutting down resulted in the loss of all usable avian acoustic data for this period. The low levels of avian activity observed during the boat-based visual surveys conducted during May 2010 may have been related to the height of nocturnal migration above Lake Erie. Such migration may be too high (most birds >300 m above ground/water level) to be effectively surveyed by either visual or acoustic means.

# 5.0 BAT ACOUSTIC SURVEYS

Tetra Tech biologists conducted a bat acoustic survey offshore at the Crib and at select sites along the shoreline of Lake Erie during the spring, summer, and fall 2010 (see **Figure 5.1**). The goal of the study was to quantify bat use of the Study Area in order to assess potential risk associated with building and operating the proposed wind energy facility (Arnett et al., 2008, Baerwald and D'Amoour 2008). This section presents the results of 61 nights of spring monitoring and 164 nights of summer/fall monitoring for bat activity levels using 8 ultrasonic acoustic detector-recorders (Anabat SD-1, Titley Scientific, Inc.). Detectors were deployed at offshore and onshore locations from April 1, 2010 to November 10, 2010.

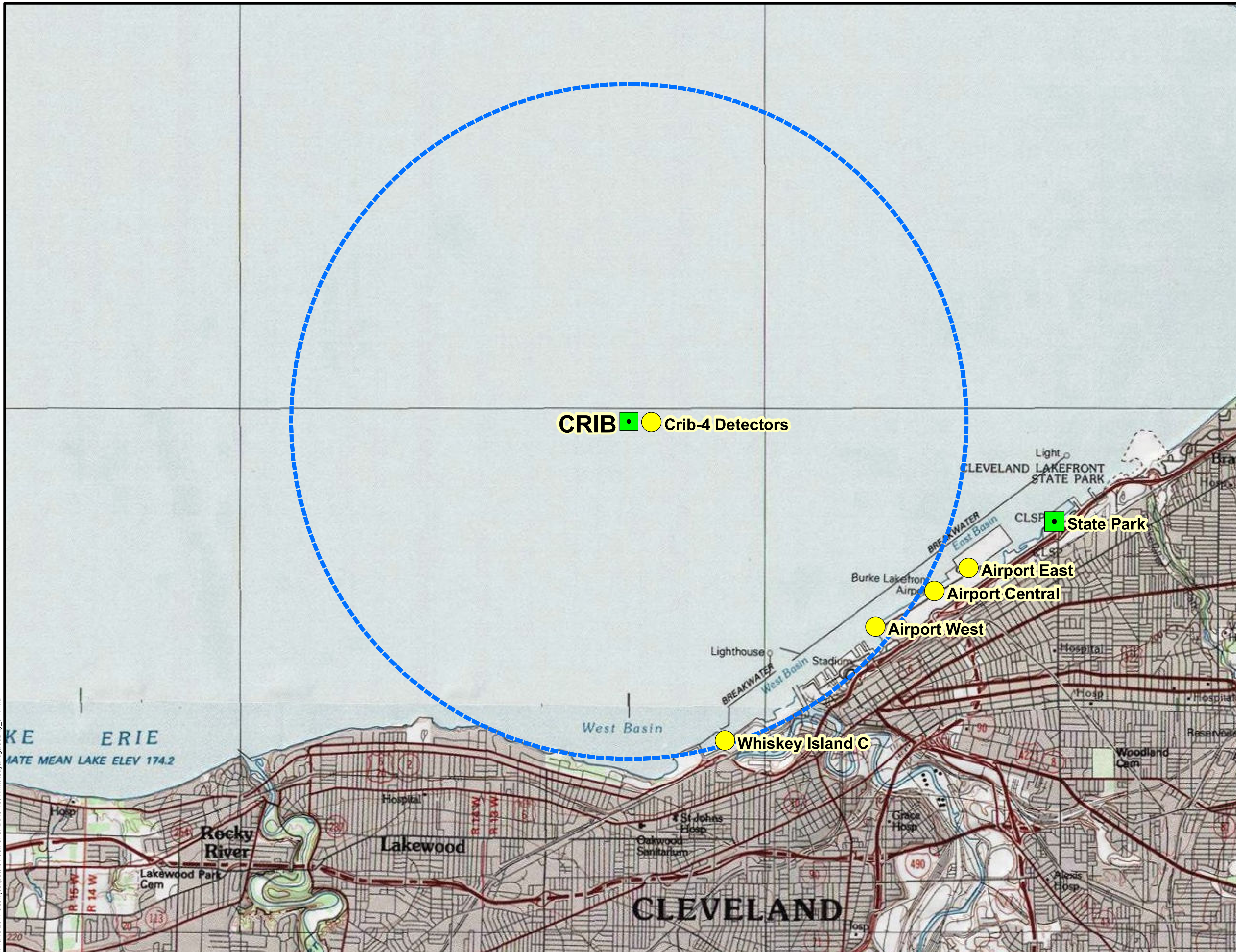
Of the 13 species of bats in Ohio (Ohio DNR 2009), 8 may occur within the Study Area. These include big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), eastern small-footed myotis (*Myotis leibii*), hoary bat (*Lasiurus cinereus*), little brown myotis (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), silver-haired bat (*Lasionycteris noctivagans*), and tri-colored bat (*Perimyotis subflavus*). The Indiana bat (*Myotis sodalis*) occurs in Ohio but is unlikely to occur in the vicinity of the Study Area. There is 1 known Indiana bat maternity colony and no known hibernacula in Cuyahoga County (USFWS 2007). In Ohio, most capture records of reproductive Indiana bat females and juveniles have been reported from western Ohio (USFWS 2009). Undisturbed forested habitat typically occupied by Indiana bats was not observed in the vicinity of the Study Area. There are no known colonies of Indiana bats in Ontario and it is almost unknown from Ontario, so it is highly unlikely that these bats migrate across the lake or are present in the study area.

## 5.1 Methods

During the spring, summer, and fall surveys 4 detectors monitored bat activity within the offshore Study Area, and 4 detectors sampled bats along the Lake Erie shoreline (see **Figure 5.1**). Offshore detectors were placed at different heights on the Crib, approximately 3.3 nm north of Cleveland, Ohio in Lake Erie. Onshore detectors were placed at 4 different locations along the shoreline of Lake Erie at the Cleveland Lakefront State Park (East 55$^{th}$ Marina), Burke Lakefront Airport, and Whiskey Island State Park (**Appendix D** provides photographs of the bat acoustic equipment at each location, as well as additional figures and results).

Offshore detectors on the Crib were stratified by height. Detectors were deployed in 2 locations on the Crib's met tower guy wires at a height of approximately 50 m above the water. The 2 detectors placed directly in the guy wires above the Crib sampled toward the east and the other toward the west ('East High' detector and 'West High' detector) (**Appendix D, Figures D.1** and **D.2**). Additionally, 2 detectors were placed on the railings of the Crib's crow's nest at approximately 35 m above the water. The detectors were orientated to survey airspace west of the Crib ('West Rail' detector) and north of the Crib ('North Rail' detector) (**Appendix D, Figures D.3** and **D.4**).

During the spring, 1 onshore detector was placed at the Cleveland Lakefront State Park (East 55$^{th}$ Marina) at the radar location ('Radar' detector), 2 detectors were placed at Burke Lakefront Airport ('Airport East' detector and 'Airport West' detector), and 1 detector was placed at Whiskey Island State Park ('Whiskey Island' detector). During the summer/fall survey, the 'Radar' detector was moved to the Burke Lakefront Airport ('Airport Central' detector); all other onshore detector locations remained the same as the spring survey (**Appendix D, Figures D.5** and **D.6**). To ensure that the period of bat activity was surveyed, the detectors were programmed to begin recording approximately 45 minutes before sunset and stop recording approximately 45 minutes after sunrise each day.




SOURCE: MODIFIED FROM USGS.

LAKE ERIE WIND PROJECT
CUYAHOGA COUNTY, OHIO

FIGURE 5.1
OFFSHORE AND ONSHORE BAT ACOUSTIC SURVEY LOCATIONS

TETRA TECH

Date: 10/18/2011 User: joel.peters Path: S:\CADD\S\13911mxd\CuyahogaCounty_5-1.mxd

Each survey location consisted of 1 Anabat SD-1 detector powered by a 5-watt or 10-watt solar panel and a 12-volt battery encased in a waterproof housing. The 4 Crib detectors were equipped with GML-1 remote data transfer systems (Titley Scientific, Inc.) to assure a continuous stream of data. The waterproof housing suspended the Anabat microphone downward and a plastic deflector shield angled at 45-degrees below the microphone facilitated recording of the airspace surrounding the detector. Each onshore detector was manually checked by Tetra Tech biologists approximately every 2 weeks. Each remotely operated Crib detector was checked once during the survey period.

### 5.1.1 Data Analysis

Potential bat call files were extracted from data files using CFCread© software. CFCread© software screens all data recorded by the bat detector and extracts call files using a filter. To ensure comparability between data sets, the default settings for the CFCread© software were used during the file extraction process. These settings include a maximum time between calls (TBC) of 5 seconds, a minimum pulse fragment line length of 5 milliseconds, and a smoothing factor of 50. The smoothing factor refers to whether or not adjacent pixels can be connected with a smooth line. The higher the smoothing factor, the less restrictive the filter is, resulting in more noise files and poor quality call sequences retained within the data set. A call is defined as a single pulse of sound produced by a bat. A call sequence is defined as a combination of 2 or more pulses recorded in a single call file.

A qualitative visual comparison was made of recorded bat call sequences of sufficient length to established reference libraries of bat calls. This technique allows for relatively accurate identification of bat species (O'Farrell et al., 1999, O'Farrell and Gannon 1999). All call sequences were also run through a series of conservative filters based on call sequence characteristics outlined by Szewczak (Szewczak et al., 2008) and from known species call sequences (hand released and zip-line individuals) from a regional call library. A call sequence was considered of suitable quality and duration to be included in data analysis if the individual call pulse(s) exhibited the full spectrum of frequency modulation produced by a bat (i.e., consisting of sharp, distinct lines) with a minimum of 5 pulses.

Relative abundance, or the magnitude of each species' contribution to spatial and temporal use, was obtained using an Index of Activity (IA) modified from Miller (2001). The method is based on the presence/absence of a species occurrence within 1-minute time increments. Thus, IA was the sum of minute-increments with a species presence divided by the unit effort (IA = # minutes / detector-nights multiplied by 100). The IA calculations allows for samples with different levels of effort (i.e., different total number of detector-nights) to be accurately compared. Thereby reducing the potential bias associated with differences in study effort. These calculations follow those employed by Miller 2001, O'Farrell and Shanahan 2006, and Svedlow et al., 2010.

## 5.2 Results

The following section will present the results of the acoustic bat monitoring efforts.

### 5.2.1 Spring Results

A total of 1,291 bat call sequences (both offshore and onshore), attributed to 5 bat species, were recorded during the spring 2010 monitoring period (see **Table 5.1**). The monitoring effort for this 61-night period resulted in 244 detector-nights of recordings (number of detectors multiplied by number of nights of operation) at onshore sampling locations and 232 detector-nights at the offshore sampling locations. All 8 detectors were operational and collected data during nearly the entire survey period, with the exception of a 12-night period that was not sampled by the West High detector on the Crib. Detectors monitored bat echolocation calls for approximately 12 hours per night, resulting in a total of approximately 5,712 detector-hours. The onshore detectors, pooled, had the highest rate of detection (5.0 call sequences/night) (see **Tables 5.1** and **5.2**). Of the 1,291 bat call sequences recorded during the spring survey period, 1,209 were recorded at the onshore detectors, 82 call sequences were recorded by the offshore detectors.

**Table 5.1** Summary of bat acoustic survey effort, spring 2010

| Location | Deployment Dates | Number of Detector Nights | Total Number of Call Sequences | Average Call Sequences Per Night | Average Call Sequences Per Hour | Index of Activity* |
|---|---|---|---|---|---|---|
| Onshore Detectors Pooled | April 1 - May 31, 2010 | 244 | 1,209 | 5.0 | 0.41 | *70.1* |
| Offshore Detectors Pooled | April 1 - May 31, 2010 | 232 | 82 | 0.4 | 0.03 | *23.3* |
| *** Index of Activity (IA) = # minutes with bat activity / detector-nights * 100** | | | | | | |

The spring 2010 survey effort identified the following 5 species from recorded calls; hoary bat, silver-haired bat, big brown bat, eastern red bat, and little brown myotis. Onshore detectors identified 2 species (big brown bat and little brown myotis) that were not identified by offshore detectors. Bat calls were identified to the lowest possible taxonomic level (see **Tables 5.3** and **5.4**). The majority (96%) of recorded calls were identified to genus level (*n* = 1,235); calls were then combined into four "Known Species Groups" based on similarities in call sequence structure: Low Frequency Species, Middle Frequency Species, *Myotis* Species, and Eastern red bat/Tri-colored bat (see **Tables 5.4** and **5.5**). Call sequences that did not meet the parameters required for genus level identification could not be classified to genus (*n* = 55) and were grouped into "Unknown Species Groups". These Unknown Species Groups consisted of bat call sequences with insufficient quality to identify to species or "Known Species Group" level, and were therefore labeled as either Middle Frequency Unknown (Characteristic Frequency [Fc] = 24 to 38 kHz) or High Frequency Unknown (Fc = 46 to 52 kHz) call sequences. The Middle Frequency Unknown category could contain call sequences for silver-haired bat or big brown bat. Most Middle Frequency Unknown calls recorded during the spring period at the Study Area appeared to be fragments of silver-haired bat. The High Frequency Unknown group could contain calls from any of the *Myotis* species present in the area, but likely consisted mostly of little brown myotis call sequences.

A total of 1,196 calls were attributed to the following long-distance migratory bat species; hoary bat, silver-haired bat, and eastern red bat (Cryan et al., 2004). Of the 1,196 total call sequences, approximately 6% (*n* = 71) were recorded by the offshore detectors. Onshore detectors recorded nearly 15 times more migrant species call sequences (*n* = 1,125) than the offshore detectors (*n* = 71). The majority (67%) of call sequences (*n* = 813) recorded at the onshore detectors were classified as silver-haired bat. Hoary bat and eastern red bat were frequently recorded (*n = 165* and *n* = 147, respectively) at the onshore detectors. The 4 offshore detectors recorded primarily silver-haired bat calls (*n* = 48), and a small number of eastern red bat (*n* = 14) and hoary bat (*n* = 9) call sequences. There were 2 High

Frequency Unknown call sequences recorded by the offshore detectors, indicating a possible *myotis* species presence offshore.

The IA values from the 8 survey locations highlighted the differences between the individual detector locations and variability in species activity between detectors (see **Tables 5.3** and **5.4** and see **Appendix D, Figure D.8**). Overall, the highest IA value was for silver-haired bat at the onshore Airport West detector (IA = 37.7). All 4 of the onshore detectors, with the exception of the radar detector, recorded higher IA values for silver-haired bat than the offshore detectors (see **Table 5.3**). Eastern red bat activity, as measured by IA, was greatest at onshore locations, with the highest eastern red bat IA at the Airport West detector (IA = 27.87). Detectors at 3 onshore locations recorded higher IA values for the eastern red bat than the 4 offshore detector locations (see **Table 5.3**).

Total number of call sequences recorded per night by each detector varied during the survey period. Peak nights of bat activity occurred during late April and early May at the onshore detector locations, with the overall peak on the night of May 1, 2010 (see **Appendix D, Figure D.9**). Peak activity at the offshore detectors occurred later in the survey period in mid-May, with the overall peak recording on the night of May 21, 2010 (see **Appendix D, Figure D.10**).

**Table 5.2** Summary of bat acoustic survey effort by detector, spring 2010

| Onshore | | | | | |
|---|---|---|---|---|---|
| **Row Labels** | **Airport East** | **Airport West** | **Radar** | **Whiskey Island** | **Total** |
| **Detector-nights** | **61** | **61** | **61** | **61** | **244** |
| **Total Call Sequences** | **408** | **454** | **12** | **335** | **1,209** |
| **Index of Activity** | **668.9** | **744.3** | **19.7** | **549.2** | **495.5** |
| **Offshore** | | | | | |
| **Row Labels** | **East High** | **North Rail** | **West High** | **West Rail** | **Total** |
| **Detector-nights** | **61** | **61** | **49** | **61** | **232** |
| **Total Call Sequences** | **10** | **35** | **7** | **30** | **82** |
| **Index of Activity** | **16.4** | **57.4** | **14.3** | **49.2** | **35.3** |

**Table 5.3** Summary of Index of Activity by bat detector, spring 2010

| Onshore Detector Location | Hoary bat | Big brown bat | Silver-haired bat | Eastern red bat | Little brown myotis | Middle Frequency Unknown | High Frequency Unknown |
|---|---|---|---|---|---|---|---|
| Airport East | 9.84 | 0.00 | 36.07 | 18.03 | 1.64 | 8.20 | 9.84 |
| Airport West | 6.56 | 9.84 | 37.70 | 27.87 | 6.56 | 4.92 | 4.92 |
| Radar | 3.28 | 0.00 | 3.28 | 4.92 | 0.00 | 0.00 | 1.64 |
| Whiskey Island | 16.39 | 6.56 | 26.23 | 24.59 | 1.64 | 4.92 | 4.92 |
| **Offshore Detector Location** | **Hoary bat** | **Big brown bat** | **Silver-haired bat** | **Eastern red bat** | **Little brown myotis** | **Middle Frequency Unknown** | **High Frequency Unknown** |
| East High | 1.64 | 0.00 | 4.92 | 3.28 | 0.00 | 4.92 | 0.00 |
| North Rail | 3.28 | 0.00 | 16.39 | 4.92 | 0.00 | 4.92 | 1.64 |
| West High | 0.00 | 0.00 | 8.16 | 2.04 | 0.00 | 0.00 | 2.04 |
| West Rail | 6.56 | 0.00 | 13.11 | 9.84 | 0.00 | 3.28 | 0.00 |

**Table 5.4** Summary of onshore bat call sequences and probable species, spring 2010

| Known Species Group | Characteristic Frequencies* | Species | Index of Activity** | Total Call Sequences |
|---|---|---|---|---|
| **Low Frequency** | 12 kHz–24 kHz | Hoary bat | 9.02 | 165 |
| **Middle Frequency** | 24 kHz–38 kHz | Big brown bat | 4.10 | 28 |
| | | Silver-haired bat | 25.82 | 813 |
| | | Silver-haired bat/ Big brown bat | 0 | 0 |
| | | Unknown middle frequency call seq. | 4.51 | 24 |
| **Eastern red bat / Tri-colored bat** | 44–45 kHz | Eastern red bat | 18.85 | 147 |
| | | Tri-colored bat | 0 | 0 |
| **High Frequency (*Myotis* species)** | 46–52 kHz | Northern myotis | 0 | 0 |
| | | Eastern small-footed myotis | 0 | 0 |
| | | Little brown myotis | 2.46 | 12 |
| | | Unknown high frequency call seq. | 5.33 | 20 |
| | | Unknown *Myotis* species | 0 | 0 |

*** Characteristic frequency (Fc) is generally defined as the frequency of the call pulse at the lowest slope, or the lowest frequency of the consistent frequency modulation sweeps. Fc represents the single most useful parameter for species identification.**
****Index of Activity (IA) = # minutes with bat activity/detector-nights*100**

**Table 5.5** Summary of offshore bat call sequences and probable species, spring 2010

| Known Species Group | Characteristic Frequencies* | Species | Index of Activity** | Total Call Sequences |
|---|---|---|---|---|
| **Low Frequency** | 12 kHz–24 kHz | Hoary bat | 3.02 | 9 |
| **Middle Frequency** | 24 kHz–38 kHz | Big brown bat | 0 | 0 |
| | | Silver-haired bat | 10.78 | 48 |
| | | Silver-haired bat/ Big brown bat | 0 | 0 |
| | | Unknown middle frequency call seq. | 3.45 | 9 |
| **Eastern red bat / Tri-colored bat** | 44–45 kHz | Eastern red bat | 5.17 | 14 |
| | | Tri-colored bat | 0 | 0 |
| **High Frequency (*Myotis* species)** | 46–52 kHz | Northern myotis | 0 | 0 |
| | | Eastern small-footed myotis | 0 | 0 |
| | | Little brown myotis | 0 | 0 |
| | | Unknown high frequency call seq. | 0.86 | 2 |
| | | Unknown *Myotis* species | 0 | 0 |

*** Characteristic frequency (Fc) is generally defined as the frequency of the call pulse at the lowest slope, or the lowest frequency of the consistent frequency modulation sweeps. Fc represents the single most useful parameter for species identification.**
****Index of Activity (IA) = # minutes with bat activity/detector-nights*100**

### 5.2.2 Summer/Fall 2010 Results

A total of 34,029 bat call sequences, attributed to 6 bat species, were recorded during the summer/fall 2010 monitoring period (see **Table 5.6**) from June 1 through November 10, 2010. The monitoring effort for this 164-night period resulted in 616 detector-nights of recordings at the 4 onshore sampling locations and 482 detector-nights at the 4 offshore sampling locations. During the summer/fall survey period, 2 offshore detectors (North Rail and West High) were operational from June 1 to November 10, 2010 and 2 detectors (High East and West Rail) were operational from August 24 to November 10. Onshore detectors (Airport Central and Airport West) were operational from June 1 to November 10, 2010 and the other onshore detectors (Airport East and Whiskey Island) were operational from June 17 to November 10, 2010. Detectors monitored bat echolocation calls for approximately 12 hours per night, resulting in a total of approximately 13,176 detector-hours. The onshore detectors, pooled, had the highest rate of detection (51.1 call sequences/night) (see **Tables 5.6** and **5.7**). Of the 34,029 bat call sequences recorded during the fall survey period, 31,484 were recorded at the onshore detectors (93%), and 2,545 call sequences were recorded by the offshore detectors (7%).

**Table 5.6** Summary of acoustic monitoring survey effort, summer/fall 2010

| Location | Deployment Dates | Number of Detector Nights | Total Number of Call Sequences | Average Call Sequences Per Night | Average Call Sequences Per Hour | Index of Activity* |
|---|---|---|---|---|---|---|
| Onshore Detectors Pooled | June 1 - November 10, 2010 | 616 | 31,484 | 51.1 | 4.26 | *3196.75* |
| Offshore Detectors Pooled | June 2 - November 10, 2010 | 482 | 2,545 | 5.3 | 0.44 | *465.15* |
| *** Index of Activity (IA) = # minutes with bat activity / detector-nights * 100** | | | | | | |

The 6 species identified during the fall 2010 survey effort were the following: hoary bat, silver-haired bat, big brown bat, eastern red bat, tri-colored bat, and little brown myotis. All detected species were recorded at onshore and offshore detectors. Bat calls were identified to the lowest possible taxonomic level (see **Tables 5.8** and **5.9**). Call sequences that did not meet the identification parameters required for distinguishing between certain species were grouped into species groups ('big brown bat/silver-haired bat' and 'little brown myotis/*Myotis* species'). To aid analysis, a total of 24,833 calls were grouped as silver-haired bat/big brown bat due to call quality and the overlap in call characteristics of the two species (Betts 1998). A total of 8,104 (24%) of recorded calls were identified to genus level and a total of 25,925 (76%) of recorded calls were identified to groups of potential species. The little brown myotis/*Myotis* species group (*n* = 738) could contain calls from any of the *Myotis* species present in the area, but likely consisted mostly of little brown myotis call sequences. Calls were then combined into four 'Known Species Groups' based on similarities in call sequence structure: Low Frequency Species, Middle Frequency Species, *Myotis* Species, and eastern red bat – tri-colored bat (see **Tables 5.9** and **5.10**).

A total of 8,008 calls were attributed to the 2 species of long-distance migratory bats: hoary bat and eastern red bat (Cryan et al., 2004). Because big brown bats are not considered to be long-distance migrants, the additional 25,187 calls of the silver-haired bat/big brown bat group were not included in this total, which may underestimate the number of long-distance migratory bats present. Of the total

8,008 hoary bat and eastern red bat call sequences approximately 26% (*n* = 2,054) were recorded at the offshore detectors. Onshore detectors recorded nearly 3 times more hoary bat and eastern red bat species call sequences (*n* = 5,954) than the offshore detectors. The majority (78%) of call sequences (*n* = 24,794) recorded at the onshore detectors were classified as silver-haired bat/big brown bat while only 15% of the offshore call sequences were attributed to the silver-haired bat/big brown bat group. Tri-colored bat was recorded at the onshore detectors (*n* = 88) and at the offshore detectors (*n* = 8). The little brown myotis/*Myotis* species group was recorded at both onshore and offshore detectors (*n* = 648 and *n* = 90, respectively).

The IA values for the 8 survey locations highlighted the differences between the individual detector locations and variability in species activity between detectors (see **Tables 5.8** and **5.9; Appendix D, Figure D.11**). Overall, the highest IA value was for the silver-haired bat/big brown bat group at the onshore Airport East detector (IA = 4,610.20). All of the onshore detectors recorded higher IA values for silver-haired bat/big brown bat than the offshore detectors (see **Table 5.8**). Eastern red bat activity, as measured by IA, was also greatest at onshore locations, with the highest eastern red bat IA at the Airport East detector (IA = 1,440.14). Eastern red bat was the most frequently detected species offshore with the 2 rail detectors on the Crib recording higher IA values for eastern red bat than the 2 high detector locations on the Crib (see **Table 5.8**). Hoary bat IA values were greater onshore with the Airport East detector recording the highest IA value (IA = 481.63). The little brown myotis / Myotis species group had higher IA values onshore with the Whiskey Island detector recording the highest IA (IA = 214.97). Tri-colored bat IA values were greater onshore with the Airport West detector recording the highest IA value (IA = 22.09).

Total number of call sequences recorded per night by each detector varied during the survey period. Peak nights of bat activity occurred during late July and early August at the onshore detector locations, with the overall peak on the night of August 2, 2010 (see **Figure D.12**). Peak activity at the offshore detectors occurred later in the survey period in mid-to late August, with the overall peak recording on the night of August 30, 2010 (see **Figure D.13**). Migratory tree-roosting species, big brown bats, and *Myotis* species were recorded at offshore detectors during all summer and fall months. The tri-colored bat was detected offshore only during August and September of the fall survey period. At onshore locations, all species were recorded during each month of the summer and fall survey period.

### 5.2.3 Bat Activity and Weather Comparisons

Recorded call sequences from the Crib detectors were compared to weather data collected from the Crib mounted meteorological tower. During the survey period mean temperatures ranged from 10°C (50°F) to 28°C (82.4°F), and mean wind speeds ranged from 2.7 m/s (6.6 mph) to 14.98 m/s (33.4 mph). Although no significant correlations between weather variables and nightly call rates were found, nights with high call rates occurred on nights with a high mean temperature [approximately 16°C (60°F) to 28°C (82°F)] and low to moderate average wind speed [approximately 3.7 m/s (8.3mph) to 11.9 m/s (26.6 mph)] (see **Figure 5.1**).

**Table 5.7** Summary of bat acoustic monitoring survey effort by detector, summer/fall 2010

| Onshore | | | | | |
|---|---|---|---|---|---|
| | Airport East | Airport West | Airport Center | Whiskey Island | Total |
| Detector-nights | 147 | 163 | 159 | 147 | 616 |
| Total Call Sequences | 18,373 | 3,789 | 7,072 | 2,250 | 31,484 |
| Index of Activity | 6,623.8 | 2,022.1 | 2,866.7 | 1,429.3 | 3,196.8 |
| **Offshore** | | | | | |
| | East High | North Rail | West High | West Rail | Total |
| Detector-nights | 79 | 162 | 162 | 79 | 482 |
| Total Call Sequences | 307 | 1,399 | 418 | 421 | 2,545 |
| Index of Activity | 388.6 | 863.6 | 258.0 | 532.9 | 465.1 |

**Table 5.8** Summary of Index of Activity by detector, summer/fall 2010

| Onshore Detector Location | Hoary bat | Silver-haired/Big brown bat | Eastern red bat | Tri-colored bat | Little brown myotis/Myotis species |
|---|---|---|---|---|---|
| Airport East | 481.63 | 4,610.20 | 1,440.14 | 15.65 | 76.19 |
| Airport West | 184.05 | 1,369.33 | 389.57 | 22.09 | 57.06 |
| Airport Center | 108.18 | 2,374.21 | 318.87 | 3.77 | 61.64 |
| Whiskey Island | 136.05 | 603.40 | 459.18 | 15.65 | 214.97 |
| Offshore Detector Location | Hoary bat | Silver-haired/Big brown bat | Eastern red bat | Tri-colored bat | Little brown myotis/Myotis species |
| East High | 51.90 | 120.25 | 181.01 | 2.53 | 12.66 |
| North Rail | 163.58 | 19.14 | 538.27 | 1.85 | 17.90 |
| West High | 20.99 | 80.86 | 85.19 | 0.62 | 25.93 |
| West Rail | 67.09 | 91.14 | 345.57 | 1.27 | 7.59 |

**Table 5.9** Summary of onshore bat call sequences and probable species, summer/fall 2010

| Known Species Group | Characteristic Frequencies* | Species | Index of Activity** | Total Call Sequences |
|---|---|---|---|---|
| **Low Frequency** | 12 kHz–24 kHz | Hoary bat | 224.03 | 1,466 |
| **Middle Frequency** | 24 kHz–38 kHz | Silver-haired bat/ Big brown bat | 2,219.32 | 24,794 |
| **Eastern red bat / Tri-colored bat** | 44–45 kHz | Eastern red bat | 638.64 | 4,488 |
| | | Tri-colored bat | 14.29 | 88 |
| **High Frequency (*Myotis* species)** | 46–52 kHz | Northern myotis | 0 | 0 |
| | | Eastern small-footed myotis | 0 | 0 |
| | | Little brown myotis/*Myotis* species | 100.49 | 648 |

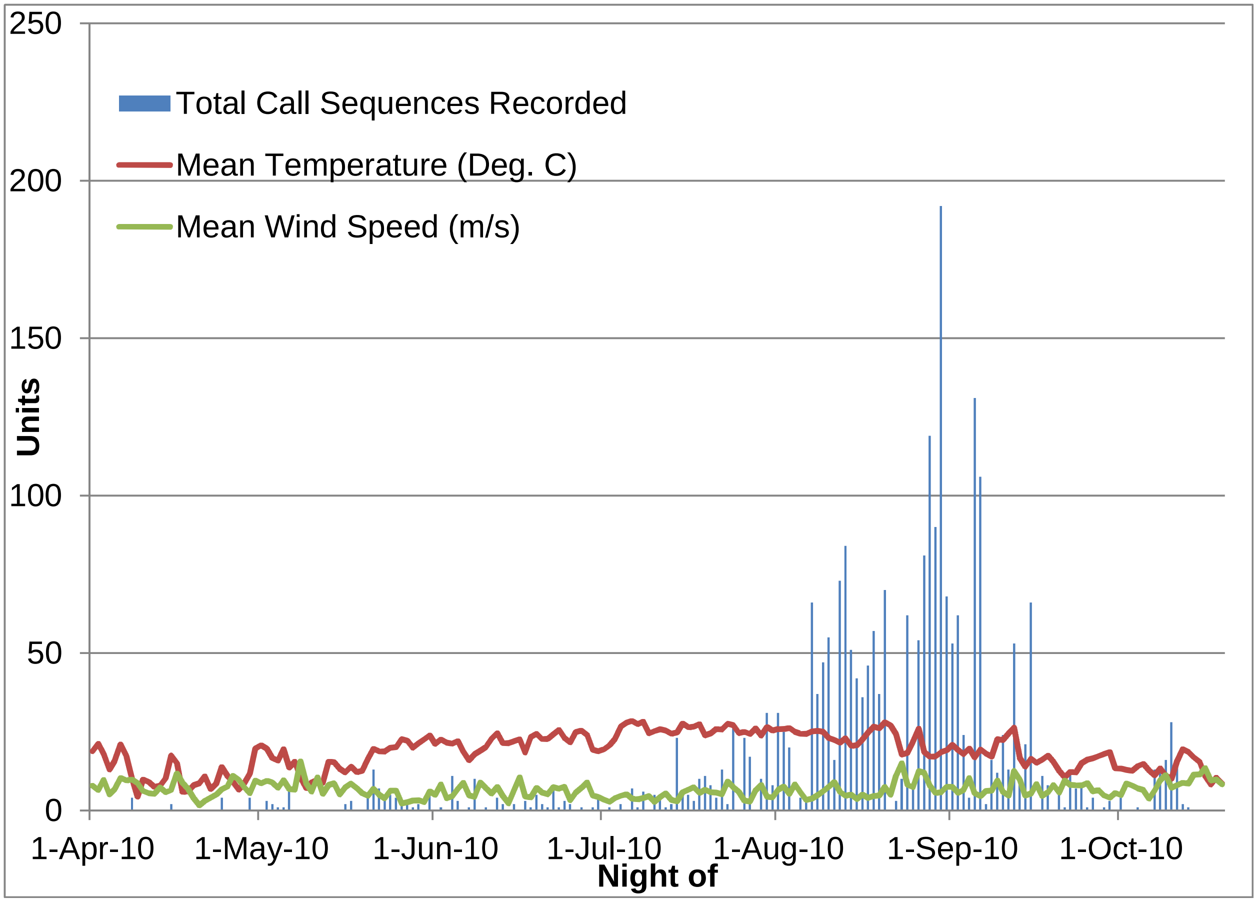
*** Characteristic frequency (Fc) is generally defined as the frequency of the call pulse at the lowest slope, or the lowest frequency of the consistent frequency modulation sweeps. Fc represents the single most useful parameter for species identification.**
****Index of Activity (IA) = # minutes with bat activity/detector-nights*100**

**Table 5.10** Summary of offshore bat call sequences and probable species, summer/fall 2010

| Known Species Group | Characteristic Frequencies* | Species | Index of Activity** | Total Call Sequences |
|---|---|---|---|---|
| **Low Frequency** | 12 kHz–24 kHz | Hoary bat | 81.54 | 488 |
| **Middle Frequency** | 24 kHz–38 kHz | Silver-haired bat/ Big brown bat | 68.26 | 393 |
| **Eastern red bat / Tri-colored bat** | 44–45 kHz | Eastern red bat | 295.85 | 1,566 |
| | | Tri-colored bat | 1.45 | 8 |
| **High Frequency (*Myotis* species)** | 46–52 kHz | Northern myotis | 0 | 0 |
| | | Eastern small-footed myotis | 0 | 0 |
| | | Little brown myotis/*Myotis* species | 18.05 | 90 |

*** Characteristic frequency (Fc) is generally defined as the frequency of the call pulse at the lowest slope, or the lowest frequency of the consistent frequency modulation sweeps. Fc represents the single most useful parameter for species identification.**
****Index of Activity (IA) = # minutes with bat activity/detector-nights*100**

**Figure 5.2** Total number of offshore call sequences, mean wind speed, & mean temperature




## 5.3 Discussion

Current research indicates that migratory bats have been the most commonly found species during post-construction mortality studies at land-based wind farms in North America, little is known about bat mortality at offshore wind farms (Arnett et al., 2008). Data from Kunz and Arnett demonstrate that 3 species of long distance migratory bat: eastern red bat, hoary bat, and silver-haired bat, were disproportionately represented (Kunz et. Al., 2007 and Arnett et al., 2008). All of these species were positively identified in the recordings from both the spring and fall 2010 monitoring periods. However, long distance migratory bat species were nearly twice as active onshore as they were offshore.

The peak activity periods and the high proportion of migrant species recorded suggest migration occurs along Lake Erie's shoreline and to a lesser extent over Lake Erie. However, in the immediate Study Area, the relatively low number of call sequences (*n* = 2,545) suggests that the area is not likely a major migratory corridor for bats. As with birds, the migration of bats over the Great Lakes is, for the most part, likely to be broad front with few concentration areas over open water. The majority of offshore call sequences were attributed to eastern red bats, which are migratory and known to occur over open water, sometimes many miles from shore (Peterson 1970). Hoary bats and silver-haired bats also travel over open water and their occurrence offshore is not unusual (Cryan and Brown 2007). It is likely that the majority of calls from the 'silver-haired bat/big brown bat' group were from long-distance migratory silver-haired bats.

The presence of migratory species calls during the putative seasonal migration period (i.e., early and mid-May and August), seems to signify that the shoreline, and to a lesser extent the Study Area, are both used by bats during migration. However, these bats can be recorded virtually anywhere that microphones are placed in the region, so their presence does not indicate a migration pathway or concentration area. There were also typical non-migratory (i.e., regional migrant) bats recorded during the survey periods, and throughout the summer and fall, at both the offshore and onshore locations. The presence of bats in the data set throughout the monitoring period demonstrates use of the Study Area during the summer residency period, possible foraging, and, or migration. Although it should be noted that relatively few calls of *Myotis* species were recorded offshore, overall there is little data to suggest that any bats are resident or forage regularly at the Crib or over the waters surrounding that structure.

There is inherent difficulty in attempting to interpret the number of recorded call sequences as an absolute indicator of bat activity levels; however, detection rates may reflect the relative level of bat activity near the sampling locations (Hayes 1997 and Gorresen et al., 2008). As such, acoustic activity may be an indicator of potential risk, although empirical confirmation of this hypothesis is scarce. The limited maximum range of a single Anabat detector, approximately 30 m (100 ft), makes the characterization of landscape-scale movements such as migration difficult to assess. A comparative assessment of the results from detectors arrayed along a shoreline and an offshore location (Crib) provides a potentially better characterization of localized bat occurrence (Gorresen et al., 2008).

The total number of bat call sequences recorded each night by a given detector may or may not reflect the absolute number of bats or bat activity at a given site. Some studies have suggested that there may be a relationship between the number of call pulses recorded and bat activity levels (Britzke 2004 and Gorresen et al*.,* 2008). The bias in acoustic surveys stems from the unknowns associated with recorded call sequences. For example, a single foraging individual may produce a large number of call sequences that are within the range of a given detector set. Conversely, a large number of individual bats may pass the detector set and produce an equally large number of call sequences. It is important to note that the survey results are a sample of bat activity in the airspace surrounding the detectors and are not necessarily indicative of bat activity or the number of individual bats throughout the entire Study Area.

Data collected during the spring and fall survey periods indicate that offshore bat activity levels were substantially less than onshore bat activity levels; species occurrence rates and IA values were different between onshore and offshore locations. It is possible that this difference is due to the spatial arrangements of the bat detectors. Onshore detectors were arrayed over a few miles along the shoreline, sampling a large swath of terrestrial and near shore habitat. Due to the constraints of working over open water, offshore detectors were clustered on the Crib. However, despite differences in spatial arrangement, there was a similar level of effort at each location, and an identical amount of airspace surveyed. It is expected that the greater height of the Crib detectors, compared to onshore detectors, would compensate for the limited spatial arrangements possible offshore by increasing the possibility of detecting bats flying at higher altitude. It is known that structures on and over the water (i.e., boats, bridges, turbines) attract insects (Ahlen et al., 2007) which may explain why bats occur around the Crib. Additionally, during the 2010 surveys the Crib was equipped with 2 lights approximately 3 to 4 feet apart at a height of 55 ft above the water. These lights were white LEDs with a 0.3 second on and 0.7 second off flashing rhythm may also attract insects. It is possible that bat use of waters hundreds of meters or miles from the Crib is much less because there are likely to be fewer insects farther from the Crib, except perhaps migrating insects.

The relatively smaller number of call sequences recorded at the offshore detectors is consistent with similar acoustic studies conducted in Rhode Island Sound, RI (Tetra Tech Wildlife Biologist, Aaron Svedlow, personal observation) and with observations made at an existing offshore wind facility in southern Scandinavia. Ahlen (Ahlen et al., 2007) conducted simultaneous bat acoustic and visually assisted acoustic surveys in the waters off Sweden, and on adjacent shorelines, over the course of 2 years from 2005 through 2006. In 2005 and 2006 Ahlen monitored bat activity 32 nights at sea and 45 nights onshore. Overall the Lake Erie studies were conducted over the course of 164 nights both onshore and offshore. A similar ratio (approximately 1:10) of bat activity levels between offshore and onshore levels was evident in both the Ahlen study and the 2010 Lake Erie study despite differences in survey duration as well as the marine and lacustrine ecosystems. Ahlen (Ahlen et al., 2007) recorded a total of 9,265 bat observations during 70 nights of combined monitoring (acoustic and visual assisted acoustic observations) onshore and offshore, resulting in 120 bat observations per night. Overall, 92% of Ahlen's bat observations were made onshore ($n$ = 8,524, 189 bat observations per night). Of the 35,320 total calls recorded during the Lake Erie study, 93% were recorded at the onshore detectors ($n$ = 32,693). Although bat observations and bat call sequences are not completely synonymous, acoustic recording 'bat passes' (i.e., number of call sequences per night) are generally analogous to a bat 'observation' as defined by Ahlen. The rate of bat passes (calls) per night for the onshore detectors, combined, was 38 calls per night, while Ahlen recorded 189 bat observations per night onshore. A combined total rate of, approximately, 4 calls per night were recorded by the offshore detectors in Lake Erie, where Ahlen counted 23 observations per survey night at sea. These results strongly suggest that although bats utilize offshore areas, including areas with existing turbines, their occurrence in the offshore environment is substantially less than at the adjacent shorelines.

The spring, summer, and fall 2010 bat acoustic study indicated that the Lake Erie shoreline, and to a lesser extent the offshore Crib location, are used during migration by some bat species, primarily eastern red bat, hoary bat, and silver-haired bat. The offshore Study Area and shoreline habitat is also used by non-migratory and migratory species during the summer residency period. Though recorded less frequently compared to migration periods, the presence of migratory and non-migratory species at the offshore detectors during the summer months (June to August, 2010) may indicate that offshore waters are used by foraging bats. In addition, it is known that structures on and over the water (i.e., boats, bridges, turbines), especially structures with some types of lighting, attract insects (Ahlen et al., 2007) which may also explain why bats occur around the Crib. A diverse species assemblage with high levels of activity was not observed offshore. The bat species recorded at the on and offshore portions of the Study Area are not listed as federal or state threatened or endangered species. However, 3 species recorded (little brown bat, big brown bat, and tri-colored bat) are identified as state Species of Concern (Ohio DNR 2009).

# 6.0 CONCLUSIONS

The suite of assessments conducted for the Lake Erie Wind Project provide a baseline of diurnal and nocturnal activity patterns in the southern Lake Erie basin and the adjacent shoreline (see **Figure 1.1**). The survey techniques used during the 2010 field effort were intended to be complementary.

Diehl (Diehl et al., 2003) found that large numbers of birds crossed the Great Lakes, particularly Lake Erie, although crossing avoidance behavior was also observed. Diehl (Diehl et al., 2003) indicated that birds presented with a coast line perpendicular to their migration route may be more inclined to undergo a lengthy water crossing, than when presented with a coastline congruent with their axis of migration. The orientation of the Lake Erie shoreline, especially in Ohio, is generally perpendicular to a north south migration route to and from boreal Canada The highly concentrated mean flight direction recorded during the spring offshore surveys demonstrates that targets moved generally perpendicular to the shoreline, towards the north. This pattern of movement is consistent with the known location of breeding grounds, in Canada, for many nocturnal migrants, including passerines, shorebirds, and some other species.

Although Diehl (Diehl et al., 2003) used NEXRAD to quantify migration over the Great Lakes his conclusion regarding the timing of migration are similar to the radar surveys undertaken at the Crib. At the Crib nocturnal target activity increased during the early hours of the night, and declined after mid-night during fall. This may suggest that target activity recorded early in the night was a result of nocturnal migrants initiating flight over the lake early in the evening. Additionally, Diehl (Diehl et al., 2003) consistently observed the phenomenon of dawn ascent. Dawn ascent may have caused targets to fly higher during the early morning when approaching the Ohio coast (during southward migration), thereby reducing TPR during the early morning. Using NEXRAD data Diehl (Diehl et al., 2003) found that birds regularly crossed the Great Lakes during migration, though some birds did avoid the crossing at times. Diehl also demonstrated that migration near Lake Erie tends to be parallel to the shoreline in spring and more perpendicular in the fall. This was not confirmed in our survey effort, in fact migration patterns in the spring were clearly perpendicular to the lake shore, whereas flight directions in fall were less uniform, many targets flew to the south, but there were also many targets moving parallel to the shoreline. Diehl (Diehl et al., 2003) found that bird density was greater over land compared to over water during both spring and fall seasons, though the trend was more pronounced during the fall. Although, the 2010 data do seem to indicate that passage rates (roughly analogous to bird density as calculated by NEXRAD) were higher offshore than onshore.

The high TPR reported offshore during both spring and fall may be an anomaly confounded by lights located on the Crib that may attract birds, bats, and insects. During the 2010 surveys the Crib was equipped with two aviation obstruction lights approximately 3 to 4 feet apart at a height of 55 ft above the water. These lights were white LEDs with a 0.3 second on and 0.7 second off flashing rhythm. This is equivalent to 60 flashes per minute, which is the highest flash rate acceptable to the Federal Aviation Administration (FAA) for obstruction lighting. It is possible that these lights attracted nocturnally migrating birds and bats, and insects flying within 5 nautical miles (the range of the lights). Lighting, including steady burning FAA lighting, has been demonstrated to attract night migrating birds (Gehring et al. 2009), but lights that flash at a rate of 24 cycles per minute did not attract these migrants. Kerlinger et al. (2010) demonstrated that lights on wind turbines that flashed about 24 times per minute did not attract night migrating birds. Because lit structures are known to attract nocturnal migrants (Larkins and Frase 1988, Gauthreaux and Belser 2006, Evans et al., 2007, Longcore et al., 2008). It is plausible that attraction to the rapidly flashing Crib lights could have attracted birds, bats, and insects, thereby causing higher than expected nighttime TPR recorded by the radar. Thus, higher than expected nighttime TPR could have been a result of lights attracting aerial vertebrates, as well as possibly insects, which can be seen with radar.

As predicted in the 2008 Avian Risk Assessment for the Project (Guarnaccia and Kerlinger 2008), species richness in the Study Area was low. Of the 3,414 birds observed during the spring and fall 2010 boat-based visual surveys the majority of observations were gulls. An extensive aerial study conducted by the Ohio Department of Natural Resources (Lott et al., 2011) on bird distribution in Ohio's portion of Lake Erie also documented a majority of gulls during surveys conducted on or near the same dates in May, 2010. Results from Lott et al. demonstrated that high densities of birds observed offshore over the open lake consisted almost entirely of gulls congregating around commercial fishing vessels. This would suggest that the a large proportion of biological targets recorded by the radar during the day, and possibly during dusk and dawn, were gulls congregating around the Crib.

The Audubon Society of Ohio has designated the Cleveland Lakefront as an Important Bird Area (IBA) for the large concentrations of migrant and wintering gulls and waterfowl that congregate to forage in the warm water outflows from power plants and mixing waters of the Cuyahoga River and Lake Erie (National Audubon Society 2010). Data collected during the 2010 surveys suggest that the near-shore area of Lake Erie may support higher concentrations of birds than offshore areas, but that density and diversity decline rapidly with distance from shore. Additionally, Lott et al. (2011) found that areas east of Cuyahoga County and areas greater than 5 miles from shore had the lower densities of birds. Lott found the highest densities of birds were found near the mouths of the Maumee and Cuyahoga Rivers, and near the islands in the Western Basin (Lott et al., 2011).

The minimal avian acoustic recording rates may be a result of the flight altitude of migrants crossing Lake Erie and the limited range of the pressure zone microphone system. For example, wood-warblers are barely audible at distances above 200 m and they are among the most common nocturnal migrants in North America. The greatest numbers of nocturnal migrant calls were recorded in early May offshore, which is consistent with the peak TPR recorded during spring migration offshore by the radar system. Calls recorded offshore were mostly from blackbird species, as well as finches, thrushes, and warblers. Extrapolations about species identification of the biological targets recorded by the radar, based on the acoustic data, during this time period (early to mid-May) should be done with caution because most blackbirds are not strictly night migrants. In addition, some birds vocalize much more than others and some migrants do not call at all. Because of the limitations of acoustic recordings it is unlikely that the recorded flight calls are representative of the migrants recorded by the avian radar system. The only statistical comparison of acoustical recording rates with radar data demonstrated minimal to no significant correlation (Farnsworth et al. 2003) at two locations in eastern North America, so it is not a surprise that radar and acoustic studies reported herein had disparate results.

Weather, season, time of day, and habitat availability all influence when, where, and how birds migrate, when they stopover, and how they are spatially distributed (Kerlinger 2009). Results from the 2010 radar and acoustic surveys demonstrate that nocturnal migrants are present offshore in Lake Erie. Interestingly, no passerine migrants or bats were observed during the boat based surveys. It is suspected that nocturnal migrants were flying too high for detection during the boat-based visual surveys. Indeed, the mean flight heights recorded by the radar system are consistent with this suspicion.

Target flight heights averaged 585.4 m during the night offshore; this is substantially higher than the detection range of avian acoustic equipment, bat acoustic equipment, or night vision goggles.

The radar results recorded during both the spring and fall radar survey periods are similar in some ways with radar surveys from New York State (no publically available avian radar survey data for Ohio was found) and elsewhere east of the Mississippi River. However, it is necessary to caution that radar surveys are not always directly comparable; differences in hardware, calibration, software, reporting metrics, insect screening, and overall study design exist. The calculated TPRs in this report may be different from other radar studies for the following reasons:

1) Type of radar system,
2) Differences in resolution,
3) Software used for analyzing raw data,
4) Method for screening insects, and
5) Calculation of TPR using vertical radar.

**Appendix A** provides a more in depth discussion of the differences between automated surveillance radars, and off-the-shelf manual surveillance radars. This background information is useful for understanding why direct comparisons between different types of radars may be in appropriate. **Table 6.0** should be used for general comparison purposes, i.e. the magnitude of each metric should be considered in relation to other recorded migration metrics, and a direct value to value comparison should not be made.

**Table 6.0** Comparison of the 2010 offshore Lake Erie avian radar study with similar radar surveys

| Site | | Nightly TPR Mean (t/km/hr) | Nightly Mean Flight Height (m) | Mean Target Flight Direction |
|---|---|---|---|---|
| **Lake Erie Offshore Site, Cuyahoga County, OH** | **SPRING** | 841 | 17 | 6.7° |
| | **FALL** | 1,694 | 466 | 208.8° |
| **Chautauqua, Chautauqua County, NY [1]** | **SPRING** | 395 | 528 | 29° |
| | **FALL** | 238 | 532 | 199° |
| **Ripley-Westfield, Chautauqua County, NY [2]** | **SPRING** | 1,062 | 340 | 27.7° |
| | **FALL** | 774 | 332 | 199° |
| **Hounsfield (Galloo Island), Jefferson County, NY[3]** | **SPRING** | 624 | 319 | 54° |
| | **FALL** | 281 | 298 | 207° |
| **Cape Vincent, Jefferson County, NY[4]** | **SPRING** | 166 | 441 | 34° |
| | **FALL** | 346 | 490 | 209.2° |

1. Cooper et al., 2003, [2.] DeTect 2009, [3.] Stantec Consulting 2008, and [4.] Young et al., 2007.

The mean nightly flight heights recorded at Lake Erie did not differ substantially from the shoreline or near-shore inland Lake Ontario radar survey results listed in **Table 6.0**. However, passage rates are generally different, as were flight heights in spring. The Lake Erie 2010 boat-based visual surveys confirmed that large numbers of gulls move around the Crib, and this may have been a source of bias in recorded TPR and flight heights overall. During the peak nights of migration offshore (as indicated by TPR), in fall flight heights trend higher above the lake than during nights with less activity. The mean flight direction recorded at the Study Area and flight directions recorded at the New York radar sites are also generally similar, which suggests that the Lake Erie radar data are likely an accurate representation of the regional movement patterns in the eastern Great Lakes.

As mentioned previously, bats were likely recorded during the radar survey, although the radar does not differentiate between species or taxa. There appeared to be episodes of increased bat acoustic recording rates that could be attributed to seasonal migration (Cryan 2003). The increases in spring activity occurred in early May 2010 onshore, and late May 2010 offshore, perhaps a result of warmer mean nightly temperatures and an increase in available insect prey during May (Racey et al., 1985 and O'Donnell 2000). The increases in activity during August 2010 may be attributed to young bats becoming newly volant from onshore nursery colonies and perhaps foraging further offshore and migrating through the area from either the north (Ahlen et al., 2007). During fall, night time radar TPRs were highest in late August 2010 and early September 2010, which corresponds with the peak call sequences recording rates from the Crib detectors, and known bat migration and swarming periods. The radar is not capable of differentiating between birds and bats, or insects in some cases, but it is highly likely that the higher TPR, during periods of increased call sequence recording rates which correspond with the fall bat migration, may be attributed to bats moving within the radar coverage area. It is also possible that some of the targets registered with radar were insects, but it is not possible to determine what percentage of targets were insects as opposed to vertebrates.

Migration activity in the Study Area consisted primarily of cormorants and gulls during the day, passerines and likely some shorebirds at night, as well as migratory bats, and insects. Flight heights were predominantly below the RSZ (RSZ of the largest commercially available offshore wind turbines at the time of the analysis), although on nights with high passage rates flight heights trended higher. The analysis represents a "worst case scenario" of risk based on the largest possible turbine configuration available. Avian species diversity was low during diurnal boat surveys, although portions of the migration period, especially early and late fall, may have been missed and therefore biased the data set. Bat activity levels were substantially higher onshore than offshore. It seems probable that the Crib and, or lights attracted some species, especially gulls, cormorants, and possibly foraging bats and insects.

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# APPENDIX A

# SUPPLEMENTAL RADAR INFORMATION

***Types of radar systems***

Small Mobile Radars vary in sophistication from manual systems to semi-manual and fully automatic systems. Manual systems require a skilled radar ornithologist to observe a standard marine radar display and record their observations of bird and bat activity. This type of system requires the operator to decide which targets are birds or bats and manually record the target count, size, direction, speed and other data. Semi-manual systems capture a digital image from the marine radar and digitize the data manually for analysis, also conducted by a skilled observer. Fully automated systems use computer-based programs to identify bird and bat targets and record target counts, size, speed and other data. One of the main differences between the manual and semi-manual systems and fully automatic systems is consistency. The decisions the software makes regarding what is and isn't a bird or bat target and the measurement of target parameters is consistent across all conditions, whereas the other radar systems rely on human observers. Although skilled, observations are susceptible to variability between observers, observer fatigue, and display saturation (when there are so many targets that the display is saturated and individuals cannot be distinguished) among other effects – all of which generally result in undercounting. The following are additional reasons automated analysis radar systems typically records higher counts.

***Higher resolution data***

The MERLIN system uses a radar computer interface (RCI) card to digitize the analog signal coming from the radar receiver. This digitizes the voltage of the signal on a 12-bit scale ranging from zero (for no voltage) to 4,096 (for the maximum voltage or receiver saturation). These 4,096 levels of reflectivity provide a much more precise dataset than the 4 to 32 levels of data encoding used on standard marine radars and allow better target categorization and measurement.

The RCI in MERLIN can also sample the receiver signal at a predefined rate up to 60 Mhz. A sampling rate this fast allows more range bins in a single radar pulse to be sampled. Although increasing the pulse length can also increase the sampling rate, the tradeoff is larger range bins and lower resolution imagery. Therefore, it is preferable to sacrifice radiated power (pulse length) for improved image resolution. The result of a short radar pulse sampled at 60 MHz is sub-sampling of range bins, which ultimately means that spatially small targets only dominate the sub range bins they occupy, and larger targets (with stronger returns) occupy all of the sub-sampled range bins and perhaps some adjacent range bins. This allows for greater distinction between differently sized targets, and improved imagery resolution.

The RCI also allows the signal to be sub-sampled in azimuth. The data can be sampled with an azimuth resolution of 512 to 4,096 samples in one rotation of the antenna. So even if the antenna azimuth beam width is 2°, the very high azimuth resolution allows sub-sampling of the azimuth beam width and the peak in radar return more precisely matches the location of the target than at lower azimuth resolution. The product of short pulse lengths, high signal sampling rate, and high azimuth sampling rate in MERLIN, is imagery with far superior resolution and reflectivity when rendered to an analog radar display compared to the standard off-the-shelf radar displays used on other radar systems. This difference is readily apparent even to the layman, and becomes even more powerful when coupled with MERLIN algorithms that use the high resolution data for further signal processing and to make precise measurements.

***Sampling bias***

Many radar studies with manual or semi-manual radar systems use a single radar, alternatively flipped, to cover both the vertical and horizontal planes. Samples are then collected for short periods of time (typically 15 minutes) and the data are extrapolated to an hour (as opposed to measuring the entire hour). Extrapolation may be relatively accurate if the trend in the numbers of targets is constant, but biological target activity tends to show continual changes in numbers of targets and when the data being captured is part of an increasing or decreasing trend, the extrapolation may result in a significant difference between the estimated and actual number. Therefore, sampled data should be considered estimates, and continuous data collection preferred as it more accurately and completely measures actual passage rates. The MERLIN system collects continuous data sets from both the horizontal and vertical planes, eliminating the need for any extrapolation.

***Calculating TPRs from VSR***

There are a number of radar scanning and data collection methods in use, but for most applications the choice is the vertical scanning radar (VSR) and horizontal surveillance radar (HSR). A number of published studies to date have used HSR. The data from any radar is biased by 1) the amount of radar display lost to ground clutter, 2) the amount of display lost under the radar horizon, 3) the detectability of targets, and 4) the evenness of the sample volume. Each of these issues is discussed below by comparing horizontal scanning radar with vertical scanning radar.

<u>Ground clutter</u>
The amount of the radar display lost to ground clutter in the HSR is generally high, unless the radar is situated on an elevated location with the ground falling away (in which case targets may pass below the radar horizon and not be counted). When the ground clutter level gets too high and saturates the receiver, or is so high that the addition of a small target such as a bird does not significantly change the signal, the target is not "seen" on the radar screen and therefore not detected.

Automated high data resolution systems using CFAR (constant false alarm rate) algorithms and ground clutter mapping techniques such as MERLIN are significantly better than manual systems in the horizontal plane as the high dynamic range of the data (typically 4,096 levels) makes it easier to "see" the contribution of a small target (as opposed to a human observer trying to visualize a difference on a radar display with little or no shade or color difference). The amount of display lost to ground clutter in an automated radar system can be minimized by the application of CFAR and ground clutter mapping techniques, but is not completely eliminated - even in MERLIN.

By contrast, vertical scanning radars look mostly at clear air and only encounters ground clutter up to the height of the terrain, leaving much of the data clear of ground clutter. Small targets imaged against clear air have greater contrast, and therefore greater detection probability, than when imaged against a background of ground clutter, even if CFAR algorithms and ground clutter mapping techniques are applied. Accordingly, the VSR has a significant advantage over horizontal radar for detecting the actual number of targets passing through a study area.

Radar Horizon

Radar is a line of sight instrument; it cannot see targets behind terrain or through other obstacles. Anything that blocks the beam creates a "radar horizon" beyond which targets cannot be seen. With a HSR, a partially blocked beam will still illuminate some clear air and track targets, and an operator may not be aware that there is a radar horizon or that the sample volume is reduced. This amount of reduction of sampling volume is difficult to determine. By contrast, a VSR will readily show the "black holes" where either ground clutter or beam blockage prevents birds from being detected by the radar beam when plotting a large number of tracks. Occlusion can still be a factor in the VSR but it is easy to determine the portions of airspace affected. If ground clutter or occlusion is a significant issue at a site with rolling terrain it can be quantified and factored into the subsequent data analysis.

Probability of Detection

Differences in radar settings such as radar gain and pulse-length, which determine maximum detection distances, as well as any clutter suppression algorithms, all vary by radar system and can affect the number of targets detected. Probability of detection is affected by these and other parameters within a radar system, but at the end of the processing chain it is the contrast of the target against the background noise that determines if a target is detected or lost. Therefore, anything that increases the amount of clear air against which targets are imaged, and doesn't introduce a radar horizon, means more accurate count data.

Sample volume

With any type of radar, a volume of airspace is sampled. With HSR, this sample volume increases with range, even with the most sophisticated of antenna beam shaping techniques. Therefore, a HSR count is a sample of different volumes and altitudes as the range changes. A HSR sampling volume may also be distorted to different degrees throughout the scan by the influence of ground clutter and occlusion of the beam. This variability makes it difficult to accurately determine both the height and volume in which a passage rate occurs.

The volume to either side of the vertical beam in a VSR also increases with altitude, but if a tracking algorithm is used then the only difference between a target in the lower portion of the beam and the upper portion of the beam is how long the target stays in the beam, and not the number of targets detected. The increased volume at higher altitudes does not capture and track significantly more birds than at lower altitudes because side lobes generally widen the effective beam width (generally 24°) at low altitudes, and most targets have sufficient time to be detected and tracked in the shorter period of time the targets are in the beam. So although the change in volume by altitude in the VSR adds some bias to the count data, the impact is not as large as that introduced by the HSR.

A VSR also samples much more airspace *above* the radar than a HSR. Although volume standardization can correct for the different amount of airspace sampled by HSR and VSR, it cannot correct for the different densities of birds, or bats, present at different altitudes. If different altitudes are sampled, simple volume standardization will only be accurate if target densities are equal across all altitudes, an assumption we know to be false. Bird and bat heights vary and are dependent upon a myriad of changing abiotic and biotic factors, which is why quantifying bird and bat activity at rotor swept altitudes is so critical. Nocturnal migration usually occurs at high altitudes; including targets from greater altitudes likely increases TPRs. However, capping target counts at a given altitude would likely create artificially low passage rates and ignore the potential of collision risk if a fallout of nocturnally migrating birds were to occur.

***Summary***

The MERLIN Avian Radar System is likely to have greater target counts both because it is a fully automatic system, and because it creates higher resolution images. Unlike fully automatic systems, manual and semi-manual radar systems are susceptible to observer fatigue and display saturation, both of which result in undercounting. In addition to lacking these human-induced biases, DeTect's MERLIN Avian Radar Systems also creates higher resolution images that are clearer and allow greater detection of targets present. The greater resolution of DeTect's MERLIN Avian Radar System data are the result of using a vertically-positioned radar for the passage rate data (which has less ground clutter than horizontal radar), signal digitization on a 12-bit scale (enabling 4,096 levels of detectable reflectivity compared to 4 – 32 levels on standard marine radars), a fast sampling rate (60 Mhz) coupled with shorter radar pulses (0.08 µsec), and sub-sampling of the azimuth beam width. MERLIN CFAR (constant false alarm rate) and ground clutter mapping techniques also decrease targets lost to clutter.

The observer bias inherent in manual and semi-manual radar systems introduces so many variables that reproducing the results becomes problematic. The effect of the biases and limitations of these types of systems on the actual activity is unknown. Therefore, one must be careful when comparing a manual radar study to an automated study. The former is likely biased downwards and probably imposes a false ceiling on the maximum numbers and types of targets counted. The latter may be biased upwards, but without limitation of the maximum numbers it can process and without extrapolation, the numbers are likely closer to the actual numbers moving through an area.

Given the different biases and limitations of the two sensors, one would expect to see the same trends, with target numbers generally going up and down in similar seasons. However, perfect correlation will not occur even if the sensors were side by side in the same season. Achieving correlation becomes even more difficult when comparing different studies at the same site in different years or different studies in different years at different locations.

Automated radar systems that record accurate metadata allow for the capture of all the key parameters of the radar performance that permit another researcher with similar equipment and configuration to follow the methods and reproduce the results. Human interaction in the radar data collection process greatly increases the bias and limits reproducibility. The true reproducibility of a manual or semi-manual radar dataset will always be difficult because of the bias and limitations inherent in the datasets.

# APPENDIX B

# RADAR TERMS GLOSSARY

1-km Front – Area extending 0.5 km on either side of the VSR forming a 1 $km^2$ area through which TPRs are quantified. This area occurs entirely within the radar scanned zone.

Rotor Swept Zone (RSZ) – The 1-km wide band within the 1-km front that encompasses the lowest and highest points swept by a wind turbine's blades. Specific to each Study and calculated using the manufacturer's specifications for the wind turbine proposed for the Study .

Plot – A single scan of a target or other objects.

Target Passage Rate – Number of specified targets passing through a 1-km wide front during 1 hour. This rate is standardized for effort, or the proportion of minutes radar data was recorded during a given time period.

Target - Object detected by MERLIN Radar and identified by MERLIN software as a biological object (e.g., bird, bat, insect) based on scanned size, speed, and other characteristics.

Track – The entire sequence of target plots that are recorded as long as an object still fits the definition of a target.

Tracking – The MERLIN software begins to track a target after it has met the criteria of a biological target for three consecutive scans. The target continues to be tracked until either the target is lost, or target fails to meet the criteria for three consecutive scans.

# APPENDIX C

# TARGET COUNTS & PASSAGE RATES

**Table C.1** Onshore radar summary results, spring 2010, per night (top section) and per day (lower section). Includes total target count, below, within, and above RSZ, as well as TPR below, within, and above RSZ

| SPRING NIGHT-Onshore | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Count Below RSZ | Count Within RSZ | Count Above RSZ | TPR below RSZ | TPR within RSZ | TPR above RSZ | OVERALL TPR | Mean Flight Height AMWL |
| 4/11/2010 | 0.0 | 8.0 | 114.0 | 0.0 | 2.7 | 38.0 | 40.7 | 458.9 |
| 4/12/2010 | 0.0 | 5.0 | 72.0 | 0.0 | 1.0 | 13.8 | 14.8 | 424.7 |
| 4/13/2010 | 0.0 | | 4.0 | 0.0 | 0.0 | 26.7 | 26.7 | 965.1 |
| 4/14/2010 | 0.0 | 18.0 | 581.0 | 0.0 | 4.5 | 145.3 | 149.8 | 545.1 |
| 4/15/2010 | 0.0 | 45.0 | 853.0 | 0.0 | 3.9 | 74.5 | 78.4 | 372.1 |
| 4/16/2010 | 0.0 | 8.0 | 191.0 | 0.0 | 1.3 | 30.9 | 32.2 | 376.6 |
| 4/18/2010 | 0.0 | 2.0 | 3.0 | 0.0 | 0.5 | 0.8 | 1.3 | 236.2 |
| 4/19/2010 | 0.0 | 3.0 | 39.0 | 0.0 | 0.3 | 4.4 | 4.7 | 493.1 |
| 4/20/2010 | 0.0 | 11.0 | 144.0 | 0.0 | 1.2 | 15.6 | 16.8 | 517.7 |
| 4/21/2010 | 0.0 | 16.0 | 111.0 | 0.0 | 2.5 | 17.2 | 19.6 | 437.4 |
| SPRING DAY-Onshore | | | | | | | | |
| Date | Count Below RSZ | Count Within RSZ | Count Above RSZ | TPR below RSZ | TPR within RSZ | TPR above RSZ | OVERALL TPR | Mean Flight Height AMWL |
| 4/11/2010 | 0 | 3 | 25 | 0.0 | 0.6 | 5.3 | 5.9 | 355.8 |
| 4/12/2010 | 0 | 1 | 164 | 0.0 | 0.1 | 14.9 | 15.0 | 384.1 |
| 4/13/2010 | 0 | 1 | 4 | 0.0 | 0.2 | 0.8 | 1.0 | 264.2 |
| 4/14/2010 | 0 | 84 | 1235 | 0.0 | 15.6 | 228.7 | 244.3 | 356.1 |
| 4/15/2010 | 0 | 260 | 2167 | 0.0 | 23.6 | 197.0 | 220.6 | 322.5 |
| 4/16/2010 | 0 | 21 | 137 | 0.0 | 5.3 | 34.3 | 39.5 | 317.4 |
| 4/18/2010 | 0 | | 2 | 0.0 | 0.0 | 1.6 | 1.6 | 229.1 |
| 4/19/2010 | 0 | 1 | 7 | 0.0 | 0.1 | 0.8 | 0.9 | 336.0 |
| 4/20/2010 | 0 | | 75 | 0.0 | 0.0 | 13.0 | 13.0 | 358.5 |
| 4/21/2010 | 0 | 1 | 79 | 0.0 | 0.4 | 32.2 | 32.7 | 398.9 |

**Table C.2** Offshore radar summary results, spring 2010, per biological period, Target Passage Rates below, within, and above RSZ

**SPRING 2010 OFFSHORE**

| Date | Dawn Recording (Minutes) | Dawn TPR below RSZ | Dawn TPR within RSZ | Dawn TPR above RSZ | Dawn Total TPR | Dawn Avg. Flight Height (m) | Dawn Median Flight Height (m) | Dawn StDev Flight Height (m) |
|---|---|---|---|---|---|---|---|---|
| 5/1/2010 | 60 | | | | | | | |
| 5/2/2010 | 1 | | | | | | | |
| 5/3/2010 | 60 | 18 | 0 | 0 | 18 | 0.9 | 0.2 | 1.9 |
| 5/4/2010 | 60 | 6 | 0 | 0 | 6 | 2.6 | 2.6 | 0.0 |
| 5/5/2010 | 60 | | | | | | | |
| 5/6/2010 | 60 | 996 | 6 | 18 | 1020 | 25.9 | 13.1 | 91.5 |
| 5/7/2010 | 60 | 1104 | 18 | 12 | 1134 | 12.9 | 3.8 | 45.2 |
| 5/8/2010 | | | | | | | | |
| 5/9/2010 | | | | | | | | |
| 5/10/2010 | 60 | 1680 | 126 | 6 | 1812 | 25.8 | 19.5 | 28.9 |
| 5/11/2010 | | | | | | | | |
| 5/12/2010 | 57 | 1800 | 25.3 | 6.3 | 1831.6 | 18.2 | 9.9 | 60.4 |
| 5/13/2010 | 60 | 1266 | 12 | 6 | 1284 | 16.9 | 10.8 | 56.7 |
| 5/14/2010 | 46 | 1119.1 | 15.7 | 39.1 | 1173.9 | 27.2 | 4.4 | 112.3 |
| 5/15/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/20/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/21/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/22/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/23/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/24/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/25/2010 | | | | | | | | |
| 5/26/2010 | 60 | 642 | 0 | 0 | 642 | 18.4 | 16.9 | 13.3 |
| Average | 53.7 | 959.0 | 22.6 | 9.7 | 991.3 | 16.5 | 9.0 | 45.6 |

| Date | Day Recording (Minutes) | Day TPR below RSZ | Day TPR within RSZ | Day TPR above RSZ | Day Total TPR | Day Avg. Flight Height (m) | Day Median Flight Height (m) | Day StDev Flight Height (m) |
|---|---|---|---|---|---|---|---|---|
| 5/1/2010 | 735 | 5.9 | 0 | 0 | 5.9 | 1.4 | 0.1 | 2.3 |
| 5/2/2010 | 752 | 43.6 | 0 | 0 | 43.6 | 1.9 | 1.4 | 3.1 |
| 5/3/2010 | 785 | 1.4 | 0 | 0 | 1.4 | 2.1 | 2.3 | 1.5 |
| 5/4/2010 | 787 | 12.4 | 0 | 0 | 12.4 | 2.5 | 2.9 | 2.5 |
| 5/5/2010 | 694 | 116.2 | 0 | 0 | 116.2 | 2.3 | 1.4 | 3.7 |
| 5/6/2010 | 717 | 1030.3 | 8 | 1 | 1039.3 | 13.4 | 9.9 | 46.6 |
| 5/7/2010 | 674 | 924.6 | 22.4 | 11.2 | 958.2 | 22.0 | 5.3 | 120.5 |
| 5/8/2010 | | | | | | | | |
| 5/9/2010 | | | | | | | | |
| 5/10/2010 | 800 | 1486.8 | 31.5 | 2.7 | 1521 | 19.4 | 16.6 | 43.4 |
| 5/11/2010 | | | | | | | | |
| 5/12/2010 | 747 | 1523.9 | 22.2 | 14 | 1560 | 30.3 | 21.2 | 100.0 |
| 5/13/2010 | 611 | 1197.3 | 17.7 | 5.9 | 1220.8 | 16.3 | 10.5 | 54.6 |
| 5/14/2010 | 808 | 1073.3 | 3.6 | 5.3 | 1082.2 | 13.2 | 6.5 | 48.5 |
| 5/15/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/20/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/21/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/22/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/23/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/24/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/25/2010 | 519 | 1041.2 | 3.5 | 0.7 | 1045.3 | 9.9 | 6.2 | 16.0 |
| 5/26/2010 | 830 | 304.5 | 1.7 | 2.6 | 308.8 | 27.5 | 20.0 | 92.3 |
| Average | 727.6 | 674.0 | 8.5 | 3.3 | 685.8 | 12.5 | 8.0 | 41.1 |

| Date | Dusk Recording (Minutes) | Dusk TPR below RSZ | Dusk TPR within RSZ | Dusk TPR above RSZ | Dusk Total TPR | Dusk Avg. Flight Height (m) | Dusk Median Flight Height (m) | Dusk StDev Flight Height (m) |
|---|---|---|---|---|---|---|---|---|
| 5/1/2010 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/2/2010 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/3/2010 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/4/2010 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/5/2010 | | | | | | | | |
| 5/6/2010 | 60 | 666 | 24 | 0 | 690 | 11.6 | 2.0 | 27.7 |
| 5/7/2010 | 23 | 1612.2 | 0 | 0 | 1612.2 | 17.0 | 18.1 | 10.2 |
| 5/8/2010 | | | | | | | | |
| 5/9/2010 | | | | | | | | |
| 5/10/2010 | 60 | 1818 | 6 | 6 | 1830 | 22.9 | 21.8 | 27.5 |
| 5/11/2010 | | | | | | | | |
| 5/12/2010 | 48 | 1702.5 | 52.5 | 7.5 | 1762.5 | 27.8 | 24.8 | 22.3 |
| 5/13/2010 | 60 | 1170 | 0 | 6 | 1176 | 19.5 | 16.6 | 59.5 |
| 5/14/2010 | 60 | 1182 | 0 | 0 | 1182 | 9.6 | 6.5 | 11.9 |
| 5/15/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/20/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/21/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/22/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/23/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/24/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/25/2010 | 60 | 1092 | 0 | 0 | 1092 | 8.8 | 5.8 | 10.5 |
| 5/26/2010 | 20 | 378 | 0 | 0 | 378 | 22.8 | 19.3 | 13.1 |
| Average | 52.6 | 801.7 | 6.9 | 1.6 | 810.2 | 11.7 | 9.6 | 15.2 |

| Date | Night Recording (Minutes) | Night TPR below RSZ | Night TPR within RSZ | Night TPR above RSZ | Night Total TPR | Night Avg. Flight Height (m) | Night Median Flight Height (m) | Night StDev Flight Height (m) |
|---|---|---|---|---|---|---|---|---|
| 5/1/2010 | 538 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/2/2010 | 505 | 30.7 | 0 | 0 | 30.7 | 1.5 | 0.8 | 2.8 |
| 5/3/2010 | 414 | 21.7 | 0 | 0 | 21.7 | 2.3 | 2.0 | 2.5 |
| 5/4/2010 | 531 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 5/5/2010 | 234 | 1009.2 | 12.3 | 6.2 | 1027.7 | 11.3 | 3.2 | 50.1 |
| 5/6/2010 | 406 | 560.4 | 16.8 | 47 | 624.2 | 45.3 | 3.2 | 140.9 |
| 5/7/2010 | 195 | 1299.7 | 0 | 0 | 1299.7 | 24.9 | 25.1 | 10.4 |
| 5/8/2010 | | | | | | | | |
| 5/9/2010 | 271 | 1481.2 | 20.6 | 8 | 1509.7 | 15.5 | 10.5 | 31.8 |
| 5/10/2010 | 483 | 1516 | 29.8 | 31.3 | 1577.1 | 30.5 | 20.9 | 70.8 |
| 5/11/2010 | 303 | 1846.3 | 396.8 | 7.1 | 2250.3 | 36.4 | 20.9 | 52.1 |
| 5/12/2010 | 257 | 988.9 | 12.6 | 22.4 | 1024 | 23.2 | 9.0 | 89.4 |
| 5/13/2010 | 47 | 1217.9 | 7.7 | 38.3 | 1263.8 | 32.5 | 14.5 | 104.8 |
| 5/14/2010 | 1 | 720 | 0 | 0 | 720 | 2.1 | 2.1 | 2.7 |
| 5/15/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/20/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/21/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/22/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/23/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/24/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 5/25/2010 | 489 | 406.4 | 9.6 | 4.4 | 420.4 | 16.4 | 5.6 | 54.0 |
| 5/26/2010 | | | | | | | | |
| Average | 333.9 | 792.7 | 36.2 | 11.8 | 840.7 | 17.3 | 8.4 | 43.7 |

Notes:

1) Actual times of Dawn, Day, Dusk, Night vary depending upon the time of the year
2) Recording Minutes = total minutes of data collection over that period of time.
3) Empty cells indicate that no targets were detected during that time.
4) -- = Data was not collected or analyzed due to weather(precipitation or fog) interference and/or radar mechanical downtime.
5) m = meters
6) km = kilometers or 1,000 m
7) TPR = Target Passage Rate = the number of targets detected within 1 km starting at 250 m from the radar and out to 1,250 m, for a total frontal width of 1 km during a 1-hour period
8) AMWL = above mean low water level
9) RSZ = Rotor Swept Zone = 27 m (89 feet) to 202.5 m (664 feet) AMWL
10) Flight height was measured in meters AMWL
11) Avg. Flight Height = Average Flight Height
12) StDev = Standard Deviation

**Table C.3** Offshore radar summary results, spring 2010, per biological period, Target Counts below, within, and above RSZ

| Date | Total Targets Counted Below the RSZ | Total Targets Counted Within the RSZ | Total Targets Counted Above the RSZ | Total Targets Counted |
|---|---|---|---|---|
| 5/1/2010 | 1,152 | 0 | 0 | 1,152 |
| 5/2/2010 | 12,864 | 0 | 0 | 12,864 |
| 5/3/2010 | 2,976 | 0 | 0 | 2,976 |
| 5/4/2010 | 2,688 | 0 | 0 | 2,688 |
| 5/5/2010 | 84,480 | 768 | 384 | 85,632 |
| 5/6/2010 | 284,256 | 3,840 | 5,568 | 293,664 |
| 5/7/2010 | 261,312 | 4,320 | 2,208 | 267,840 |
| 5/8/2010 | 0 | 0 | 0 | 0 |
| 5/9/2010 | 270,576 | 10,944 | 2,592 | 284,112 |
| 5/10/2010 | 568,416 | 12,672 | 4,800 | 585,888 |
| 5/11/2010 | 149,184 | 32,064 | 576 | 181,824 |
| 5/12/2010 | 420,480 | 6,336 | 4,512 | 431,328 |
| 5/13/2010 | 249,312 | 3,168 | 1,632 | 254,112 |
| 5/14/2010 | 264,096 | 960 | 1,632 | 266,688 |
| 5/15/2010 | -- | -- | -- | -- |
| 5/16/2010 | -- | -- | -- | -- |
| 5/17/2010 | -- | -- | -- | -- |
| 5/18/2010 | -- | -- | -- | -- |
| 5/19/2010 | -- | -- | -- | -- |
| 5/20/2010 | -- | -- | -- | -- |
| 5/21/2010 | -- | -- | -- | -- |
| 5/22/2010 | -- | -- | -- | -- |
| 5/23/2010 | -- | -- | -- | -- |
| 5/24/2010 | -- | -- | -- | -- |
| 5/25/2010 | 214,560 | 1,728 | 672 | 216,960 |
| 5/26/2010 | 79,680 | 384 | 576 | 80,640 |
| **Grand Total** | **2,866,032** | **77,184** | **25,152** | **2,968,368** |

Notes:

1) -- = Data was not collected or analyzed due to weather(precipitation or fog) interference and/or radar mechanical downtime.
2) m = meters
3) km = kilometer or 1,000 m
3) Count = the number of targets detected within 1 km starting at 250 m from the radar and out to 1,250 m over a 24 hour period
4) AMWL = above mean low water level
5) RSZ = Rotor Swept Zone = 27 m (89 feet) to 202.5 m (664 feet) AMWL

**Table C.4** Offshore radar summary results, fall 2010, per biological period, Target Passage Rates below, within, and above RSZ

**FALL 2010 OFFSHORE**

| Date | Dawn Recording (Minutes) | Dawn TPR below RSZ | Dawn TPR within RSZ | Dawn TPR above RSZ | Dawn Total TPR | Dawn Avg. Flight Height (m) | Dawn Median Flight Height (m) | Dawn StDev Flight Height (m) | Date | Day Recording (Minutes) | Day TPR below RSZ | Day TPR within RSZ | Day TPR above RSZ | Day Total TPR | Day Avg. Flight Height (m) | Day Median Flight Height (m) | Day StDev Flight Height (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8/19/2010 | | | | | | | | | 8/19/2010 | 717.0 | 135.1 | 54.7 | 60.8 | 250.5 | 194.3 | 17.4 | 372.4 |
| 8/20/2010 | | | | | | | | | 8/20/2010 | 370.0 | 152.3 | 348.3 | 33.6 | 534.2 | 91.6 | 36.3 | 230.8 |
| 8/21/2010 | | | | | | | | | 8/21/2010 | 345.0 | 131.0 | 249.9 | 26.1 | 407.0 | 103.7 | 34.4 | 301.3 |
| 8/22/2010 | | | | | | | | | 8/22/2010 | | | | | | | | |
| 8/23/2010 | | | | | | | | | 8/23/2010 | | | | | | | | |
| 8/24/2010 | | | | | | | | | 8/24/2010 | 185.0 | 252.0 | 459.2 | 90.5 | 801.7 | 122.6 | 49.4 | 309.4 |
| 8/25/2010 | | | | | | | | | 8/25/2010 | 528.0 | 136.7 | 220.6 | 367.8 | 725.1 | 328.6 | 207.6 | 378.4 |
| 8/26/2010 | | | | | | | | | 8/26/2010 | 88.0 | 288.4 | 315.0 | 184.1 | 787.5 | 151.2 | 36.0 | 242.7 |
| 8/27/2010 | | | | | | | | | 8/27/2010 | 300.0 | 226.8 | 118.2 | 24.6 | 369.6 | 59.9 | 16.5 | 227.8 |
| 8/28/2010 | | | | | | | | | 8/28/2010 | 135.0 | 717.3 | 698.7 | 764.0 | 2180.0 | 181.5 | 102.4 | 249.5 |
| 8/29/2010 | | | | | | | | | 8/29/2010 | 566.0 | 197.8 | 187.0 | 102.1 | 486.9 | 268.4 | 29.9 | 555.7 |
| 8/30/2010 | | | | | | | | | 8/30/2010 | 415.0 | 162.7 | 276.7 | 131.9 | 571.2 | 170.9 | 47.2 | 345.3 |
| 8/31/2010 | 60.0 | 165.0 | 48.0 | 312.0 | 525.0 | 569.3 | 353.0 | 660.9 | 8/31/2010 | 595.0 | 118.6 | 468.3 | 470.4 | 1057.3 | 350.9 | 167.0 | 423.3 |
| 9/1/2010 | 60.0 | 156.0 | 108.0 | 282.0 | 546.0 | 415.1 | 217.9 | 574.5 | 9/1/2010 | 468.0 | 126.9 | 201.9 | 701.2 | 1030.0 | 304.3 | 321.9 | 236.6 |
| 9/2/2010 | | | | | | | | | 9/2/2010 | 409.0 | 154.0 | 486.3 | 335.8 | 976.1 | 214.2 | 125.1 | 255.6 |
| 9/3/2010 | 60.0 | 99.0 | 39.0 | 186.0 | 324.0 | 438.3 | 275.2 | 485.4 | 9/3/2010 | 134.0 | 141.0 | 61.8 | 201.5 | 404.3 | 343.4 | 178.0 | 416.4 |
| 9/4/2010 | | | | | | | | | 9/4/2010 | | | | | | | | |
| 9/5/2010 | | | | | | | | | 9/5/2010 | 60.0 | 114.0 | 54.0 | 15.0 | 183.0 | 44.2 | 18.3 | 105.2 |
| 9/6/2010 | | | | | | | | | 9/6/2010 | 193.0 | 162.3 | 107.3 | 178.1 | 447.7 | 492.5 | 46.5 | 692.1 |
| 9/7/2010 | 10.0 | 522.0 | 414.0 | 594.0 | 1530.0 | 359.9 | 40.8 | 577.7 | 9/7/2010 | 240.0 | 495.7 | 694.5 | 142.5 | 1332.8 | 119.0 | 29.6 | 311.6 |
| 9/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/9/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/9/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/10/2010 | | | | | | | | | 9/10/2010 | 171.0 | 383.2 | 728.4 | 1003.2 | 2114.7 | 356.4 | 172.2 | 466.0 |
| 9/11/2010 | | | | | | | | | 9/11/2010 | 180.0 | 271.0 | 356.0 | 214.0 | 841.0 | 322.9 | 37.2 | 654.8 |
| 9/12/2010 | | | | | | | | | 9/12/2010 | | | | | | | | |
| 9/13/2010 | | | | | | | | | 9/13/2010 | 136.0 | 123.1 | 37.1 | 4453.7 | 4613.8 | 879.9 | 928.3 | 377.1 |
| 9/14/2010 | | | | | | | | | 9/14/2010 | 360.0 | 119.0 | 670.5 | 1678.0 | 2467.5 | 406.8 | 360.3 | 349.5 |
| 9/15/2010 | | | | | | | | | 9/15/2010 | 285.0 | 111.8 | 240.0 | 82.1 | 433.9 | 292.7 | 64.0 | 629.9 |
| 9/16/2010 | | | | | | | | | 9/16/2010 | 45.0 | 452.0 | 304.0 | 40.0 | 796.0 | 76.3 | 19.5 | 316.9 |
| 9/17/2010 | | | | | | | | | 9/17/2010 | 369.0 | 132.4 | 193.5 | 63.7 | 389.6 | 224.3 | 36.7 | 536.7 |
| 9/18/2010 | | | | | | | | | 9/18/2010 | 428.0 | 154.8 | 66.7 | 49.6 | 271.1 | 227.8 | 17.1 | 561.5 |
| 9/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/20/2010 | | | | | | | | | 9/20/2010 | 34.0 | 448.2 | 310.6 | 1108.2 | 1867.1 | 433.4 | 415.1 | 561.9 |
| 9/21/2010 | | | | | | | | | 9/21/2010 | 618.0 | 119.6 | 67.8 | 70.7 | 258.1 | 306.0 | 26.2 | 646.9 |
| 9/22/2010 | 25.0 | 172.8 | 196.8 | 580.8 | 950.4 | 421.1 | 361.0 | 566.1 | 9/22/2010 | 405.0 | 96.6 | 63.4 | 404.4 | 564.4 | 437.5 | 300.5 | 482.3 |
| 9/23/2010 | | | | | | | | | 9/23/2010 | 524.0 | 51.2 | 19.6 | 27.1 | 97.9 | 299.6 | 20.7 | 585.3 |
| 9/24/2010 | 60.0 | 36.0 | 23.0 | 22.0 | 81.0 | 274.1 | 27.7 | 579.1 | 9/24/2010 | 233.0 | 151.4 | 120.3 | 17.3 | 288.9 | 75.1 | 21.9 | 256.8 |
| 9/25/2010 | | | | | | | | | 9/25/2010 | 41.0 | 212.2 | 401.0 | 29.3 | 642.4 | 105.6 | 30.8 | 395.8 |
| 9/26/2010 | | | | | | | | | 9/26/2010 | 225.0 | 58.1 | 104.8 | 81.1 | 244.0 | 616.4 | 73.8 | 969.7 |
| 9/27/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/27/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/28/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/28/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/29/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/29/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/30/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/30/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/1/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/1/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/2/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/2/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/3/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/3/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/4/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/4/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/5/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/5/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/6/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/6/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/7/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/7/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/9/2010 | | | | | | | | | 10/9/2010 | 255.0 | 193.6 | 316.0 | 287.3 | 796.9 | 590.1 | 55.5 | 862.9 |
| 10/10/2010 | 60.0 | 221.0 | 459.0 | 816.0 | 1496.0 | 921.4 | 480.7 | 982.1 | 10/10/2010 | 96.0 | 254.4 | 246.3 | 166.9 | 667.5 | 485.1 | 35.2 | 867.0 |
| 10/11/2010 | 50.0 | 266.4 | 60.0 | 357.6 | 684.0 | 748.5 | 299.9 | 921.8 | 10/11/2010 | 224.0 | 155.4 | 49.8 | 16.1 | 221.3 | 109.3 | 11.9 | 460.5 |
| 10/12/2010 | | | | | | | | | 10/12/2010 | | | | | | | | |
| Average | 48.1 | 204.8 | 168.5 | 393.8 | 767.1 | 518.5 | 257.0 | 668.4 | Average | 296.5 | 205.7 | 265.7 | 389.2 | 860.6 | 279.6 | 116.9 | 446.7 |

| Date | Dusk Recording (Minutes) | Dusk TPR below RSZ | Dusk TPR within RSZ | Dusk TPR above RSZ | Dusk Total TPR | Dusk Avg. Flight Height (m) | Dusk Median Flight Height (m) | Dusk StDev Flight Height (m) | Date | Night Recording (Minutes) | Night TPR below RSZ | Night TPR within RSZ | Night TPR above RSZ | Night Total TPR | Night Avg. Flight Height (m) | Night Median Flight Height (m) | Night StDev Flight Height (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/17/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/18/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 8/19/2010 | 60.0 | 255.0 | 72.0 | 18.0 | 345.0 | 70.8 | 10.4 | 316.5 | 8/19/2010 | 18.0 | 200.0 | 50.0 | 130.0 | 380.0 | 224.1 | 19.1 | 381.6 |
| 8/20/2010 | 35.0 | 118.3 | 421.7 | 0.0 | 540.0 | 39.7 | 32.6 | 22.3 | 8/20/2010 | | | | | | | | |
| 8/21/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/21/2010 | | | | | | | | |
| 8/22/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/22/2010 | | | | | | | | |
| 8/23/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/23/2010 | | | | | | | | |
| 8/24/2010 | 41.0 | 535.6 | 706.8 | 74.6 | 1317.1 | 94.3 | 34.7 | 302.9 | 8/24/2010 | | | | | | | | |
| 8/25/2010 | 27.0 | 60.0 | 293.3 | 360.0 | 713.3 | 294.6 | 210.9 | 308.6 | 8/25/2010 | | | | | | | | |
| 8/26/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/26/2010 | | | | | | | | |
| 8/27/2010 | 15.0 | 180.0 | 72.0 | 12.0 | 264.0 | 23.2 | 11.1 | 99.9 | 8/27/2010 | 45.0 | 172.0 | 740.0 | 404.0 | 1316.0 | 254.9 | 107.9 | 388.5 |
| 8/28/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 8/28/2010 | 384.0 | 104.1 | 795.5 | 780.9 | 1680.5 | 340.6 | 182.3 | 445.4 |
| 8/29/2010 | 60.0 | 123.0 | 144.0 | 207.0 | 474.0 | 350.2 | 90.8 | 472.7 | 8/29/2010 | 524.0 | 70.8 | 466.8 | 837.1 | 1374.7 | 589.7 | 308.0 | 632.5 |
| 8/30/2010 | 60.0 | 261.0 | 144.0 | 123.0 | 528.0 | 149.9 | 24.8 | 273.9 | 8/30/2010 | 581.0 | 100.7 | 785.4 | 1018.7 | 1904.7 | 450.8 | 228.9 | 531.9 |
| 8/31/2010 | 60.0 | 243.0 | 144.0 | 60.0 | 447.0 | 110.6 | 18.3 | 333.8 | 8/31/2010 | 509.0 | 131.9 | 1023.1 | 1924.8 | 3079.8 | 377.0 | 243.5 | 378.8 |
| 9/1/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/1/2010 | | | | | | | | |
| 9/2/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/2/2010 | 403.0 | 125.1 | 731.6 | 1200.1 | 2056.8 | 374.1 | 268.2 | 343.8 |
| 9/3/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/3/2010 | | | | | | | | |
| 9/4/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/4/2010 | | | | | | | | |
| 9/5/2010 | 60.0 | 120.0 | 81.0 | 78.0 | 279.0 | 194.5 | 37.2 | 444.2 | 9/5/2010 | 150.0 | 135.6 | 1225.2 | 584.4 | 1945.2 | 245.1 | 114.0 | 383.5 |
| 9/6/2010 | 60.0 | 24.0 | 51.0 | 252.0 | 327.0 | 1042.6 | 859.2 | 872.5 | 9/6/2010 | 541.0 | 263.5 | 676.4 | 510.4 | 1450.3 | 260.8 | 96.9 | 428.6 |
| 9/7/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/7/2010 | | | | | | | | |
| 9/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/9/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/9/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/10/2010 | 54.0 | 326.7 | 480.0 | 396.7 | 1203.3 | 357.6 | 92.0 | 620.2 | 9/10/2010 | 81.0 | 184.4 | 2146.7 | 3451.1 | 5782.2 | 417.6 | 256.0 | 463.7 |
| 9/11/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/11/2010 | | | | | | | | |
| 9/12/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/12/2010 | 15.0 | 48.0 | 1392.0 | 1860.0 | 3300.0 | 667.2 | 296.3 | 743.4 |
| 9/13/2010 | 44.0 | 360.0 | 85.9 | 3534.5 | 3980.5 | 744.7 | 829.4 | 422.8 | 9/13/2010 | | | | | | | | |
| 9/14/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/14/2010 | | | | | | | | |
| 9/15/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/15/2010 | | | | | | | | |
| 9/16/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/16/2010 | | | | | | | | |
| 9/17/2010 | 60.0 | 102.0 | 102.0 | 58.0 | 262.0 | 325.8 | 33.8 | 717.6 | 9/17/2010 | 6.0 | 200.0 | 80.0 | 80.0 | 360.0 | 233.9 | 19.4 | 569.1 |
| 9/18/2010 | 37.0 | 142.7 | 32.4 | 103.8 | 278.9 | 647.2 | 22.1 | 967.9 | 9/18/2010 | | | | | | | | |
| 9/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/19/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/20/2010 | 56.0 | 327.9 | 216.4 | 627.9 | 1172.1 | 542.6 | 371.9 | 729.0 | 9/20/2010 | | | | | | | | |
| 9/21/2010 | 60.0 | 172.0 | 170.0 | 70.0 | 412.0 | 139.7 | 34.9 | 282.0 | 9/21/2010 | 490.0 | 90.9 | 346.5 | 525.8 | 963.2 | 472.5 | 250.5 | 564.7 |
| 9/22/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/22/2010 | | | | | | | | |
| 9/23/2010 | 60.0 | 87.0 | 25.0 | 31.0 | 143.0 | 117.8 | 14.3 | 290.2 | 9/23/2010 | 510.0 | 36.0 | 118.1 | 117.9 | 272.0 | 331.1 | 153.9 | 463.9 |
| 9/24/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/24/2010 | | | | | | | | |
| 9/25/2010 | 60.0 | 225.0 | 366.0 | 79.0 | 670.0 | 229.7 | 30.6 | 630.9 | 9/25/2010 | 4.0 | 390.0 | 675.0 | 255.0 | 1320.0 | 164.7 | 56.1 | 375.0 |
| 9/26/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/26/2010 | | | | | | | | |
| 9/27/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/27/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/28/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/28/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/29/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/29/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 9/30/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 9/30/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/1/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/1/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/2/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/2/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/3/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/3/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/4/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/4/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/5/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/5/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/6/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/6/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/7/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/7/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/8/2010 | -- | -- | -- | -- | -- | -- | -- | -- |
| 10/9/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/9/2010 | 189.0 | 71.4 | 338.7 | 1911.1 | 2321.3 | 860.1 | 462.8 | 819.1 |
| 10/10/2010 | 60.0 | 218.0 | 21.0 | 100.0 | 339.0 | 508.5 | 13.1 | 892.7 | 10/10/2010 | 505.0 | 35.9 | 311.9 | 514.9 | 862.7 | 559.0 | 258.2 | 709.2 |
| 10/11/2010 | 60.0 | 107.0 | 17.0 | 68.0 | 192.0 | 598.6 | 18.1 | 993.7 | 10/11/2010 | 219.0 | 24.7 | 51.0 | 184.4 | 260.0 | 937.5 | 438.9 | 980.1 |
| 10/12/2010 | -- | -- | -- | -- | -- | -- | -- | -- | 10/12/2010 | 150.0 | 15.6 | 177.6 | 1365.2 | 1558.4 | 1101.4 | 857.1 | 818.3 |
| Average | 51.5 | 199.4 | 182.3 | 312.7 | 694.4 | 329.1 | 139.5 | 499.7 | Average | 280.2 | 126.3 | 638.5 | 929.3 | 1694.1 | 466.4 | 243.1 | 548.5 |

Notes:

1) Actual times of Dawn, Day, Dusk, Night vary depending upon the time of the year
2) Recording Minutes = total minutes of data collection over that period of time.
3) Empty cells indicate that no targets were detected during that time.
4) -- = Data was not collected or analyzed due to weather(precipitation or fog) interference and/or radar mechanical downtime.
5) m = meters
6) km = kilometers or 1,000 m
7) TPR = Target Passage Rate = the number of targets detected within 1 km starting at 250 m from the radar and out to 1,250 m, for a total frontal width of 1 km during a 1-hour period
8) AMWL = above mean low water level
9) RSZ = Rotor Swept Zone = 27 m (89 feet) to 202.5 m (664 feet) AMWL
10) Flight height was measured in meters AMWL
11) Avg. Flight Height = Average Flight Height
12) StDev = Standard Deviation

**Table C.5** Offshore radar summary results, fall 2010, per biological period, Target Counts below, within, and above RSZ

| Date | Total Targets Counted Below the RSZ | Total Targets Counted Within the RSZ | Total Targets Counted Above the RSZ | Total Targets Counted |
|---|---|---|---|---|
| 8/16/2010 | -- | -- | -- | -- |
| 8/17/2010 | -- | -- | -- | -- |
| 8/18/2010 | 0 | 0 | 0 | 0 |
| 8/19/2010 | 30,864 | 11,856 | 12,528 | 55,248 |
| 8/20/2010 | 16,128 | 38,304 | 3,312 | 57,744 |
| 8/21/2010 | 12,048 | 22,992 | 2,400 | 37,440 |
| 8/22/2010 | 0 | 0 | 0 | 0 |
| 8/23/2010 | 0 | 0 | 0 | 0 |
| 8/24/2010 | 18,288 | 30,384 | 5,280 | 53,952 |
| 8/25/2010 | 19,680 | 33,168 | 54,384 | 107,232 |
| 8/26/2010 | 6,768 | 7,392 | 4,320 | 18,480 |
| 8/27/2010 | 20,928 | 18,624 | 6,864 | 46,416 |
| 8/28/2010 | 36,480 | 106,608 | 107,472 | 250,560 |
| 8/29/2010 | 41,712 | 95,760 | 135,696 | 273,168 |
| 8/30/2010 | 37,776 | 154,608 | 174,384 | 366,768 |
| 8/31/2010 | 43,248 | 216,240 | 341,856 | 601,344 |
| 9/1/2010 | 18,336 | 26,928 | 92,016 | 137,280 |
| 9/2/2010 | 30,240 | 131,664 | 165,600 | 327,504 |
| 9/3/2010 | 6,624 | 2,832 | 10,176 | 19,632 |
| 9/4/2010 | 0 | 0 | 0 | 0 |
| 9/5/2010 | 9,168 | 51,168 | 24,864 | 85,200 |
| 9/6/2010 | 46,752 | 103,920 | 86,832 | 237,504 |
| 9/7/2010 | 33,120 | 45,552 | 10,704 | 89,376 |
| 9/8/2010 | 0 | 0 | 0 | 0 |
| 9/9/2010 | 0 | 0 | 0 | 0 |
| 9/10/2010 | 26,160 | 86,496 | 126,000 | 238,656 |
| 9/11/2010 | 13,008 | 17,088 | 10,272 | 40,368 |
| 9/12/2010 | 192 | 5,568 | 7,440 | 13,200 |
| 9/13/2010 | 8,688 | 2,352 | 202,992 | 214,032 |
| 9/14/2010 | 11,424 | 64,368 | 161,088 | 236,880 |
| 9/15/2010 | 8,496 | 18,240 | 6,240 | 32,976 |
| 9/16/2010 | 5,424 | 3,648 | 480 | 9,552 |
| 9/17/2010 | 14,976 | 20,800 | 7,328 | 43,104 |
| 9/18/2010 | 19,072 | 7,936 | 6,688 | 33,696 |
| 9/19/2010 | 0 | 0 | 0 | 0 |
| 9/20/2010 | 8,960 | 6,048 | 19,424 | 34,432 |
| 9/21/2010 | 34,336 | 59,168 | 81,472 | 174,976 |
| 9/22/2010 | 11,584 | 8,160 | 47,552 | 67,296 |
| 9/23/2010 | 13,440 | 19,200 | 20,320 | 52,960 |
| 9/24/2010 | 9,984 | 7,840 | 1,424 | 19,248 |
| 9/25/2010 | 6,336 | 10,960 | 1,856 | 19,152 |
| 9/26/2010 | 3,488 | 6,288 | 4,864 | 14,640 |
| 9/27/2010 | 0 | 0 | 0 | 0 |
| 9/28/2010 | -- | -- | -- | -- |
| 9/29/2010 | -- | -- | -- | -- |
| 9/30/2010 | -- | -- | -- | -- |
| 10/1/2010 | -- | -- | -- | -- |
| 10/2/2010 | -- | -- | -- | -- |
| 10/3/2010 | -- | -- | -- | -- |
| 10/4/2010 | -- | -- | -- | -- |
| 10/5/2010 | -- | -- | -- | -- |
| 10/6/2010 | -- | -- | -- | -- |
| 10/7/2010 | -- | -- | -- | -- |
| 10/8/2010 | -- | -- | -- | -- |
| 10/9/2010 | 16,768 | 38,560 | 115,856 | 171,184 |
| 10/10/2010 | 18,368 | 55,984 | 88,272 | 162,624 |
| 10/11/2010 | 15,984 | 7,024 | 17,584 | 40,592 |
| 10/12/2010 | 624 | 7,104 | 54,608 | 62,336 |
| **Grand Total** | **675,472** | **1,550,832** | **2,220,448** | **4,446,752** |

Notes:

1) -- = Data was not collected or analyzed due to weather(precipitation or fog) interference and/or radar mechanical downtime.
2) m = meters
3) km = kilometer or 1,000 m
3) Count = the number of targets detected within 1 km starting at 250 m from the radar and out to 1,250 m over a 24 hour period
4) AMWL = above mean low water level
5) RSZ = Rotor Swept Zone = 27 m (89 feet) to 202.5 m (664 feet) AMWL

# APPENDIX D

# BAT ACOUSTIC SURVEY PHOTOGRAPHS & FIGURES

**Figure D.1** Photo (1) of the East High and West High bat detectors on Crib, 2010

**Figure D.2** Photo (2) of the East High and West High bat detectors on Crib, 2010

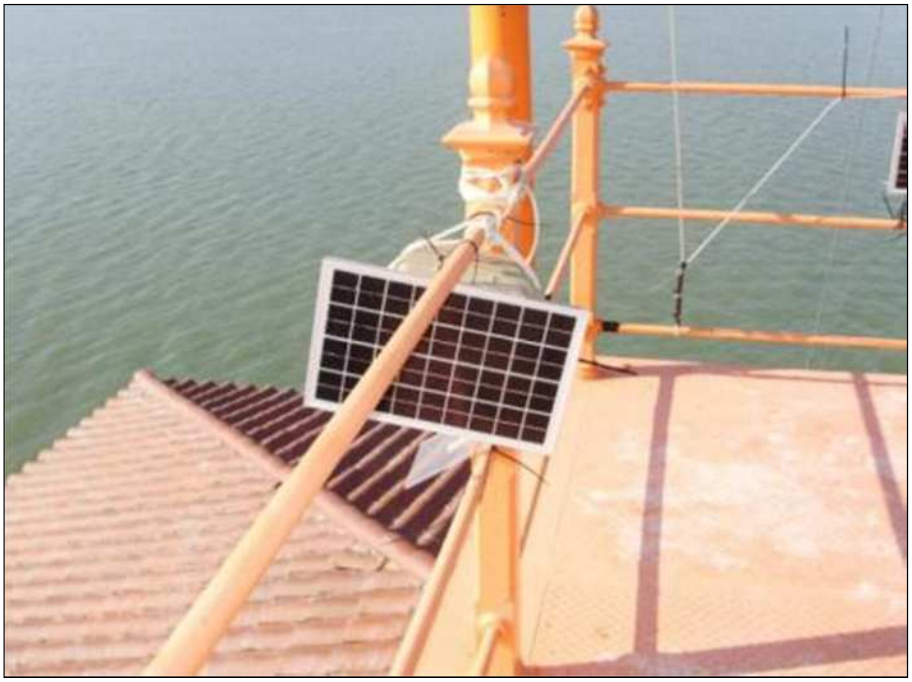


**Figure D.3** West Rail detector on Crib, 2010

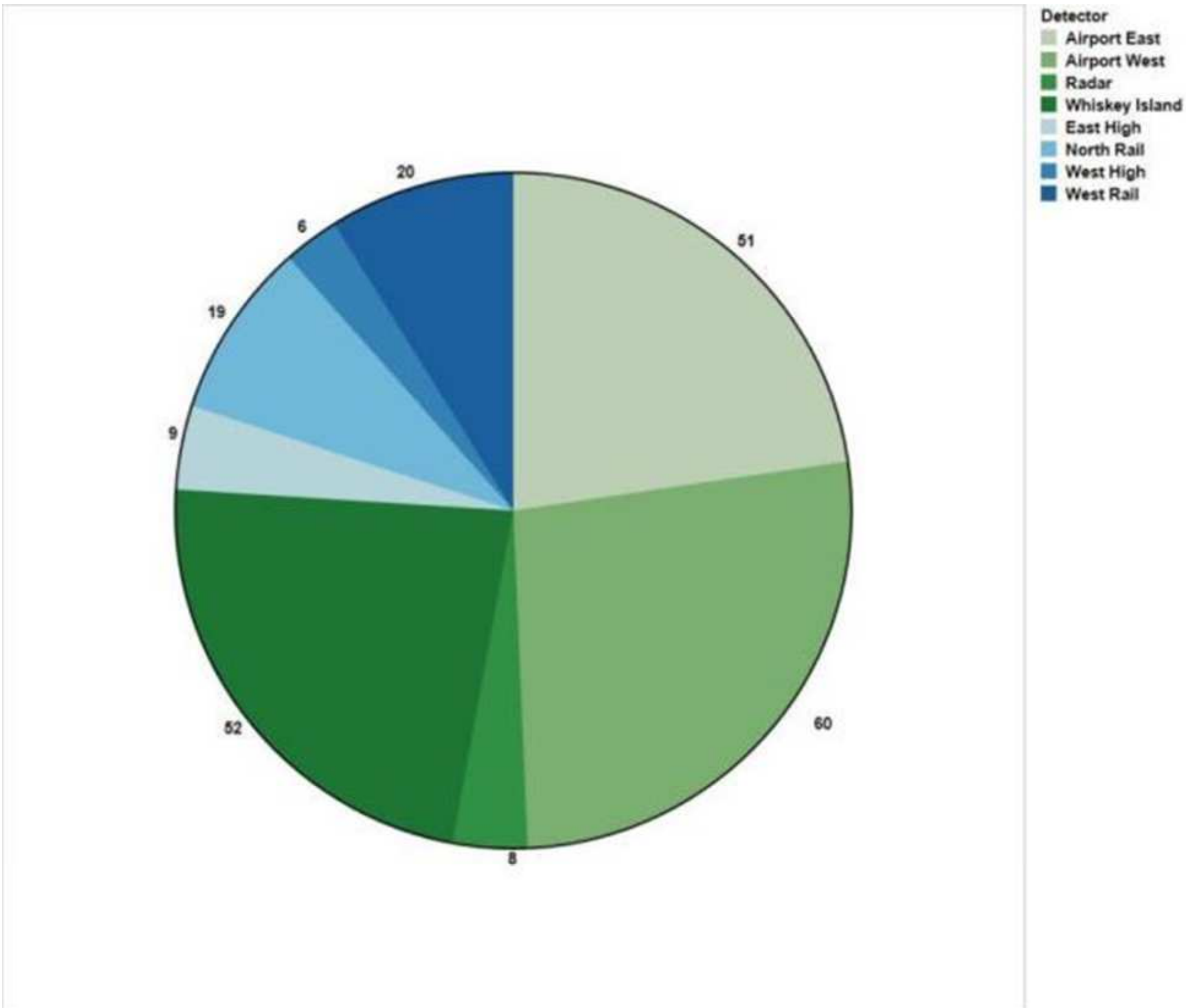
**Figure D.4** North Rail detector on Crib, 2010

**Figure D.5** Airport West detector on the shore of Lake Erie, 2010

**Figure D.6** Whiskey Island detector on the shore of Lake Erie, 2010


**Figure D.7** Radar detector at onshore location, spring 2010

**Figure D.8** Index of Activity values by species, spring 2010




Note:
Onshore detectors = green shading
Offshore detectors = blue shading

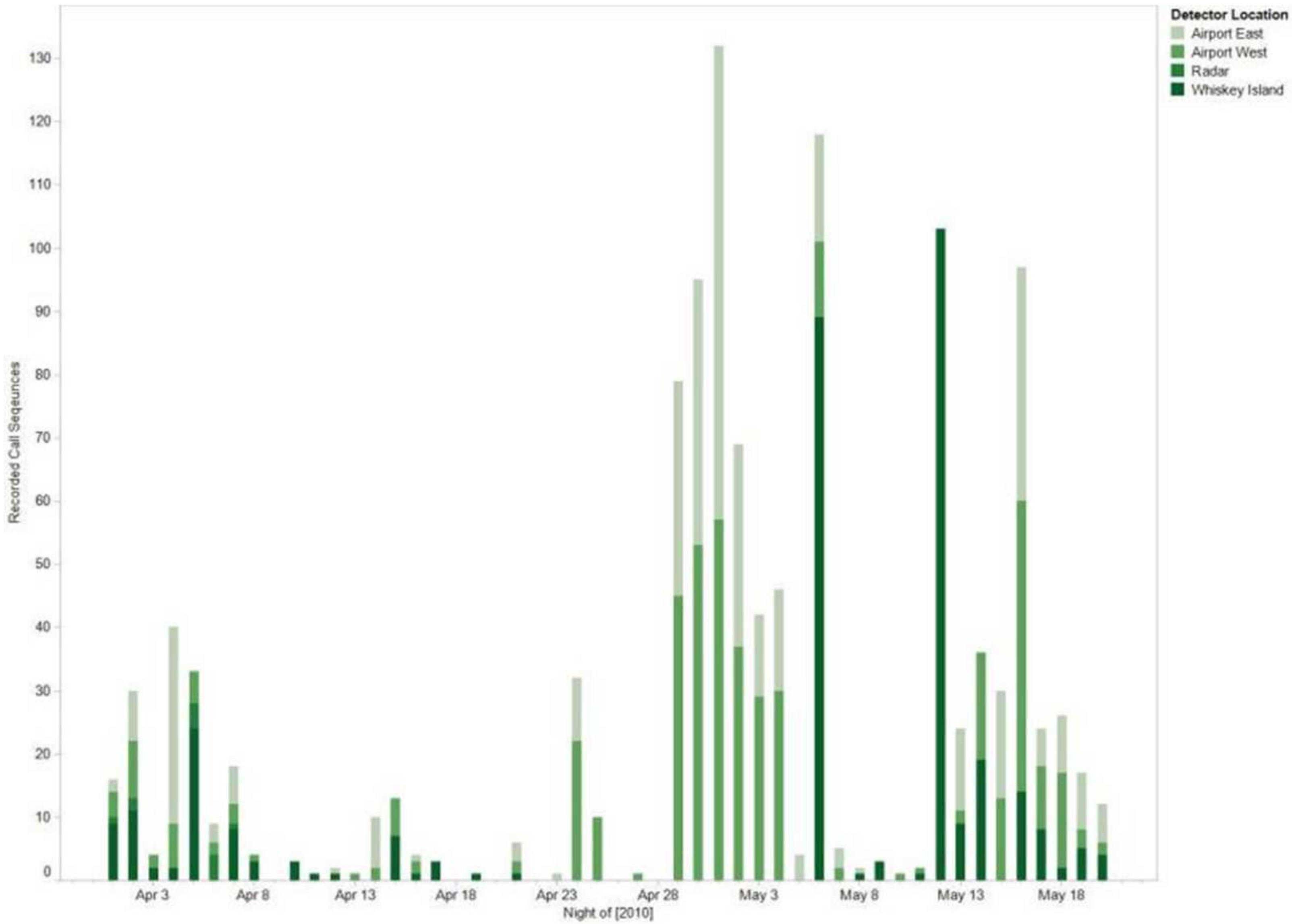



**Figure D.9** Total number of bat call sequences recorded per night by the onshore detectors, spring 2010

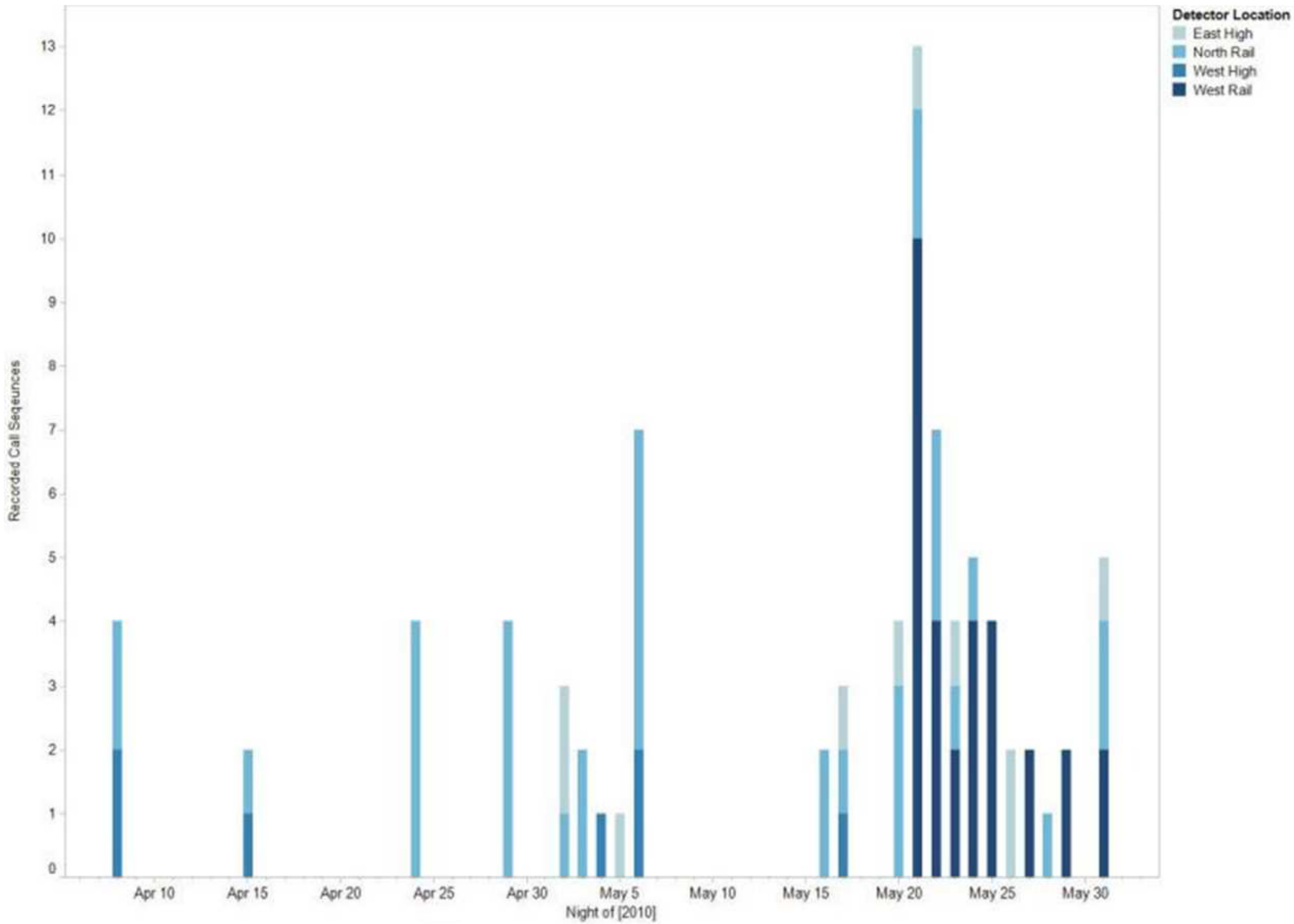
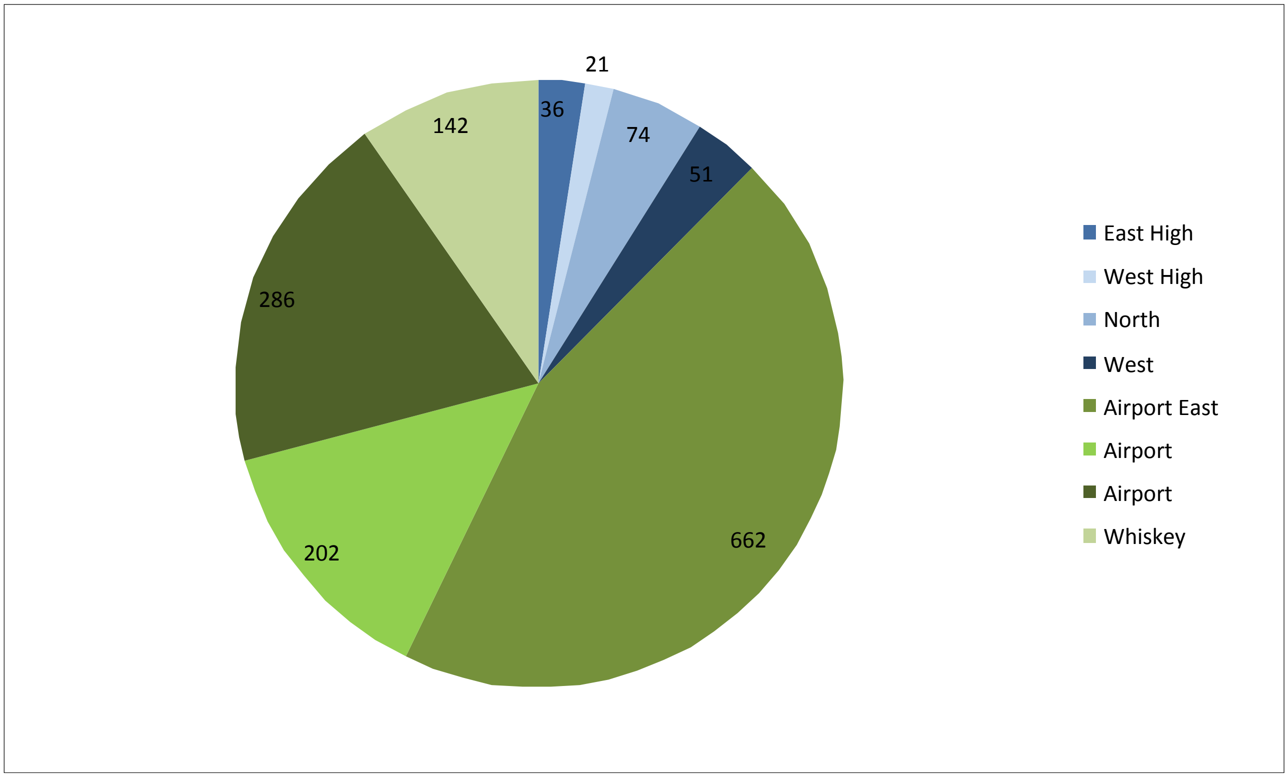
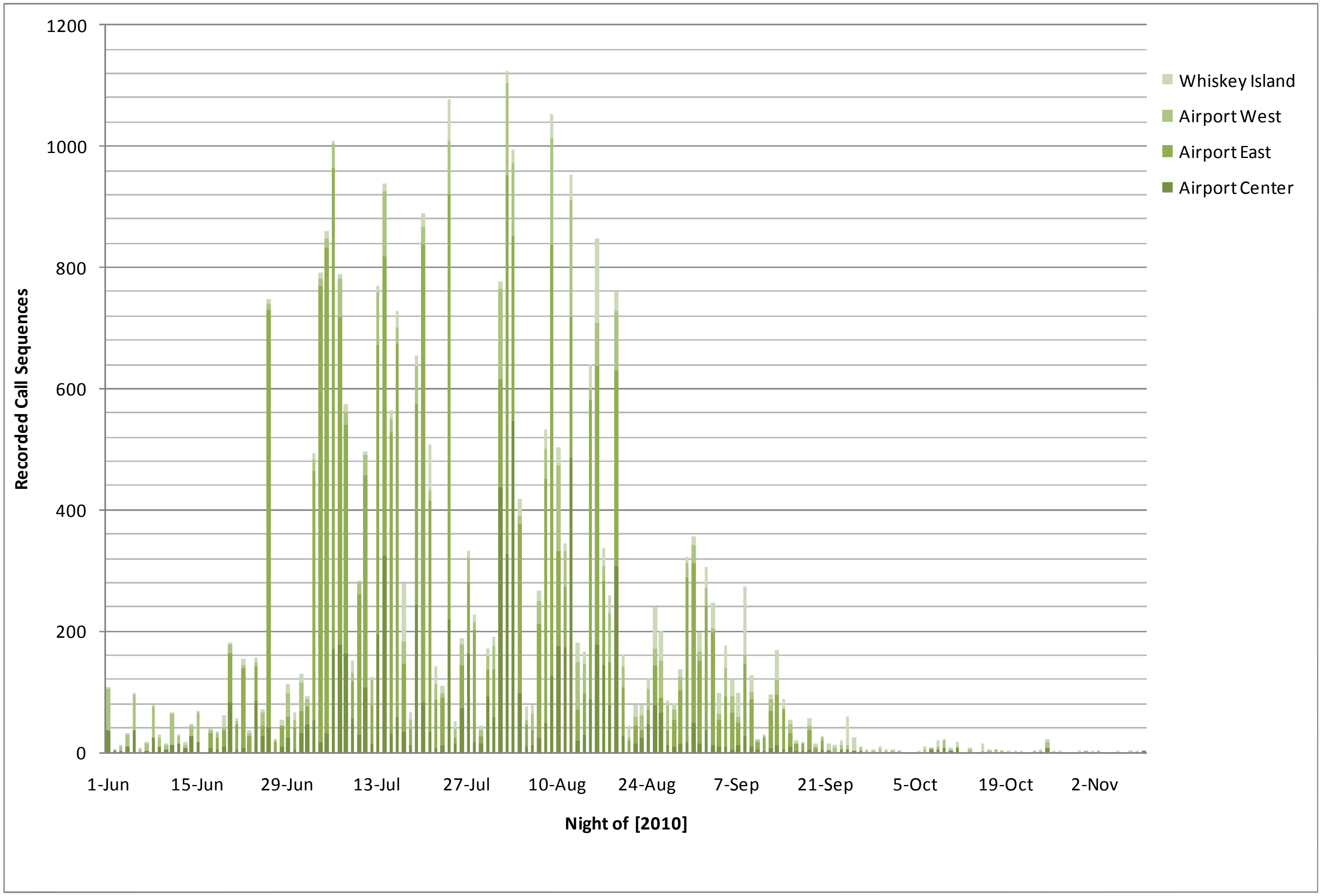



**Figure D.10** Total number of bat call sequences recorded per night by the offshore detectors, spring 2010

**Figure D.11** Index of Activity values by species, fall 2010




Note:
Onshore detectors = green shading
Offshore detectors = blue shading




* 25 nights in this figure were omitted from Airport East detector due to incorrect date recording (data recording malfunction).

**Figure D.12** Total number of bat call sequences recorded per night by the onshore detectors, fall 2010

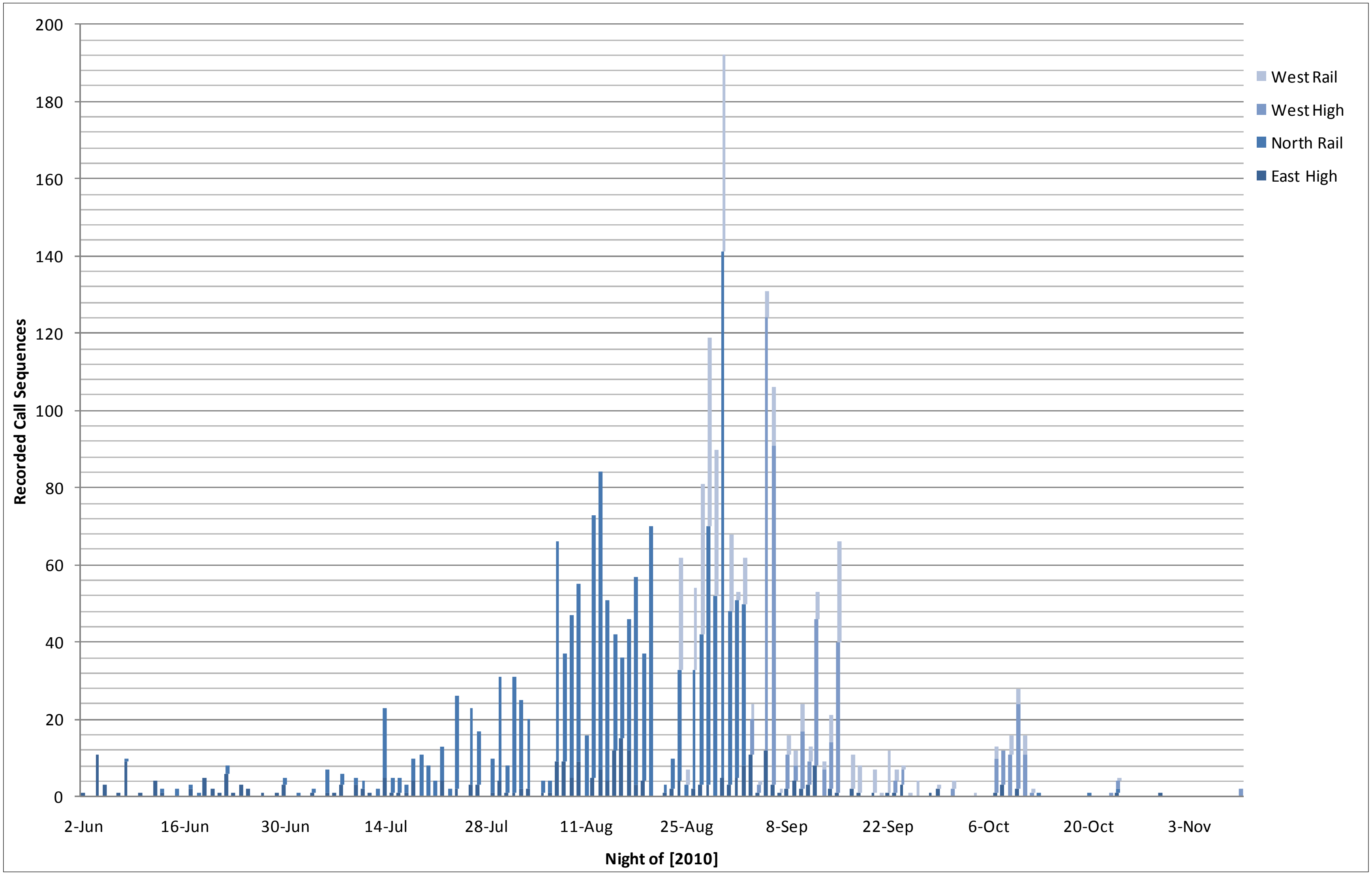



**Figure D.13** Total number of bat call sequences recorded per night by the offshore detectors, fall 2010