Migratory Bird and Bat Monitoring in the Thousand Islands Region of New York State

Final Report

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Biodiversity Research Institute (BRI) is a nonprofit organization located in Gorham, Maine. BRI's mission is to assess emerging threats to wildlife and ecosystems through collaborative research, and to use scientific findings to advance environmental awareness and inform decision makers.

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FRONT PHOTO CAPTIONS*:* Silver-haired bat on Grindstone Island, New York; Bat acoustic detector being erected on Grindstone Island, New York; Adult male American Redstart. Photos provided by BRI staff.

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Executive Summary

Biodiversity Research Institute used a variety of complementary methods to study bird and bat migration in the Thousand Islands region of New York State. These methods included captures, visual surveys, and passive acoustic studies of bird and bat populations on Grindstone and Carleton Islands in the fall of 2011 and spring of 2012, as well as analysis of NEXRAD radar data from 2010-2012 for the Thousand Islands region (eastern Lake Ontario and the western St. Lawrence River, including focal islands of Grindstone, Carleton, Galloo, Stony, and Grenadier). This report includes a summary of background and project goals; a detailed description of project methodologies; project results from the capture, census, acoustic, and NEXRAD project components; analysis of the data, including a comparison of abundance and diversity of migratory birds between major habitat types; NEXRAD analysis of migratory movements and relative abundance throughout the study region; a comparison of results obtained from different monitoring methods; and a characterization of spring and fall migration timing, patterns, composition, and locations for both birds and bats in the region.

Avian captures and acoustic detections were much higher in fall than in spring, and included large proportions of warblers. Acoustic monitoring revealed different species profiles between islands, possibly due to differences in habitat, and detected several species that were not detected via captures or visual surveys on Grindstone Island. There were no significant differences in avian capture rate or species diversity on Grindstone between fields vs. forested habitats, though field nets had wider variation in capture rates and lower species richness on average.

Bat captures were much less frequent than expected. The effects of WNS on local bat populations clearly impacted our detections rates in this study, but the causes of our low detection rate for tree bats remains unclear. No Indiana bats were definitively identified on Grindstone or Carleton Islands, although acoustic detections from both islands included possible calls from this species. Eastern red bats were detected in much higher numbers in fall than in spring (via both captures and acoustic monitoring), possibly suggesting that this species changes migratory routes between seasons or was otherwise less available to be detected in spring via commonly used monitoring methods.

Measures of migratory exodus via NEXRAD radar analysis from island and open water locations were not significantly different from each other, and clear exodus signatures were regularly detected from locations in Lake Ontario. As a result, our measures of migratory exodus were assumed to be flawed, possibly due to ground clutter or other factors, and we focused primarily on peak migratory activity from the middle of each night for analyses of broader migratory patterns and to compare results obtained from our three primary monitoring methods (banding, passive acoustics, and NEXRAD). MANOVA modeling found that several environmental variables were important for describing migratory activity, as measured via these monitoring methods: frontal passage, wind direction, and time of year. However, the migration monitoring techniques employed in this study were not highly correlated in all environmental conditions. Peak NEXRAD activity during nighttime did not correlate with the assessments of birds on the ground (banding) and those migrating close to the ground (acoustics) unless environmental conditions were taken into account. Monitoring results were more highly correlated during tailwind conditions, in both fall and spring; on nights when migrants had the greatest chance of moving, we saw the most alignment in these separate indices of abundance. In general, NEXRAD detected higher levels of migratory activity during tailwinds; acoustics detected more birds in headwinds; and banding showed no clear pattern in this regard.

While coastal migratory activity was high in both seasons, migratory activity over Lake Ontario appeared to be much higher in spring than fall. This may represent a more risky migratory strategy for animals in the spring, when they are competing to arrive first at the breeding grounds. In fall, migratory activity seemed to be higher around the eastern edge of Lake Ontario, as many animals circumvented the lake instead of crossing it. These observed patterns are similar to those noted in other recent studies in the region. While NEXRAD is useful for describing such broad migratory movements, it is much less useful for predicting risk to migrants from wind power development at a site level; other techniques like nocturnal

acoustic monitoring and banding are required to provide site-specific context. Given the significant differences in migratory activity between years, however, more than one year of such studies may be required to accurately characterize a site's value as a migratory stopover location.

Introduction

A diverse community of migratory birds and bats pass through the Great Lakes region twice a year. The lakes themselves act as barriers to migration that funnel and condense migrating species on the many islands and peninsulas in the region. These same shoreline locations that act as migratory hotspots also tend to be areas with good wind resources and are sought after for wind power development. While the effects of wind power on migratory populations are still being explored, it is clear that responsible siting of wind power facilities must take into account migratory routes and hotspots to avoid injury to these populations (Drewitt and Langston 2008). The Biodiversity Research Institute (BRI) monitored migratory bird and bat migration in the Great Lakes region using a complementary methodological approach of bird and bat banding (capture surveys), visual and aural censuses, passive acoustic monitoring, and NEXRAD (Next Generation Radar) analysis to estimate migratory patterns and abundance on a variety of scales. This multi-tiered design allowed for collection of detailed migratory data on high priority study islands, and also allowed us to compare results between methods and to examine regional migration patterns throughout the study area. Our results can be readily incorporated into spatial planning efforts and used to inform future wind power development siting and possible mitigation.

Background

Increased development of wind energy promises to help reduce dependence on fossil fuels, but the rapid development of the on-shore, utility-scale wind energy industry in the U.S. has led to some unexpected environmental impacts. Both onshore and offshore wind development may affect migratory birds via direct effects, such as collision mortality; via behavioral changes (e.g., turbine avoidance), that can lead to short- or long-term habitat loss, reproductive or survival impacts; and indirect effects, such as changes to prey distributions (Exo et al. 2003). For many terrestrial wind facilities, direct collision mortality has been a primary concern; large numbers of birds and bats are being killed at wind energy facilities in both forested and agricultural landscapes (Kunz et al. 2007a; Arnett et al. 2008). Recent evidence from Ontario's Wolfe Island wind facility in the St. Lawrence River indicates that coastal and shoreline locations may also have high mortality rates (Stantec 2010). Some of the highest mortality rates in North America have occurred during past migration seasons at the Wolfe Island and Maple Ridge wind facilities in southern Ontario and upstate New York. As such, reliable quantitative estimates of migratory species' population abundance, movements, and habitat use in this region may be important for siting future wind facilities. The identification of migration routes and stopover hotspots, and an understanding of how the importance of these areas may change with season or environmental conditions, is critical to accurately assess risk and minimize impacts from wind energy facilities (Exo et al. 2003).

Birds

Avian migration across and around the Great Lakes is well-documented, including such famous migration hotspots as Long Point Bird Observatory on Lake Erie (Mackenzie 2012). The lower Great Lakes are identified as an area of continental significance in the North American Waterfowl Management Plan, and most areas of the coastal Great Lakes contain large concentrations of migrant landbirds during spring, fall, or in both migration seasons (Ewert and Hamas 1996). This coastal concentration of migratory landbirds is suggested to occur in large part due to a barrier effect, in which birds wait to cross large bodies

of water until weather conditions are favorable or they have stopped over and built up energy reserves (or perhaps choose to migrate around the barrier, thus avoiding it altogether; Diehl et al. 2003). Regardless of cause, migrant abundance and diversity are higher on average along the coast of the Great Lakes than anywhere else in the region (France et al. 2012). Diverse habitats in the coastal Great Lakes also make it a significant stopover areas for migrants, and by some estimates every major habitat type bordering the lakes probably harbors relatively high concentrations of migrants during certain times of year (Ewert and Hamas 1996).

Migratory birds are federal trust species and many of their populations are declining. Mortality rates of populations during migration are generally poorly known, but based on available data may be high enough to cause the observed population declines (Sillet and Holmes 2002, Newton 2004). Thus, understanding how migratory birds use the aerosphere and stopover habitats is useful for conservation planners, regulators and developers. Unfortunately, estimating migratory abundance and understanding migratory patterns is notoriously difficult, especially at larger scales, but recently developed methods such as avian passive acoustic monitoring (Evans 2012) and NEXRAD monitoring (Chilson et al. 2012a) can provide valuable insights into migratory activity.

Bats

New York has three common migratory tree bat species: the Eastern red bat (*Lasiurus borealis*, LABO), Hoary bat (*L. cinereus*, LACI), and Silver-haired bat (*Lasionycteris noctivagans*, LANO; Table 1). Unlike other species of vespertillionids that are present in the Great Lakes region, these bats are largely solitary, only congregating to mate along inland and coastal routes around the time of fall migration (Cryan 2007). Long-distance migration of other vespertillionids is limited to observations of the Indiana bat (*Myotis sodalis*, MYSO) with at least one individual documented to have traveled over 325 km between hibernacula and summer roost sites (Kurta 2002, Winhold and Kurta 2008). As several hibernacula containing *M. sodalis* are known within this radius of the Thousand Islands region, it is possible that Indiana bats may use the islands as migratory stopover points after spring emergence. Shorter migratory movements from mainland populations to the islands are also possible.

In addition to the Indiana bat, other species of cave-hibernating bats present in the Thousand Islands region include the Little brown bat (*M. lucifugus*, MYLU), Northern long-eared bat (*M. septentrionalis*, MYSE), Eastern small-footed bat (*Myotis leibii,* MYLE), Tri-colored bat (*Perimyotis subflavus*, PESU) and Big brown bat (*Eptesicus fuscus*, EPFU). Diverse habitats, large areas (>100ha) and availability of roosting sites in abandoned buildings and caves suggests that many islands along the St. Lawrence River may support year-round populations of these species, all of which are known to migrate short distances after emergence from winter hibernacula (Frick et al. 2008). Given the tremendous impact that white-nose syndrome (WNS) has had on bat populations in recent years (Fenton 2012), the stability and metapopulation dynamics of bat populations in the area are of interest to conservationists and regulators.

Objectives

The goal of this research was to provide the U.S. Fish and Wildlife Service with data on the migratory movements of birds and bats in priority areas of the coastal Great Lakes, in order to help guide the siting of wind power proposals and minimize environmental impacts of wind energy development to bird and bat populations. Specific objectives for the study area (the western St. Lawrence River and eastern Lake Ontario) were to gain detailed information about bird and bat migration for a group of high priority islands, and to use remote data collection techniques to cultivate a broad understanding of migration throughout the study area. To achieve these objectives we used four main types of data collection for birds and bats:

(1) Bird and bat migratory capture surveys (banding);
(2) Visual and aural censuses of diurnal birds;
(3) Passive acoustic monitoring for birds and bats; and
(4) NEXRAD analysis of migratory patterns.

Methods

Study area

The five priority study islands of Grindstone, Carleton, Grenadier, Stony and Galloo in upstate New York (Figure 1) were selected for study by the Conservation Planning Assistance Program of the U.S. Fish and Wildlife Service. They are in an area of New York with the potential for impacts to birds and bats from wind facilities, as demonstrated at the Maple Ridge and Wolfe Island wind farms nearby. Banding of migratory birds and bats was conducted on Grindstone Island, an island of approximately 39 km^2 in the St. Lawrence River (Figure 1); this island is large enough to have a variety of habitats for use by migrants, including forest and grasslands, and has large tracts of undeveloped land that could be used to operate banding stations during the study period. Grindstone and nearby Carleton Island were the locations for both avian and bat passive acoustic studies (Figure 2). No field studies were conducted at the remaining three study islands, but they were included with Grindstone and Carleton Islands in NEXRAD radar analyses of regional migration patterns.

Visual surveys for birds

Researchers conducted daily point counts at a site midway between the bird banding station and avian passive acoustic detector (Figure 2). The point count location was on the edge of a cliff overlooking part of Grindstone Island and the St. Lawrence River. Each point count was conducted over a 10-minute time period; recorded data included species heard or seen, numbers of individuals, and approximate distance from observer, according to established protocols (Ralph et al. 1995). Point count data were not analyzed in conjunction with other monitoring techniques, for several reasons. First, two different observers conducted the fall and spring point counts, and inter-observer differences are known to be substantial in such counts. Second, they are a relatively short survey that makes detection of often highly spatially clustered and temporally variable migrants difficult (Diefenbach et al. 2003). As a result, the data can be useful for detecting species that are not often caught in other survey types (e.g., Cerulean Warbler), but are not a reliable index of abundance, particularly in non-breeding seasons (Faaborg et al. 1996). For these reasons, point count data are summarized in the results section and in Appendix III, but no additional analysis of these data was conducted.

Capture surveys for birds

We captured birds each day where weather permitted from 1 September – 31 October, 2011 and 1 May – 1 June, 2012 on Grindstone Island (46 days of netting and 3,754 total net hours in fall 2011; 28 days of netting for 3,016 total net hours in spring 2012). We placed 12 m long, 2.5m tall, 30mm mesh mist nets strategically around the study plot and checked each net at least once every 45 minutes. Birds are passively caught in these nets due to their lack of familiarity with the habitat and their inability to detect the finely meshed nets. Between 10 and 20 nets (usually 18 to 20) were open on any given day (Table 2), based on weather, staffing, and other considerations. When conditions were favorable (i.e., no high winds, rain or cold temperatures) nets remained open for at least 6 hours starting at sunrise (after Ralph et al. 1995). Nets were located in a variety of habitat types. Once captured, we identified each individual to species, placed a uniquely numbered USGS band on the bird's leg, and determined the age and sex of the individual. Morphometric measurements of unflattened wing chord and tarsus length were also collected, along with data on energetic condition via body mass, an estimate of body fat and an estimate of pectoral muscle mass.

Lastly we evaluated the quality of feathers and what feathers the bird was molting at the time of capture. The bird capture site remained the same in the both the spring and fall field seasons (Figure 2, Table 2).

Capture surveys for bats

Bat captures and acoustic monitoring occurred between 3 August and 6 October, 2011 and 15 April – 29 May, 2012 (51 nights of netting and 2,754 total net hours in fall 2011; 37 days of netting and 1,998 total net hours in spring 2012). During the fall season two bat netting sites were situated at the northeastern head of the island crossing the road on either side of Delaney Marsh (Table 3; Figure 2). Habitat in the area consisted of mature secondary deciduous forest with a dominant structure of sugar and striped maple. The Delaney Marsh borders a large inlet of the St. Lawrence River, and netting locations were situated 150-200m from this water source. Due to construction activities, one site was moved in the spring of 2012 to the southeastern side of the island (Figure 2). The site had a similar forest structure and proximity to water, although more shagbark hickory was noted in the forest patch.

Throughout the duration of the study we trapped each site on alternating nights six days a week. Nets were deployed during two sessions each night for three hours after sunset and three hours before sunrise. To avoid stress to captured bats, nets were not deployed during periods of heavy rain, high winds, or temperatures at or below freezing. Due to high road traffic we suspended work on Saturday nights shortly after beginning the study. A total of three Triple High Forest Filter systems (Bat Conservation and Management, Carlisle, PA) suspended with Avinet (Dryden, NY) bat specific mist nets were opened for bats at dusk on each night of trapping. A triple-high set consisted of three 5m tall nets stacked vertically a total of 15m high (Figure 3). The length of nets deployed was influenced by habitat and corridor width at each location (Table 3). All nets were disinfected between trapping nights and sampling equipment was disinfected between bats according to the USFWS Bat Disinfection Protocol (USFWS 2011).

Bats were identified and morphometric data recorded on sex, weight, forearm length, ear length and hind-foot length. Bats were also given a wing score value during assessment for past white-nose syndrome infections (WNS), according to established protocols (Reichard and Kunz 2009). Photographs were taken of all *M. lucifigus* caught for verification purposes. Finally, all bats were banded with uniquely numbered aluminum clips affixed around the forearm and released within 20 minutes of capture.

Passive acoustic monitoring for birds

Most bird species migrate at night, and many emit short vocalizations during flight (Farnsworth 2005, Evans 2012). These flight calls are thought to be a form of communication between individuals, or possibly serve as a type of "echolocation," helping birds determine their altitude (Evans 2012). Many bird species can be identified by their vocalizations, so nocturnal acoustic monitoring stations can achieve species-specific presence data and indices of abundance for birds that vocalize during migration. Such monitoring stations also sample a different cohort of birds than does capture (banding), including those species that are active at night or stay high in the habitat during daylight hours.

Avian acoustic monitoring occurred nightly for eight hours (beginning fifteen minutes after dusk) on Grindstone and Carleton Islands during the fall of 2011 and spring of 2012 (Table 4). Two Song Meter 2 acoustic recording setups (Wildlife Acoustics, MA) that store data on flash cards for subsequent downloading and analysis were deployed with weatherproof microphones designed especially for recording distant night flight calls in the sky. Microphones were set atop 5.5m poles and Plexiglas plates to reduce ground-level noise (Figure 4), and operated for eight hours each night beginning and nautical sunset. The use of a single acoustic monitor to characterize each site is common practice for passive acoustic avian studies (e.g., Evans 2012), due in part to the labor-intensive data analysis required for each set of recordings. Because of this practice, it is important that the location of each monitoring setup be carefully chosen to ensure a clear field of detection. Both monitors in this study were deployed in open fields with clear north-south fields of view. Detection distance is influenced by factors such as humidity, temperature, air pressure, call frequency and amplitude, and vegetation and other obstacles. As such, the detection cone

for passive acoustic detectors varies widely within and between sites. A recent study of Golden-crowned Warblers (*Basileuterus culicivorus*) indicated that Song Meter detection range during calm weather was around 75 meters for that species (Warren 2011).

Bird acoustic analysis was conducted using Tseep and Thrush (Old Bird Inc.) and Program Raven (Cornell Lab of Ornithology). Tseep and Thrush are software programs used to isolate potential night flight calls from the recordings. Thrush is tuned to pick out calls in the 3-5 KHz range while Tseep focuses on higher pitched calls greater than 6 KHz. The isolated files were then brought into Program Raven for species identification (via visual analysis of audio spectrograms) by BRI ornithologists Robert Lambert and Evan Adams. Calls were identified to species or to a complex of species with similar calls (Evans 2012, Murray 2004); calls that could not be definitively identified to species or species grouping were labeled as "no ID" but were used in analyses of nightly migratory activity (Evans 2012). Non-flight calls (such as territorial calls) were excluded from the dataset. Tseep and Thrush use automated detection algorithms that are not as efficient at detecting flight calls as trained human technicians; standards checking involved manual analysis by technicians of five randomly selected 20-minute samples from each Song Meter to compare number of calls detected via automated and manual analyses.

Passive acoustic monitoring for bats

Some bat species are not well represented in capture surveys, but are frequently recorded in audio surveys (or vice versa). For this reason, high quality bat surveys should include both survey components (O'Farrell and Gannon 1999, Manley et al. 2006). Two bat acoustic monitoring units (Petersson D500X detectors) were mounted on 10m poles facing the closest water body; at the Grindstone Island study site the detector was located next to a 50-meter wide inlet into Delaney Marsh, oriented northeast, and approximately 10m from the water's edge. This location was directly adjacent to a large stand of deciduous hardwoods dominated by American elm and silver maple (Table 4). On Carleton the unit was situated along a small stand of hawthorn within an open field historically used for cattle grazing, facing southwest over a 10x5m pond located 10m from the detector. Units were run continuously throughout the fall 2011 and spring 2012 field seasons with battery replacement and data retrieval occurring every five days. The use of a single acoustic monitor to characterize a site is common practice for bat acoustic studies (e.g., Buler et al. 2012), due in part to the labor-intensive data analysis required for each set of recordings.

Recording was started one hour before sunset and ended one hour after dawn. Sensitive between 5 and 200 kHz, the D500X automatically records 5 seconds of sound when an ultrasonic frequency is first detected. This sensitivity is similar to that of the Song Meter SM2BAT recorder from Wildlife Acoustics, which in a recent study regularly detected calls from 40 meters away (Adams et al. 2012), although it must be noted that detection distance is likely to vary with humidity, temperature, air pressure, call frequency and amplitude, and vegetation and other obstacles. Bat acoustic detection differs from our avian detection methodologies in that the microphones are optimized to detect bats flying within a horizontal plane to the detector, unlike the Song Meter setup which is optimized to detect flights of birds above the unit. This is an unavoidable difference due to the low detectability of ultrasonic calls, which are best acquired when bats call directly towards the detector unit. To increase detectability we recorded 'full spectrum' sound files, a method which does not compress or otherwise alter the data as it is written to the card. Although full spectrum data is time-intensive to analyze, this method of recording allows the identification of partial and low-quality calls with greater precision than other bat acoustic monitoring systems such as zero-crossing Anabat. After data collection, files were analyzed using the Sonobat NE 3.1 software (Arcata, CA). Due to high insect activity during the fall season, a 15 kHz anti-katydid filter was selected during scrubbing and analysis. Scrubbing is an automated routine which identifies call files where bats are not present. A conservative 'Medium' filter was used that retains files where noise may obscure call sequences that a more rigorous filter may reject. All files which passed the filter were individually assessed for call sequences, and bats identified to species when possible.

For two species of bat, MYLU and MYSO, call sequences from the majority of call types cannot always be reliably differentiated to species. For instances where calls could not be identified to species, or fragmented / low quality signals were recorded, calls were identified to the lowest possible taxonomic group. Analyses were conducted by BRI mammalogists Jonathan Fiely, Carl Anderson, and David Yates, who have been trained by Sonobat personnel and Bat Conservation International (BCI) in the use of Sonobat software to identify bat echolocation calls.

NEXRAD analysis of migratory patterns

WSR-88 (NEXRAD) radar units measure reflected microwaves from matter in the atmosphere. In addition to detecting weather, such units can detect "bioscatter," or radar reflectivity caused by biological entities aloft, such as migratory animals in the atmosphere. Recent methods have been developed to analyze unfiltered NEXRAD data to estimate the relative abundance, direction of movement, speed, and altitude of migrants based on radar reflectivity data (Horn and Kunz 2008). When multiple animals are present, radar reflectivity values express cumulative reflectivity per volume of sampled air. The size of migrants can affect cumulative reflectivity; a goose, for instance, reflects back more microwaves than a warbler, so without knowing the identities of migrants, reflectivity alone cannot be directly translated to abundance of animals. However, reflectivity is directly correlated with biomass density in the atmosphere, and as such can be regarded as an index of migratory activity at the measured altitude (Horn and Kunz 2008, Chilson et al. 2012a). It should be noted that the average height of the volume of air sampled by the radar beam increases in altitude with distance from the radar station (e.g., see Figure 5). Thus it becomes increasingly difficult to detect low-level bioscatter with increasing range from the radar.

The results of NEXRAD analysis are superficially similar to traditional marine radar, but the data are collected over a much broader geographic scale and lack the single target identification abilities of site-based radar. Though they lack this fine scale resolution, NEXRAD data allow us to efficiently monitor migrants on a broad scale over the entire study area, and the monitoring may be done at any time of day or night (weather permitting, as weather fronts can obscure the presence of birds). Radar data analysis was conducted by collaborators Dr. Phillip Chilson and Charles Kuster at the School of Meteorology and Atmospheric Radar Research Center at the University of Oklahoma. Dr. Chilson is an internationally recognized expert in the use of NEXRAD data to examine biological migration.

We accessed data from 2010 and 2011 fall and spring migration seasons and the 2012 spring migration season from the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory database, housed at the University of Oklahoma. Data were accessed for the Fort Drum WSR-88D NEXRAD station (KTYX; Figure 5). We developed tools in MATLAB and open-source Geographic Information System (GRASS GIS; http://grass.osgeo.org/) to process three years of May, September, and October NEXRAD reflectivity radar data, weather data, and the vector images for the focal islands and for 30 standardized comparison sites around the study region (Figure 6). Data consist of mosaicked un-quality-controlled composite values of the radar reflectivity value (Z) with a spatial resolution of 0.01º x 0.01º (here we use the term "un-quality-controlled" in a meteorological sense, meaning that the radar data have not yet been filtered to remove non-meteorological signals such as bioscatter). Mean, maximum and minimum Z values were calculated for each five minute period, and then averaged in linear units over the time period of interest (in our case, either the hour immediately after sunset, when exodus of nocturnal migrants from stopover habitats was expected to occur, or the peak migration hours from two hours after sunset to two hours before sunrise). For all nights without weather inference, these values were converted to the more biologically relevant metric of reflectivity η, or scattering area per unit of volume (cm^2 per km^3). When values of η are log-transformed with a reference value of $\eta_o = 1$ cm^2 per km^3, the resulting quantity is known as $dB\eta$. The log-transform follows the relationship: $dB\eta = 10*\log_{10}(\eta/\eta_o)$, so a value $\eta = 1000$ cm^2/km^3 is equivalent to a $dB\eta$ of 30 (Chilson et al. 2012b). Log transformations of reflectivity data are common practice in the field of radar aeroecology to normalize reflectivity data for analyses (Chilson et al. 2012b).

Custom-written scripts for data mining, management, and interpretation used during this study will be made available in accordance with guidelines of the open-source geospatial community. Analysis of the resulting three-year dataset was conducted using generalized linear mixed models and ANOVAs in JMP v.9.03 (SAS Institute, Inc., NC).

As previously mentioned, the lowest height that can be sampled by NEXRAD increases with increasing range from the radar. The distances of the five islands considered in this study from KTYX were: 68 km (Grindstone and Carleton), 64 km (Grenadier), 61 km (Galloo), and 54 km (Stony). Taking the elevations of the sites (of both islands and radar) into account, the theoretical radar sampling volumes over the different islands are at heights above ground level of: 734-1914m (Grindstone), 731-1918m (Carleton), 707-1816m (Grenadier), 690-1760 m (Galloo), and 641-1588m (Stony). To evaluate the impact of this effect, a collection of control sites were chosen near the KTYX and the radar reflectivity corresponding to these sites were analyzed. The control sites were placed at equi-angular spacing (45°) on three co-centered rings (with radii of 30, 60, and 90 km) around the radar site (Figure 6). Note that the control sites on the 60-km ring had roughly the same distance from KTYX as the five islands. This allowed us to examine biological activity over the islands in comparison with a background signal, via other sites that had approximately the same radar beam height. Additionally, several control sites were selected to account for potential differences in migration activity based on topography. More on this is presented and discussed below. In the following discussions about radar results, the terms "NEXRAD sites" or "radar sites" refer to the locations of the five islands and 30 control sites, rather than the location of the KTYX radar itself.

NEXRAD analysis for peak migratory activity

The time of peak migration activity was defined in our study as the period from two hours after sunset to two hours before sunrise, and thus included the bulk of the period during which nocturnal migration occurs. A general linear mixed model (GLMM) was used to determine the site attributes most important to predicting this peak migratory activity (measured as average relative reflectivity dBη, as described above, over the nightly period from two hours after sunset to two hours prior to sunrise). The analysis included factors such as the type of substrate the site was placed over (water, island or mainland), year, season (spring or fall), Julian date, distance to the NEXRAD unit (because the altitude of the sampling area changes with distance, as described above), the elevation of the site relative to the NEXRAD unit (as higher-elevation sites can sometimes have higher levels of detectable radar activity, known as ground clutter), and wind direction and wind speed at 850 millibars (mb; roughly 5,000 ft in altitude) at midnight for each night with migratory activity data. Site and date were included as random variables. Interactions between all non-nuisance factors were explored (nuisance factors meaning variables that influenced radar detection but were not variables of interest, such as site elevation, which ranged from 74 to 450 meters above sea level, and distance from radar, which was between 30 and 90 km for all sites; Figure 6).

Spatial analysis of migratory activity data also involved the use of a general linear mixed model, in which we controlled for nuisance factors described above, and these bias-corrected results (least squares mean dBη values for each site) were mapped over the effective NEXRAD coverage area to look at relative abundance of migrants moving through the study area in relation to geographic features and variables of interest, such as season and wind direction.

NEXRAD analysis for exodus

To assess migratory exodus (the upward movement of birds into the aerosphere to begin nocturnal migration), we measured dBη values according to the same methodology as above, but for a period from sunset to one hour after sunset at each of the 35 sites. As with peak migratory activity, we utilized a GLMM to examine predictors that affected exodus; used a simplified GLMM to correct predicted values just for elevation and distance from radar; and used the predicted least squares mean dBη values from this second model in an ANOVA to compare exodus between individual sites across all years of study. Exodus data

were not used in the methods comparison below, for reasons which are discussed in the results and conclusions sections of this report.

Methods comparison

We compared the temporal patterns of avian banding, acoustics, and NEXRAD data from Grindstone and Carleton Islands to develop an understanding of the relative utility of each method for monitoring migratory populations (Table 5). To compare our banding results to other banding stations across North America and to provide the most unbiased possible estimate of relative migratory bird abundance, we summarized capture data by dividing the number of new birds captured for each day by the number of net hours (i.e., the number of 12 m nets open multiplied by the number of hours each net was open). Bat capture data were too sparse to analyze in a similar way, so we examined the relative abundance of the bat species caught and the temporal patterns of capture.

For the methods comparison, acoustic detections were quality controlled to only include migratory flight calls from passerines. No bat acoustic data were eliminated based on species, and all types of ultrasonic sounds (including feeding buzzes) were analyzed. All detection data were subsequently standardized by how long the detector was turned on for any given evening.

NEXRAD data were summarized for each evening by averaging dBη values from two hours after sunset to two hours prior to sunrise each evening—the period of highest migratory activity—as described above. Data on wind speed and wind direction, atmospheric front passage, and date were used as covariates in this model. Wind speed and direction were obtained at 850 millibars (mb) of atmospheric pressure (roughly 5000 ft above sea level) at midnight for each of the days of interest from the NOAA Storm Prediction Center. Front passage was determined by a biologist examining archival NEXRAD data for the site and determining if a frontal boundary that brought rain to the site passed between sunset and sunrise. As frontal passage disrupts migration and often forces birds to land, this variable was thought to increase the number of birds detected at the banding station.

New bird captures per 100 net hours (log transformed for normality), acoustic detections per hour (square root transformed for normality), and mean dBη values (also log transformed as described above) were compared to one another and to environmental covariates using a multivariate analysis of variance (MANOVA; Table 5). Model selection using Akaike's Information Criterion was used to select the model that best described the data.

Results

Bird captures and visual surveys

Two thousand ninety-six individuals of 71 bird species were captured during fall banding efforts, including 1,810 new captures and 286 recaptures of birds from the same location earlier in the season. There seemed to be a large number of boreal migrants, in particular, that passed through Grindstone Island during the fall migration season. The five most common species were the Myrtle Warbler (*Setophaga coronata coronata*), Magnolia Warbler (*S. magnolia*), Nashville Warbler (*Oreothlypis ruficapilla*), Golden-crowned Kinglet (*Regulus satrapa*), and Blackpoll Warbler (*S. striata*); six of the top ten species captured were warblers, in fact (Appendix II), and warbler diversity was quite high (22 species), which is fairly unusual at banding stations in the U.S. Other notable captures included an Orange-crowned Warbler (*O. celata*), a Pileated Woodpecker (*Dryocopus pileatus*), and several Ruffed Grouse (*Bonasa umbellus*).

Fall visual surveys (n=47) encountered 1530 individuals from 55 species (Appendix III), for an encounter rate of 31.2 birds per point count. Several individuals of rare species like the Cerulean Warbler (*S. cerulea*) and Black-billed Cuckoo (*Coccyzus erythropthalmus*) were also detected on the island during

non-study periods (e.g., outside of point counts or banding). Ceruleans, known to be early migrants, were all detected in late August prior to when nets were opened and point counts were initiated. Other species that were detected on the island but were never captured or detected during a point count include Philadelphia Vireo (*Vireo philadelphicus*), Northern Harrier (*Circus cyaneus*), and Red-shouldered Hawk (*Buteo lineatus*).

A total of 511 new birds and 196 recaptures were caught in the spring. The 196 recaptures were all originally banded by us at the same location, mostly within the same season. However, that total also included 36 birds banded on Grindstone the previous fall (mostly Black-capped Chickadees, *Poecile atricapilla*; Common Yellowthroats, *Geothylpis trichas*; and Song Sparrows, *Melospiza melodia*). Captures per net hour were less than half what they were in the fall (0.23 birds per net hour in spring, as opposed to 0.55 birds per net hour in the fall). Fifty-five species were captured in spring, also a clear drop in species diversity from the 71 species captured during the autumn field season. However, eleven new species were captured in the spring, including a Golden-winged Warbler (*Vermivora chrysoptera*), a Clay-colored Sparrow (*Spizella pallida*), a Hooded Warbler (*S. citrina*), an Indigo Bunting (*Passerina cyanea*), several Baltimore Orioles (*Icterus galbula*) and Mourning Warblers (*Oporonis philadelphia*), and large numbers of Yellow Warblers (*S. petechia*). Appendix II presents a comparison of species and numbers of birds caught at the Grindstone Island banding station in fall 2011 and spring 2012. The biggest differences in numbers of new captures between fall and spring were for Myrtle Warblers (530 more captures in fall than spring) and Magnolia Warblers (169 more in fall than spring); several other species, including Golden-crowned Kinglets, Nashville Warblers, Blackpoll Warblers, Tennessee Warblers (*Oreothlypis peregrina*), and Hermit Thrushes (*Catharus guttatus*), were also much more commonly captured in the fall. Yellow Warblers and Common Yellowthroats, both of which likely breed on Grindstone Island in good numbers, were much more common in spring than in fall. A few species, such as the Black-throated Green Warbler (*S. virens*), were caught in decent numbers in fall and were present in the spring but never captured; Black-throated Greens tend to stay higher in the treetops than some other species, and thus are likely underrepresented in national banding data (although for reasons unknown, they appeared to be lower in the canopy during the fall season on Grindstone). In both spring and fall, warblers represented a majority of captures (Figure 7).

Seven hundred ninety six individuals from 69 species were detected during spring point count surveys (n=27; Appendix III). While this is about half the number of individuals counted during fall surveys, the rate of birds detected per count was similar (29.5 per point count). As with banding data, Yellow Warblers and Common Yellowthroats were more commonly detected in spring than fall. A high proportion of individuals detected during spring point counts were suspected to breed in and around the banding station; many species detected in large numbers in spring are known or suspected to breed on the island, including Bobolinks (*Dolichonyx oryzivorus*), Black and White Warblers(*Mniotilta varia*), Brown-headed Cowbirds (*Molothrus ater*), Chipping Sparrows (*Spizella passerina*), and Chestnut-sided Warblers (*Setophaga pensylvanica*).

Nets for the bird banding station were placed in two major habitat types: field (grasses and small shrubs, with occasional isolated cedars) and forest (primarily oak, hemlock, cedar, and pine). Nets on habitat edges were generally considered to be in the "field" category. Of the 27 net locations used during the study, 11 nets were in field and 16 in forest. Two of the 16 forest nets were open for less than 20 hours, and thus were excluded from habitat analysis. Captures per 100 net hours and species richness (e.g., number of distinct species captured per 100 net hours) were examined for variation due to habitat type. There were no significant differences in capture rate (χ^2=0.012, df=1, P=0.913) or species richness (χ^2=0.971, df=1, P=0.338) between the two habitat types. However, field nets had a much wider variation in capture rates (41.74 ± 25.29 vs. 39.25 ± 8.25 captures/100 net hours) and lower mean species richness (9.54 ± 2.87 vs. 11.34 ± 4.09 species captured/100 net hours) than did forest nets (Figure 8). There was higher capture effort in forested areas (4,136 total net hours as opposed to 2,634 net hours in field habitats); corrected for this difference in effort, a higher proportion of individuals were captured in forest than field nets for most taxa

(Figure 9). Forested areas had more consistent capture rates, and also had greater species diversity on average, though this difference was not statistically significant. Sparrows (including juncos and towhees) were much more likely to be captured in field nets than in forested areas; most other taxa were more likely to be captured in forested areas, even correcting for greater effort in these areas (Figure 9). Corvids, thrushes, vireos and woodpeckers were all at least twice as likely to be captured in a forested area as in a field.

When looking at the top five species of warbler captured in fall, we see that Magnolia Warblers, Nashville Warblers and Common Yellowthroats make up the majority of the early season captures. In October Myrtle Warblers begin to dominate the activity of the station (Figure 10). This pattern is commonly seen at banding station throughout the northeastern United States. Temporal patterns of species capture were less distinct in spring, but Nashville Warblers were again early and Common Yellowthroats were common throughout the season, peaking in mid-May (Figure 11).

Bat captures

A total of 94 unique bats were banded in 89 nights of capture effort between the fall and spring seasons. Capture rates across both seasons were extremely low in relation to effort (n=123 captures in 4,642 total net hours, for an overall capture rate of 0.027 bats/net hour). Three triple-high nets, rotated nightly between two sites for three hours after dusk and three hours before dawn, resulted in only 101 total captures over 51 nights trapping in the fall, totaling 0.037 bats/net hour (Figure 12). Of these, 11 were recaptures and 14 were observed escaping from the nets before they could be removed. Most commonly captured species included LABO (45%; n=45), EPFU (35%, n=36), and MYLU (13%, n=13). Five MYSE and one LANO were also captured, and one unidentified *Myotis* sp. escaped before a positive identification could be made. In spring, 22 bats were captured in 42 nights of effort, including two recaptures and two bats that escaped prior to handling, resulting in 0.011 bats/net hour over the course of the season (Figure 13). Although this sample size is too low for statistical comparison between the two seasons, our fall capture rate was over three times that in spring. We captured fewer LABO in spring than in the previous fall (9%, n=2), along with EPFU (27%, n=6), MYLU (36%, n=8), and five LANO (23%). No MYSE were captured in the spring. All five LANO were captured at site #2 on the southeastern side of the island. One individual was captured in the fall and then recaptured in the spring (an EPFU captured on 3 August, 2011 and recaptured on 8 May, 2012).

Bird acoustic analysis

Numbers of avian flight calls detected on Grindstone and Carleton Islands during nocturnal passive acoustic monitoring in fall 2011 are presented by date and site in Figure 14. A total of 6,370 calls were detected; the number of calls detected per night ranged from zero to over 300 per site, with peak migration appearing to occur around 25 September. Although there is some variation between sites, temporal patterns of acoustic detections are quite similar between the two monitoring sites. The data approximate a normal distribution and look similar to the bird banding data. The number of higher-pitched ("Tseep") and lower-pitched ("Thrush") calls throughout the season varied temporally, with peaks in mid- to late September and early October, respectively (Figure 15). Thrush migration tends to be later in the season than migration for many warbler species, and this is reflected in the higher relative abundance of lower-pitched flight calls heard in October (Figure 15). Flight calls tended to occur in regular nocturnal patterns, with an immediate peak in calls just after sunset, followed by a longer second peak of activity between roughly two and five hours after sunset (Figure 16). Calls identified from the fall of 2011 are from fifty-six species (Appendix IV), including a Henslow's Sparrow (*Ammodramus henslowii*), which is listed as a threatened species in the state of New York.

In the spring of 2012, just 323 calls were recorded in the one month of study (May 2012), from 18 species (Appendix IV). The smaller number of total calls makes patterns more difficult to infer, but the data have a single mode on 12 May and are otherwise non-normal in distribution (Fig. 17). This lack of visible

data structure is likely due to the low number of detections. Unlike in fall, many fewer detections occurred at Carleton than Grindstone, and the temporal distributions of calls throughout the migration season appeared to be less tightly correlated between islands in spring as well. The temporal distribution of calls throughout the night lacked the early post-sunset peak commonly seen in fall, and peak activity at both sites occurred later than in the fall (around seven hours after sunset; Fig. 18).

A matched pair analysis indicated that there was no difference between the two islands in daily detection rates ($p=0.45$) across both seasons, though numbers of detections in the fall were roughly an order of magnitude higher than the spring at both sites. Evans (2012) conducted similar analyses on island and mainland sites around Lake Ontario in fall and spring of 2007 and 2008, and our results from Carleton and Grindstone were low compared to his results (roughly half the number of calls detected) in the fall and an order of magnitude lower in the spring. Differences in methodology and years of study prevent us from determining if these results are due to real biological phenomena.

There were almost exactly the same number of total detections from each island, but species assemblages were significantly different between islands ($n=4501$, $\chi^2=85.4$, $df=3$, $p<0.0001$) for the four major species groups for which there were more than 100 representatives in the database (wood warblers, sparrows, thrushes, and waterbirds). Numbers of sparrow calls detected were very similar between islands (380 sparrow calls detected on Carleton vs. 368 on Grindstone). More waterbirds, mostly Canada Geese, were detected flying over Carleton than Grindstone (128 vs. 22 calls), while more thrush (105 vs. 67) and warbler (1756 vs. 1675) calls were detected on Grindstone.

Standards checking (manual location of flight calls from 200 minutes of data, compared to automated detection algorithms in the Tseep and Thrush programs) indicated that on average Tseep and Thrush identified 31% of the flight calls present in recordings. Within each twenty-minute section of recording that was examined, the calls identified by the technician as birds were about 2.6 times as common as the flight calls picked up by the detection algorithms (summed across all samples, $n=320$ by human observer vs. $n=76$ via automated detection). However, these automated detection results appear to provide a reasonably good index of abundance—e.g., the more calls that occur in a given sampling period, the more are detected via these algorithms ($r^2=0.8$ using a simple linear regression model). Both of these results in are in line with previous studies that have used this methodology, although this Tseep and Thrush detection performance is at the low end described in the literature. While these automated detection algorithms are still not as efficient as human observers at isolating flight calls from recordings, our bird acoustic data can be considered a reasonable index of flight call activity. As such, the resulting acoustic data are particularly useful for: (1) Evidence of species presence at the study sites; and (2) Examination of nightly and seasonal patterns in migratory activity.

Bat acoustic analysis

Fall acoustic monitoring for bats positively identified the presence of at least eight species, all of which were expected to be present in the Great Lakes region. Carleton and Grindstone Island detectors averaged approximately six detections per night in fall 2011 over 50 and 60 active detector nights, respectively. A total of 643 confirmed detections were identified to species or species complex (Table 6). Fifty-four percent of detections on Carleton Island were migratory tree bat species (LABO, LANO, and LACI) in contrast to 46% on Grindstone Island (Table 6). Of particular note is the paucity of calls detected on Carleton Island from 12-19 August (Figure 19). During this period 14 EPFU and 2 LABO were detected during two nights of deployment, while on Grindstone 49 bats of five species were recorded during the same period. MYLE were detected on Carleton but not Grindstone, while PESU and MYSE were detected on Grindstone but not Carleton. PESU was detected within the first week of deployment, but not again for the duration of the project.

Spring acoustic monitoring confirmed the presence of all species noted in the fall with the exception of MYLE, which were not detected at either island. Technical problems related to firmware

malfunctions in the D500X resulted in several nights where data was not recorded (Figure 20). In total we collected 39 nights of acoustic data at Carleton and 43 nights at Grindstone in spring 2012. Six hundred and four call sequences were identified to their highest species complex, with 248 and 356 calls recorded on Carleton and Grindstone Island, respectively (Table 7). The proportion of tree bat activity fell to 24% of the total at Carleton Island and 20% at Grindstone. Only five LABO calls were detected in total, though the activity levels of LANO remained high at 111 calls recorded over 41 detector nights.

We did not positively identify the presence of Indiana bat (MYSO) during either spring or fall surveys, but the possibility of this species' presence cannot be discounted. One hundred and six *Myotis* calls were ambiguous in nature, with no clear defining characteristics in the call signatures that would allow us to positively identify the call as either a MYSO (*M. sodalis*) or MYLU (little brown bat, *M. lucifugus*). While all other species of northeastern bats have well-defined attributes and shapes to their acoustic signature, MYSO shares over 98% of MYLU's call space when described mathematically (Szewczak 2012), and visually appear virtually identical when comparing known species call libraries. Some calls were confidently identified as MYLU (n=98, Table 6, Table 7), as the species is known to have slightly greater variation in call structure (Szewczak and Harris 2013) which allows calls at these extremes of variation be positively identified as belonging to MYLU. In contrast, the characteristics of MYSO calls very rarely exceed the shared call space of the two species. For *Myotis* calls for which a confident determination could not be made, the designation 'LUSO' (*M. sodalis/M. lucifugus*) was used to indicate that the call could belong to either species. Carleton (n=42) and Grindstone Island (n=15) had LUSO detections in both spring and fall (Table 6, Table 7).

Both islands, in both seasons, exhibited similar trends in emergence of bats during the night. No calls were detected <1 hour after sunset, with an average earliest detection at 1.86 hrs (±1.01 hrs) after sunset. Bats were last detected >30 minutes before sunrise; the last detections of bat acoustic activity each night averaged 2.96 hrs (±1.35 hrs) before sunrise.

Given the nature of bat acoustic data, a fine-scale quantitative comparison of rates of detection between the islands has limited instructive value. Foraging behavior of bats often results in multiple passes by a single individual during a night, limiting the value of acoustics to broad estimates of activity and the presence of species on a given night. However, it is notable that both Carleton and Grindstone hosted similar diversities of bats, including the possibility of Indiana bats (MYSO). Only the tri-colored bat (PESU) was not detected on Carleton Island during either the spring or fall. Low detection rates for this species and for small-footed bat (MYLE) suggest these species may be infrequent visitors to both islands.

Other broad-scale patterns in detection rates were also similar between islands. For instance, there was a virtual absence of the red bat (LABO) at both islands during the spring; fall detection totals of LABO at Carleton (n=67, 23%) and Grindstone (n=67, 19%) fell to just 2 and 3 detections at Grindstone and Carleton, respectively (1% of each island's total captures for the season; Tables 6-7). This is in contrast to the rates of detection of the hoary bat (LACI), which remained steady at 2-4% of total detections per island in each season, and silver-haired bat (LANO), which represented between 17% and 26% of detections by island and season. Total numbers of detections were also consistent between islands and seasons, with 56% of all fall detections (n=643) and 59% of all spring detections (n=604) occurring on Grindstone.

NEXRAD modeling: Temporal patterns and environmental covariates for peak migratory activity

Patterns of migratory activity from periods in the middle of each night (e.g., from two hours after dusk to two hours before dawn) varied among years, seasons, and landscape features, as well as by date. Examples of nightly migration profiles for selected sites and dates are presented in Figures 21-23. Figure 21 illustrates the methodology adopted for the radar analysis. In Figure 21A, the various NEXRAD sites considered in the study are shown. Each site consists of a number of grid cells corresponding to pixels in a data matrix (Cartesian coordinates) that have been created and mosaicked from different NEXRAD data files (spherical coordinates). Such a raster image is shown in Figure 21B. The raster data for each collection

of grid cells for a NEXRAD site was then averaged to produce a measure of biological activity above the site as a function of time. See Figure 21C, where nightly activity from the five islands of interest along with two null sites are shown. The null sites are positioned over land and water as shown in Figure 21A. Next we consider a few specific examples of this analysis procedure for select days and different sites.

The first example (Figure 22B) is for radar observations collected on 1 May 2011. Nightly migratory activity was fairly consistent across the study area on this date, though temporal patterns varied slightly between locations; Site 13 (ice blue line), for instance, which is on the mainland near Oneida Lake, had lower migratory activity levels on average throughout the night. Sites 15 and 23 (over open water in Lake Ontario) had lower levels of migratory activity near sunset, but as the night progressed showed peak reflectivity levels as high or higher than the mainland and island sites examined. Closer to sunrise, activity over Sites 5 and 13 (inland sites) and Site 23 (in Lake Ontario) started dropping off earlier than did migratory activity at the island (Sites 1-2), coastal (Site 16) or other open water (Site 15) sites.

The second example shown in Figure 22C is for 12 May 2011. In this case, nightly migratory activity was fairly high at all sites (and began well before sunset at most sites as well), but there were three distinct migratory activity patterns that occurred at the examined sites. Inland sites 5 and 13 (orange and ice blue lines) steadily increased in migratory activity throughout the night, peaking just after sunrise; open water sites 16 and 23 (purple and black lines) had a clear peak in activity in the middle of the night; and the remaining three island and coastal sites (red, green and dark blue lines) showed an intermediate migratory pattern where activity remained relatively steady throughout the night. For several of the sites there appeared to be a peak in activity around sunset, perhaps related to an exodus of migrating animals. It is difficult to state definitively, however, whether or not the local maximum in reflectivity is indeed related to exodus (see below).

Finally we examine an example corresponding to radar observations for 31 May 2011 (Figure 22D). Several different patterns of migratory activity occurred at sites examined for this date; as with Figure 22C, the two island and the coastal mainland sites (red, green and dark blue lines) all showed very similar and consistent levels of activity throughout the night. One of the inland sites (orange line) showed a similar, although more active, temporal pattern. The two open water sites over the lake (purple and black) and the farthest inland site (ice blue), in contrast, had clear peaks in activity early in the night, followed by drops in migratory activity before dawn.

To capture more robust behavioral trends in observed migration, data from each month was averaged after removing days that contain weather interference. Examples of these calculations are presented in Figure 23. When nightly migratory activity patterns are averaged by site across the entire month of October, several consistent patterns begin to emerge (Figure 23B). Though all sites exhibit a similar temporal patterns of migratory activity, with a peak in migration activity between 2:00-3:00 UTC (10-11 PM EST), Sites 12-14 (the more inland and southern sites, represented by black, dark blue and ice blue lines in the figure) have consistently lower activity levels than do the more northern sites on focal islands and the coastal mainland. We can compare these results taken from 2010 with similar measurements for 2011 (Figure 23C). Similar groupings of sites occur on October 2011 and October 2010, in which Sites 12-14 appear to have different migratory activity patterns on average than do Sites 1-2, 9, and 16. There is a less defined peak in activity in October 2011 than during October 2010, however, and the timing of this peak activity appears to vary by location (unlike in October 2010). In 2011, the northern and coastal sites again have similar migration patterns, with a peak in activity around 10-11 PM; in contrast, the southern and inland sites peak in activity levels closer to 5:00 UTC (1 AM EST). With a peak in migration activity between 2:00-3:00 UTC (10-11 PM EST), Sites 12-14 (the more inland and southern sites, represented by black, dark blue and ice blue lines in the figure) have consistently lower activity levels than do the more northern sites on focal islands and the coastal mainland.

Although inspection of individual time histories of radar reflectivity for various sites on particular days can be both interesting and informative, one must turn to modeling to generate statistically significant

results. Important factors for determining migration activity (in a general linear mixed model with both fixed and random effects; r^2=0.84) included year, distance from the radar, land elevation, wind direction, season, and site type. Of the three years assessed (2010-2012), 2011 had significantly lower activity than the previous and subsequent periods (Fig. 24). Elevation was not significant, but did help to explain some variation in the model (it may have failed to come out as a significant term because there was minimal variability in elevation between sites). The model term that represented nonlinear changes in radar detection based on distance from the radar was close to significant. Season (spring or fall) wasn't a significant variable in and of itself, but interacted with several other terms in the model; wind direction at 850 millibars (roughly 5000 feet above sea level) interacted with season, for instance, so while there may not have been major differences between levels of migratory activity (dBη values) in spring vs. fall, there were significant differences between values from nights with north winds in the fall vs. north winds in the spring– which makes logical sense, as tailwinds from the north would be a more important predictor of migratory activity during fall than spring (MANOVA, Fig. 25A). The site type– whether it was an island, on the mainland, or over open water in Lake Ontario– again wasn't important by itself, but had an important interaction with season, indicating that the way migrants are using these types of sites varies between spring and fall.

NEXRAD modeling: Geographic patterns across the landscape

Over the three years included in the NEXRAD analysis, there was no significant difference in migratory activity between island locations, mainland locations, and locations over open water (in eastern Lake Ontario; Figure 6). However, mainland sites had significantly lower activity levels in spring than in fall (MANOVA, Figure 25B). When modeled least squares mean dBη values (in a GLMM controlling for distance from radar and altitude of each site) were mapped for each location, this change between spring and fall migratory patterns over the study area becomes clear (Figure 26). In fall, there are fairly high levels of migratory activity over northeastern Lake Ontario and many of our focal islands, while migration seems to be less prevalent at the water sites farther offshore. From a superficial glance at this it would seem that many birds flying south in the fall may approach the north shore of the lake and then fly around all or part of it, over the St. Lawrence River and the northeast shoreline of the lake. From there it seems that many birds may actually head east, towards the Atlantic coast (Figure 26A). During spring migration, areas of high activity appear to shift over Lake Ontario and away from the mainland (Figure 26B), although high levels of activity remain along the eastern shore of the lake in both seasons.

NEXRAD modeling: Temporal patterns, environmental covariates, and geographic patterns of exodus

As with peak migratory activity, we utilized a GLMM with both fixed and random effects to examine predictors that affected exodus. Important factors for determining migration activity during the hour after sunset included year, season, Julian date, site type (mainland, island or open water), and wind direction, although the model did not fit the observed data well (r^2=0.18). Exodus values from 2011 were lower than those for 2010 across all locations (consistent with peak migratory activity values, which also showed 2011 as significantly different from other years).

Predicted least squares mean dBη values from a simplified GLMM that corrected just for elevation and distance from radar were used to compare exodus between individual sites across all years of study. Within the hour after sunset, migratory activity at mainland sites was significantly higher than open water sites on average (p=0.0074), but island sites were not significantly different than either mainland or open water locations (Table 8; Figure 27). The island with the highest exodus value on average was Stony Island (19.388 dBη), followed by Galloo, Grenadier, Carleton, and finally Grindstone at 18.707 dBη); however, these values were not significantly different from each other (Figure 27). Open water locations, though they had lower mean activity levels during the exodus period than mainland sites, still maintained clear activity during this period and were not significantly lower than island sites. Exodus, as commonly defined, should not be occurring at open water locations, where land birds have no habitat in which to land and rest during the day. As such, the migratory activity measured in this study in the hour after sunset may represent

something other (or in addition to) true exodus, and the "exodus" values presented here should be interpreted with extreme caution. A discussion of this topic is included in the Conclusions section below.

Methods comparison for birds: Banding, acoustic monitoring, and NEXRAD

Temporal patterns of migratory activity, as measured via the migration monitoring techniques employed in this study, were not consistently correlated in all environmental conditions. Peak NEXRAD activity at night was not correlated with the assessments of birds on the ground (banding) or those migrating close to the ground (acoustics) unless environmental conditions were taken into account; raw correlations among the three variables were all below r^2=0.10 except the banding and acoustic data (r^2=0.49), and despite the statistical significance of the correlation between banding and acoustic results, the species compositions detected by the two methods were statistically dissimilar (χ^2=1724.4, df=30, p<0.0001; included all species with >25 detections). This may suggest that NEXRAD data, because it is assessing a broad range of altitudes for nocturnal migrants, do not correlate with techniques that estimate activity closer to the ground. However, nocturnal migration flight height and stopover choices are both affected by weather conditions, and it seems reasonable to predict that estimates of migratory activity from the three monitoring methods (NEXRAD, acoustics, and banding) may be dependent on some of the same environmental factors. Using MANOVA modeling, we found that several environmental variables were important for describing migratory activity, as measured via all three monitoring methods (p=0.0138): frontal passage, wind direction at 850 mb, and time of year. Each of these factors was nested within season to control for differences in weather and bird abundance between spring and fall, and each were statistically significant (Pillai's Trace test, P<0.05; Table 9). More birds were captured at the banding station when fronts passed over the site in the evening. This did not happen often as nighttime frontal passage usually precluded banding the following day (due to inclement weather), but some of the busiest days at the station came after such events. Front passage was a particularly important variable for predicting banding results, as birds were equally likely to be captured after nights with headwinds as tailwinds (e.g., with either favorable or unfavorable winds for migration), at least in fall; in spring, birds were more likely to be captured during/after periods with tailwinds. Birds were more likely to be detected acoustically during periods with headwinds, in either fall or spring (e.g., north winds in the spring, south winds in the fall), while NEXRAD was more likely to detect birds during tailwinds. Once we corrected for these factors, correlation among the response variables improved, though the acoustic and NEXRAD data sets remain uncorrelated (Table 10). While these partial correlations are still relatively low, it is clear that including environmental variables help explain the differences in the banding and NEXRAD data. A further exploration of this pattern finds that NEXRAD and banding results are more highly correlated during tailwind conditions in the fall and spring (r^2=0.37). On nights when migrants have the greatest chance of moving we see the most alignment in these separate indices of abundance.

Discussion and Conclusions

The problem with exodus: Why estimates of exodus activity may be misleading

There are several explanations for why we regularly detected exodus activity from open water sites. It is possible that these sites had waterfowl that were sitting on the water's surface, and thus we are truly measuring exodus from open water locations, but this explanation seems unlikely, at least at the scale at which the phenomenon was observed. It seems more likely that our measure of exodus is flawed for one of two reasons: ground clutter or other types of interference (see Appendix I), or some combination of variable exodus timing and beam height precluded detection of an accurate exodus signal from the habitat below.

An in-depth analysis by Buler and Dawson (2012) of migratory stopover habitat utilization distribution across the northeastern U.S. was published in mid-2012. While it suggested certain limitations in coverage for the KTYX radar, the study used estimated migratory activity levels near sunset from 16

radars to develop a predictive model of stopover habitat use, which they applied to areas (such as our study site) that they deemed to be inadequately radar-sampled to examine exodus directly. Though the specifics of their approach vary from the approach used here, a summary of potentially relevant findings from the Buler and Dawson report may be found in Appendix I. If Buler and Dawson are correct in their assessment of the coverage of the KTYX radar, then ground clutter of some kind could presumably have affected our estimates of exodus activity and complicated analyses.

The initiation of migratory activity at the sampled radar volume also appears to be highly variable from one night to the next (Figures 21-23), so that our one-hour window immediately following sunset may have missed exodus activity on some nights. If this latter hypothesis is correct, then what we are calling exodus is simply a measure of migratory activity over each site; we cannot tell if the detected birds are ascending through the sampled volume of air (e.g., taking off from the site), or are moving horizontally through the sampled volume (and took off from somewhere else). This effect is compounded by the high elevation of the radar beam at our sites of interest (640-1918m at focal islands) which allows birds to travel long distances from their exodus to where they are detected by our analysis.

We hypothesize that our suspect exodus estimates are due to a combination of these factors. The recent Buler and Dawson report did suggest that ground clutter or other interference with the KTYX radar beam precludes reliable estimation of stopover habitat use for most of our study area (Appendix I). But that report, and our own estimates of exodus, rely on the assumption that birds detected during a period immediately after sunset are in fact taking off from the sites directly below where the animals are detected, which may or may not be the case. Rather than calling these values estimates of "exodus," they should more appropriately be called "post-sunset migratory activity". It is likely that these values include animals passing horizontally through the radar beam, as well as ascending through it from below. For these reasons, we suggest that the measures of exodus presented in this study (in Table 8 and elsewhere) are in truth measures of post-sunset migratory activity, not exodus per se, and should be treated accordingly.

Methods comparison for bats

Physical capture of bats through mist-netting provides several benefits over passive acoustic detection (O'Farrell and Gannon 1999). Foremost is the high degree of overlap between the call structure of Indiana bat (MYSO) and Little brown bat (MYLU); positive identification to species is difficult from acoustic calls only, often requiring the physical capture of individuals to confirm the presence of the species. However, bats whose feeding habits typically prefer dense clutter, such as the tri-colored bat (PESU) and long-eared bat (MYSE) are difficult to capture using mist-nets, while their acoustic calls are easy acquire and distinguish. Use of the two methods in combination provides a far more comprehensive and accurate assessment of species diversity and abundance than either method can provide alone. It should be noted (for both bats and birds) that a failure to detect a given species does not mean that it is not present; while banding and acoustic monitoring can provide data on species presence and diversity, conclusively proving species absence from a site is a more elusive goal.

Methods comparison for birds

Some species of birds, like some bats, are known to have a higher likelihood of detection via one method than another; Myrtle Warblers, for instance, which were captured in greater numbers than any other species on Grindstone Island, vocalize relatively rarely during flight, and are underrepresented in our acoustic dataset (Appendix IV). Non-passerines (particularly waterbirds and shorebirds) are represented in the acoustic dataset, but are not targeted during banding efforts. Henslow's Sparrow, a species of concern in New York State, was detected via acoustic monitoring but never seen or captured on the island.

In order to determine the utility of NEXRAD estimates of peak nightly migratory activity, we compared those data to our acoustic and banding station data. Estimators of peak nighttime bird migration activity (acoustics and NEXRAD), while uncorrelated with each other, were each loosely correlated with daytime capture numbers on the subsequent day across all sampling days. Low correlation between acoustic

detections of flight calls and NEXRAD radar activity has also been seen at other locations (Buler et al. 2012). The environmental variables that were significant predictors of all three measures of migratory activity (Julian date, front passage, and wind direction) were all nested with season, indicating that the importance of these variables changed with time of year. For example, results from the three techniques were better correlated in north and west winds than for south winds (there were very few days with east winds in our dataset); in south winds radar measures of migratory activity become less correlated with banding and acoustic results. This is particularly true in spring, which we suspect is due to the fact that spring migrants with a southern tailwind were probably not stopping often on their way north—so while they were being detected in the atmosphere via NEXRAD, they weren't being detected on or near the ground via the other two methods. Front passage was a particularly important variable for predicting banding results (Table 9), while birds were more likely to be detected acoustically during periods with headwinds. The importance of headwinds for acoustic detections has not been widely reported in the literature, so far as we know; this relationship may be due to birds flying at lower altitudes during headwinds, so they are more likely to enter the acoustic detector's range of detection, or to birds calling more often during headwinds to help orient themselves.

A large proportion of migrants passing through on a given night probably do not land on island sites, and the difference between these estimators may be due to both local weather events and to the likelihood that these estimators are monitoring different populations. The main reason that the three monitoring methods are not more consistently correlated, even after accounting for environmental factors, is likely that none of these metrics have been corrected for detection probability. While it is not necessary for every survey to be detection-corrected to be useful, it can be difficult to compare multiple metrics—all with different latent biases—to one another. With no known "true" abundance estimate it is also difficult to determine which metric is the most useful. All are measures of migratory activity that we hypothesize are related to total migratory abundance but each survey measures a different subgroup out of the whole (Table 5) and are subject to different biases. Banding stations certainly do not capture all migrants in a habitat, and acoustic monitoring can only detect individuals that make noise while low enough in the sky to heard (Evans 2012). NEXRAD does not detect individuals at all, rather focusing on aggregations of bioscatter, and certain weather conditions like fog in coastal areas can complicate analyses. Additionally, bioscatter is a combination of many migratory species, including mammals and insects as well as birds, and detectability of each group will change based on their average body size. Each of these detection processes are likely affected by environmental covariates ranging from weather to time of day to community structure, and until a firm handle on these factors is established, comparing multiple indices of migratory abundance may be difficult.

However, our results the show the independent utility of each of these monitoring methods. While NEXRAD is useful for describing broad migratory patterns (e.g., our finding here that migrants fly over open water more in the spring) they are much less useful for predicting risk to migrants from wind power development at a site level. NEXRAD coverage often does not include altitudes low enough to be directly affected by wind turbines; as such it is not a direct measure of collision risk to migrants. Our research suggests that under certain environmental conditions these data would be useful for predicting low-altitude migration and stopover, but this relationship requires further investigation. Regional migratory patterns and the ability to assess year to year variation in migratory activity are useful data for planning wind energy development, but other techniques like nocturnal acoustic monitoring and bird banding are required to provide context for NEXRAD data. Acoustics and banding both have their own biases, as well, but can be used together to develop more complete species profiles for sites of interest, and present data that is more useful for predicting site-specific risk from development. The biases associated with acoustics are less well understood than those for banding, but can be a useful complement for banding data, particularly for detecting species uncommonly captured during banding (such as passerines that stay high in the canopy, larger birds like waterfowl and waders, and nocturnal species like owls and woodcocks).

According to NEXRAD measures of migratory activity in the aerosphere, 2011 was a quiet migration season compared to 2010 and 2012. As such, the high levels of migration activity noted on Grindstone (via banding) and both Grindstone and Carleton (via passive acoustic monitoring) in the autumn of 2011 may still be below "normal" levels of migratory activity for the season and area. Alternatively, the reduced NEXRAD activity in 2011, coupled with high capture and acoustic detection rates, could mean that a larger proportion of migrants were flying at altitudes below those monitored via the KTYX radar. The availability of reliable exodus data from the 2010-2012 study period, or the use of marine radar systems that can produce vertical flight height profiles (as discussed in Harmata et al. 1999), might have clarified this point. Unfortunately, we were unable to employ vertical marine radar for this study, or examine reliable estimates of migratory exodus from focal areas (see above).

Migratory patterns across the study area

The GLMM that included year, distance from the radar, land elevation, wind direction, season, and site type accounted for 84% of the variance in peak migratory activity as measured via NEXRAD. Given that NEXRAD peak nightly migratory activity data appears to be useful in predicting lower elevation migration and migration stopover activities under certain weather conditions, we used those data to evaluate regional migratory patterns. Migratory patterns at a landscape scale (measured via radar) clearly vary with wind direction, season, and date within each season. Migratory activity is not evenly distributed across the landscape, but follows clear patterns that emerge over the course of seasons, both on- and offshore. Focal islands did not have statistically different migratory activity levels from each other on average, but when analyzing the data by season, higher densities of bioscatter occur over the more inland islands (Grindstone and Carleton) during fall and over the islands in Lake Ontario (Grenadier, Stony and Galloo) during spring.

Based on NEXRAD patterns of migratory activity across the landscape in spring vs. fall (Figure 26), it is possible to hypothesize what migratory strategies may be at play in the study region. It seems likely that in fall many birds flying south arrive on the north shore of Lake Ontario and then fly around all or part of the lake, over the northeastern shoreline and the St. Lawrence River, and then potentially farther east towards the Atlantic coast; in contrast, spring patterns of migratory activity seem to indicate a larger number of birds directly crossing the lake. This may represent a more risky migratory strategy in the spring, in which birds are heading north and hurrying to the breeding grounds, so may be more likely to take direct routes across bodies of water and other potential obstructions. This hypothesis also explains the dichotomy between the high levels of NEXRAD-measured flight activity at 640-1918m above sea level in spring, in conjunction with the low levels of activity measured via banding and acoustics during the same period—birds may be migrating through the area in spring in the same numbers as in fall, but are not stopping unless forced to by ambient weather conditions.

Bonter et al. (2009) found higher bird migration densities in coastal areas of the Great Lakes, particularly forest fragments in developed landscapes. Diehl et al. (2003) indicated that migratory bird densities were generally higher in the eastern Great Lakes in fall, and were higher in western areas of the Great Lakes region in spring. According to our own NEXRAD results, coastal areas of Lake Ontario and the St. Lawrence River see high migration levels in both fall and spring migration seasons, but avian migration through the study area (as measured via banding and acoustic monitoring) appeared to be substantially higher in fall than in spring. A recent study by The Nature Conservancy that modeled stopover habitat use among migratory birds around Lake Ontario appears to have predicted these observed patterns of passerine migration quite accurately (France et al. 2012); specifically, the authors state that "Both species richness and abundance of migrants is greater closer to the shores of Lake Ontario than farther inland. This pattern holds in the fall as well as the spring, but the band of higher concentration of migrants is wider in the fall, extending out to approximately 8 km." This relationship between bird migration density and proximity to coastlines has also been found along the Atlantic coast of the U.S. (Buler and Dawson 2012) and the Gulf of Mexico (Buler and Moore 2011), and may partially explain the relatively high

mortality rate observed at the Wolfe Island Wind Farm near the source of the St. Lawrence River (Stantec 2010).

A comparison of nocturnal acoustic avian flight call activity between Grindstone and Carleton islands indicated that they had similar levels of activity in the fall and spring. This result is congruent with the results from the NEXRAD analysis, which suggested that patterns of migratory activity at Carleton and Grindstone were more similar to each other than to Grenadier, Galloo or Stony. Grindstone and Carleton acoustic detection rates were lower than some other sites surveyed in the region five years earlier by Evans (2012), but it is unclear if the differences are related to consistent differences in migratory activity or effects due to annual variability and differences in methodology.

Given this observed pattern, we would suggest that coastal areas of the Great Lakes and nearby St. Lawrence may be of high importance as stopover habitats for avian migrants, particularly passerines. As intensity of migration may vary significantly from one year to the next, however (Figure 24), assessment of the importance of specific sites for migratory stopover will require multiple years of data collection.

Grindstone and Carleton Islands' utility as migratory stopover habitat for bat species

Bat captures were much less frequent than expected. The majority of captures on Grindstone occurred within three days of nets being set up in the fall, a pattern frequently seen in mist-netting studies where net sets are not moved. Resident bats which may forage regularly around areas where nets are set up quickly learn to avoid nets, a pattern reflected by low recapture success and declining rates of capture after two or more days of net deployment (Kunz and Brock 1975). This pattern of net avoidance by "local" resident bats is not expected to affect capture success of non-resident bats that arrive on the island during their migration, however. Our low capture success may indicate that either the frequency or detectability (via mist-netting) of non-resident bats arriving on the island is extremely low.

Bat detections via acoustic monitoring remained remarkably consistent between seasons, though the species composition changed between fall and spring. Eastern red bats (LABO) comprised over 23% of the total calls recorded in the fall at both Grindstone and Carleton, and fell to just 1% of the total in the spring. Capture surveys also showed a similar decrease in LABO detection in spring, falling from 38% to 10% of the total. In combination, our banding and acoustic data indicate that Grindstone may be less heavily utilized by this species during spring migration than during fall—either due to the island's location in relation to migratory routes, or due to unknown habitat characteristics that may affect the island's attractiveness to red bats during migration.

Though we were primarily targeting migratory bat populations with our study, the effects of white-nose syndrome (WNS) on local bat populations clearly impacted our detections rates. Given the information we obtained from about a dozen island residents, it appears that WNS hit Grindstone between three and five years ago and essentially wiped out local bat populations. Our bat crew explored multiple island structures (an old silver mine, the church belfry, and old barns where residents assured us there used to be thousands of bats) and saw no bats or any sign of recent occupation. Several Indiana bats were recently captured as part of preconstruction studies at nearby Cape Vincent, on the mainland east of Carleton Island (Tetratech 2010), and appropriate roosting trees were available on Grindstone for this species' use, but we captured no Indiana bats (and few bats of any species) during this study.

While the low abundance of cave roosting bats may be largely attributed to WNS, the cause of our low detection rate for tree bats such as Eastern red, Silver-haired, and Hoary bats remains unclear. The island study location is not expected to have been a major factor, as migratory tree bats are known to cross large bodies of water and even hunt over open water (Ahlén et al. 2009, Czenze et al. 2011, Williams 2013). Although we feel an adequate and extensive effort was made to survey the island's available habitat for these species, we still sampled only a subset of areas available for migrating bats to travel. There remains the possibility that migrating bats visiting the island during their migration used areas of the island where we were not sampling, despite our best efforts to site acoustic and capture activities in attractive bat habitats

(near small ponds, streams and wetlands; across potential travel corridors; and near shagbark hickory trees that could be used as roosting sites). Alternatively, the island may simply not be utilized as a regular migratory stopover location for these species. However, according to our bat biologists' best judgment, this low estimate of bat abundance on Grindstone is certainly not due to poor habitat quality or availability.

The importance of islands in the Great Lakes region to migrants

Grindstone appears to provide relatively high quality stopover habitat for many bird species, particularly warblers during fall migration. The relatively low proportion of developed land on the island, as well as the diverse habitats available to migrants, probably are factors. Exodus studies conducted with data from other radars have indicated that areas of deciduous forest near the shores of major water bodies or in heterogeneous landscapes (including developed and agricultural lands) are likely to be important stopover sites for avian migrants (Buler and Dawson 2012). The average capture rate for birds on Grindstone in fall 2011 was above average for banding stations in the United States. Given that banding stations are typically placed in areas of locally high migratory abundance, these data preliminarily suggest that if Grindstone Island is used consistently by migratory birds in autumn, it could be a migratory hotspot. In spring, however, captures were below average for migration banding stations, in part due to weather (as spring migration capture rates tend to be more weather-dependent than fall). Whether this is a consistent phenomenon for the site is unknown. NEXRAD data suggest significant differences among the three study years, but the weather dependence of correlations between NEXRAD and banding station data prevent us from easily generalizing our banding results beyond the year of capture. A more complex predictive model that could incorporate the required factors would be created and be useful for translating peak activity NEXRAD data into number of birds stopping over on islands around the region, but development of such a model would require substantial investment in both field work and radar data analysis.

Our avian banding and acoustic results appear roughly similar to that of other studies that have been conducted in the area in recent years. Preconstruction field studies for the proposed St. Lawrence Wind Farm (which in 2012 was merged with the proposed Cape Vincent Wind Farm, on the mainland near Carleton Island), detected several Henslow's Sparrows, as well as other grassland species of concern, but in low numbers (Tetratech 2010). Interestingly, these surveys detected Grasshopper Sparrows (*Ammodramus savannarum*) with relative frequency, a species which was not detected on Grindstone; however, the Cape Vincent/St. Lawrence surveys were conducted during breeding season, and likely detected several breeding bird species that may not have been present during migration on Grindstone. Other state species of concern such as the Common Loon (*Gavia immer*), Osprey (*Pandion haliaetus*), Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*A. cooperii*), Bicknell's Thrush (*Catharus bicknelli*), Golden-winged Warbler (*Vermivora chrysoptera*), and Cerulean Warbler, as well as the threatened Northern Harrier (*Circus cyaneus*), were detected on Grindstone (and in the case of Common Loons are known to breed on the island), but were not observed in large numbers (again, similarly to other studies in the region, such as the Avian Risk Assessment for the proposed Hounsfield wind project on Galloo Island; Evans 2009). However, while several Great Blue Herons were observed on Carleton Island (and it was hypothesized by field researchers that there was a Great Blue Heron rookery in the vicinity), there was no notable concentration of seabirds in the area of Grindstone or Carleton study sites such as is present near Galloo Island.

Grindstone Island is both a heterogeneous landscape and near the shore of a major water body, so it is not surprising that we detected large numbers of passerines migrants during our study, particularly in forested habitats. Stony and Galloo Islands have similar proportions of forested habitat, suggesting that they be similarly suitable for migrants; Carleton and Grenadier have both been largely deforested, and may be less attractive to migrants according to Buler and Dawson's hypothesis regarding the characteristics of high-quality stopover habitat. Our own examination of exodus at the island sites, while potentially flawed (see above), indicated similar levels of migratory stopover and exodus from all five islands, though patterns of stopover between sites varied with environmental and temporal variables. It seems probable that all five islands can serve as important stopover habitats for migrants, depending upon weather patterns; e.g., even

those islands that may have lower intrinsic value as stopover habitats may still be essential stopover locations based on extrinsic factors (Mehlman et al. 2005). It is also possible that Grenadier and Carleton islands, which have large percentages of grassland areas, may be more attractive to a subset of migrants with an affinity for grasslands (for instance, they may attract more sparrows or geese and fewer wood warblers). Acoustic data from Grindstone and Carleton provide some support for this theory; significantly greater proportions of wood warblers and thrushes were detected at Grindstone, while a higher proportion of Canada Geese was detected at Carleton.

The high levels of coastal avian migration activity observed here and in other recent studies, particularly in the fall, means that coastal wind development occurring and proposed in the region may be of potential concern. High levels of coastal activity are commonly seen in other regions, and it has been suggested that coastal areas should be avoided for offshore wind development (Garthe and Hüppop 2004) and that migratory flyways or areas that are strategic migration staging areas should also be avoided (Drewitt and Langston 2008). Evidence from NEXRAD indicates that there are migratory flyways around the eastern edge of Lake Ontario (primarily in fall) and across eastern Lake Ontario (primarily in spring), and recent evidence from both this and other studies indicates that these coastal and island areas of the Great Lakes may see relatively high use by migratory birds in both seasons. Islands in Lake Ontario may be particularly important as stopover habitats in spring, when a greater proportion of migrants are crossing the lake instead of flying around it, and thus are more vulnerable to weather perturbations that may require stopovers midflight. While high use areas are not necessarily "high risk" areas of potential wildlife impacts from wind development, a key strategy for minimizing impacts from development is going to be identifying these high-use areas and understanding when and why birds are using those areas, so that both siting and mitigation efforts are effective.

Data Accessibility and Communications Efforts

In addition to making our raw data publicly available via the Avian Knowledge Network, we have also shared information about the project in several scientific and public forums:

1. Preliminary data on birds and bats were presented in a poster at the New York State Energy Research and Development Authority (NYSERDA)'s annual EMEP meeting ("Environmental Monitoring, Evaluation, and Protection in New York: Linking Science and Policy") in Albany on November 15-16th, 2011.
2. Two oral presentations on the complementary techniques being used to monitor avian populations for this project (both titled, "Comparison of banding, acoustic, and NEXRAD radar data for studying passerine migration in upstate New York: A complementary approach," have been presented at the North American Ornithological Conference (Vancouver, British Columbia, 17 August 2012), and the Bird Conservation Conference in the Northeast (Plymouth, Massachusetts, 19 October 2012). A poster presentation on this same topic was presented at the National Wind Coordinating Collaborative's Wildlife Workgroup Research Meeting in Denver, Colorado November 27-30.
3. BRI biologists created a short educational video during the spring 2012 field season that discusses and shows excerpts from field efforts on Grindstone Island. The video is available for viewing from BRI's home page (www.briloon.org) and on YouTube.
4. Quarterly reports and copies of the 2011 poster were posted at the Grindstone Island community center for interested residents.
5. The final report will be shared with island residents and other interested parties who have inquired, including the Thousand Islands Land Trust (TILT), Save the River (an environmental advocacy group for the Upper St. Lawrence), and other organizations.

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Literature Cited

Ahlén I, Baagoe HJ, Bach L. 2009. Behavior of Scandinavian bats during migration and foraging at sea. Journal of Mammalogy 90: 1318–1323.

Arnett EB, K Brown, WP Erickson, J Fiedler, BL Hamilton, TH Henry, A Jain, GD Johnson, J Kerns, RR Kolford. 2008. Patterns of fatality of bats at wind energy facilities in North America. Journal of Wildlife Management 72:61-78.

Bonter DN, Gauthreaux SA, Donovan TM. 2009. Characteristics of important stopover locations for migrating birds: remote sensing with radar in the Great Lakes Basin. Conservation Biology 23, 440–448.

Buler JJ, Moore FR. 2011. Migrant–habitat relationships during stopover along an ecological barrier: extrinsic constraints and conservation implications. Journal of Ornithology 152:S101-S112.

Buler JJ, Dawson DK. 2012. Radar analysis of fall bird migration stopover sites in the Northeastern US. Final Report to the US Geological Survey Science Support Partnership Program.

Buler J, Horton K, Shriver G. 2012. Post-construction avian and bat impact assessment of the University of Delaware wind turbine in Lewes, DE: interim report. Accessed 21 March 2013; http://www.ceoe.udel.edu/LewesTurbine/documents/lewes_turbine_interim_report_2012.pdf

Chilson PB, Frick WF, Kelly JF, Howard KW, Larkin RP, Diehl RH, Westrook JK, Kelly TA, Kunz TH. 2012a. Partly cloudy with a chance of migration: Weather, radars, and aeroecology. Bulletin of the American Meteorological Society 93(5): 669–686.

Chilson PB, Frick WF, Stepanian PM, Shipley JR, Kunz TH, Kelly JF. 2012b. Estimating animal densities in the aerosphere using weather radar: to Z or not to Z? Ecosphere 3(8):72. 19 pp.

Cryan PM, Brown AC. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation 139(102):1-11.

Czenze, Z. S.N.P. Wong and C.K.R. Willis. (2011) Observations of eastern red bats (*Lasiurus borealis*) 160 km off the coast of Nova Scotia. Bat Research News. 52:28-30.

Diefenbach DR, Brauning DW, Mattice JA. 2003. Variability in grassland bird counts related to observer differences and species detection rates. Auk 120(4):1168-1179.

Diehl RH, Larkin RP, Black JE. 2003. Radar observations of bird migration over the Great Lakes. Auk 120(2):278-290.

Drewitt AL, Langston RHW. 2008. Collision effects of wind-power generators and other obstacles on birds. Annals of the New York Academy of Sciences 1134:233-266.

Evans WR. 2012. Avian acoustic monitoring study at the Maple Ridge Wind Project, 2007-2008: Final Report. NYSERDA Report 12-23. Accessed 21 February 2013; http://www.nyserda.ny.gov/Publications/Research-and-Development-Technical-Reports/Environmental-Reports.aspx.

Evans, WR. 2009. Avian risk assessment for the Hounsfield wind energy project on Galloo Island, Jefferson County, NY. Old Bird, Inc. Prepared for Upstate New York Power Corp.

Ewert DN, Hamas MJ. 1996. Ecology of migratory landbirds during migration in the Midwest. In: Management of midwestern landscapes for the conservation of neotropical migratory birds, Thompson FR III, ed. U.S. Department of Agriculture, Forest Service Gen. Tech. Rep. NC-GTR-187. Pp. 200-208.

Exo, K.-M., Hüppop, O. & Garthe, S. 2003. Birds and offshore wind farms: a hot topic in marine ecology. *Wader Study Group Bull*. 100: 50–53.

Faaborg JA, Anders AD, Baltz ME, Gram WK. 1996. Non-breeding season considerations for the conservation of migratory birds in the Midwest: post-breeding and wintering periods. In: Thompson FR III (ed.) Management of Midwestern landscapes for the conservation of neotropical migratory birds. USDA Forest Service Gen. Tech. Rep. NC-187, St. Paul, MN. Pp 189-199.

Farnsworth A. 2005. Flight calls and their value for future ornithological studies and conservation research. Auk 122(3):733-746.

Fenton MB. 2012. Bats and white-nose syndrome. Proceedings of the National Academy of Sciences 109(18):6794-6795.

France KE, Burger M, Howard TG, Schlesinger MD, Perkins KA, MacNeil M, Klein D, Ewert DN. 2012. Final report for Lake Ontario Migratory Bird Stopover Project. Prepared by The Nature Conservancy for the New York State Department of Environmental Conservation, in fulfillment of a grant from the New York Great Lakes Protection Fund (C303907).

Frick WF, Hayes JP, Heady PA III. 2008. Patterns of island occupancy in bats: influences of area and isolation on insular incidence of volant mammals. Global Ecology and Biogeography 17(5):622-632.

Garthe S, Hüppop O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41:724-734.

Gauthreaux SA Jr., CG Belser. 2003. Radar ornithology and biological conservation. The Auk 120(2):266-277.

Harmata AR, KM Podruzny, JR Zelenak, ML Morrison. 1999. Using marine surveillance radar to study bird movements and impacts assessment. Wildlife Society Bulletin 27(1):44-52.

Horn, JW, TH Kunz. 2008. Analyzing NEXRAD Doppler radar images to assess nightly dispersal patterns and population trends in Brazilian free-tailed bats (*Tadarida brasiliensis*). Integrative and Comparative Biology *48*: 24-39.

Kurta A, Murray SW. 2002. Philopatry and migration of banded Indiana bats (Myotis sodalis) and effects of radio transmitters. Journal of Mammalogy 83(2):585-589.

Kunz TH, Brock CE. 1975. A comparison of mist nets and ultrasonic detectors for monitoring flight activity of bats. Journal of Mammalogy, 56(4):907-911.

Mackenzie, S. 2012. Long Point Bird Observatory 2011 Program Report. 24 pp. Accessed 21 February 2013. http://www.bsc-eoc.org/library/LPBOreport.pdf

Manley PN, Van Horne B, Roth JK, Zielinski WJ, McKenzie MM, Weller TJ, Weckerly FW, Vojta C. 2006. Chapter 7: Bat Monitoring. In: Multiple species inventory and monitoring technical guide. Gen. Tech. Rep. WO-73. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 204 p.

Mehlman DW, Mabey SE, Ewert DN, Duncan C, Abel B, Cimprich D, Sutter RD, Woodrey MS. 2005. Conserving stopover sites for forest-dwelling migratory landbirds. Auk 122:1281–1290.

Murray J. 2004. Nocturnal flight call analysis as a method for monitoring density and species composition of migratory songbirds (Order Passeriformes) across southern Vancouver Island, British Columbia in 2004. Rocky Point Bird Observatory, Vancouver. Accessed 2 May 2011. Available at: http://www.islandnet.com/~rpbo/acousticmonjjm.pdf.

Newton, I. 2004. Population limitation in migrants. Ibis 146(2):197226.

O'Farrell MJ, WL Gannon. 1999. A Comparison of acoustic versus capture techniques for the inventory of bats. Journal of Mammalogy 80(1):24-30.

Old Bird Inc. 2008. 2008 Diurnal Bird Movement Study on Big Galloo Island, Jefferson County, NY. Report prepared for the Upstate New York Power Co.

Old Bird, Inc. 2009. Avian Risk Assessment for the Hounsfield Wind Energy Project On Galloo Island, Jefferson County, NY. Report prepared for the Upstate New York Power Co.

Ralph, CJ, JR Sauer, S Droege. 1995. Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. 187 p. Accessed 12 February 2011. Available at: http://www.fs.fed.us/psw/publications/documents/wild/gtr149/gtr_149.html.

Reichard JD, Kunz TH. 2009. White-nose syndrome inflicts lasting injuries to the wings of little brown myotis (Myotis lucifugus). Acta Chiropterologica 11(2):457-464.

Sillett, T. S., & Holmes, R. T. (2002). Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology, 71(2), 296–308.

Stantec 2010. Wolfe Island Ecopower Centre post-construction followup plan: bird and bat resources monitoring report No. 2, July-December 2009. Report for the TransAlta Corporation.

Szewczak J, Harris L. 2013. A field test of two acoustic classification systems to discriminate Indiana Bats (*Myotis sodalis*). Oral Presentation, North-eastern Bat Working Group.

Szewczak J. 2012. Sonobat Discrimination of Myso vs. Mylu: Technical support papers for Sonobat v3.1. (Accessed 1 March 2013; www.sonobat.com/download/MysoMyluClassificationNote-NE-v3.1.pdf).

Tetratech. 2010. Final Environmental Impact Statement for the proposed St. Lawrence Windpower Project. Towns of Cape Vincent and Lyme, Jefferson County, New York.

U.S. Fish and Wildlife Service. 2011. White-Nose Syndrome Revised Decontamination Protocol. Available at: http://whitenosesyndrome.org/topics/decontamination.

Warren CC. 2011. Singing behavior leads to detection bias in a territorial songbird. Masters thesis. Texas State University-San Marcos. Accessed 21 March 2013; https://digital.library.txstate.edu/bitstream/handle/10877/2413/WARREN-THESIS.pdf?sequence=1.

Williams KA. 2013. Modeling Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Continental Shelf: Annual Report for 2012. Biodiversity Research Institute report to the Department of Energy Wind and Water Power Program. DOE award number DE-EE0005362.

Winhold L, Kurta A. 2008. Netting surveys for bats in the northeast: differences associated with habitat, duration of netting, and use of consecutive nights. Northeastern Naturalist 15(2):263-274.

Tables

Table 1: Bat species present in New York State

Scientific Name	Common Name	Abbreviation	Federal Listing Status Under Endangered Species Act
Myotis lucifugus	Little brown bat	MYLU	Assessment request
Myotis septentrionalis	Northern long-eared bat	MYSE	Petitioned for listing
Myotis sodalis	Indiana bat	MYSO	Federally Endangered
Myotis leibii	Eastern small-footed bat	MYLE	Petitioned for listing
Eptesicus fuscus	Big brown bat	EPFU	None
Perimyotis subflavus	Tri-colored bat	PESU	None
Lasiurus borealis	Eastern red bat	LABO	None
Lasiurus cinereus	Hoary bat	LACI	None
Lasionycteris noctivagans	Silver-haired bat	LANO	None

Table 2. Net locations for bird banding station on Grindstone Island in Fall 2011 and Spring 2012

Net #	Latitude	Longitude	Habitat
1	44.289900	-76.119433	forest
2	44.289367	-76.118217	forest
3	44.288800	-76.118717	forest
4	44.288833	-76.118917	forest
5	44.289083	-76.118900	forest
6	44.289200	-76.119217	field
7	44.289233	-76.118433	forest
8	44.289317	-76.118767	field
9	44.290550	-76.118617	forest
10	44.290617	-76.118283	field
11	44.290900	-76.118100	forest
12	44.290917	-76.117950	forest
13	44.291317	-76.116650	forest
14	44.291233	-76.116483	forest
15	44.289567	-76.118800	field
16	44.289683	-76.118117	field
17	44.290900	-76.117417	field
18	44.290867	-76.117233	field
19	44.291000	-76.117100	forest
20	44.291317	-76.116067	forest
21	44.289174	-76.119225	field
22	44.289226	-76.119177	field
23	44.289130	-76.119570	field
24	44.289070	-76.119730	field
25	44.289790	-76.119140	forest
26	44.290992	-76.117369	forest
27	44.291083	-76.117611	forest

Table 3: Bat Mist-netting locations on Grindstone Island in Fall 2011 and Spring 2012

Location	Latitude	Longitude	Start Date	End Date	Triple-high nets (N)
Fall Set #1	44.28809	-76.09238	2 Aug 2011	6 Oct 2011	9m(2),12m(1)
Fall Set #2	44.28942	-76.08781	3 Aug 2011	7 Oct 2011	6m(1), 12m(2)
Spring Set #1	44.28809	-76.09238	14 Apr 2012	28 May 2012	9m(2),12m(1)
Spring Set #2	44.26207	-76.1487	15 Apr 2012	29 May 2012	6m(1), 9m(1),12m(1)

Table 4: Location and dates of deployment for acoustic D500X bat detectors and Song Meter 2 bird detectors

Taxon	Location	Latitude	Longitude	Dates
Bat	Carleton Island	44.18677	-76.29435	12 Aug-03 Oct 2011 12 Apr-28 May 2012
Bat	Grindstone Island	44.29090	-76.09204	02 Aug-01 Oct 2011 14 Apr-29 May 2012
Bird	Carleton Island	44.18666	-76.29307	31 Aug -22 Oct 2011 30 Apr-28 May 2012
Bird	Grindstone Island	44.29123	-76.11465	05 Sep-26 Oct 2011 30 Apr-31 May 2012

Table 5. Comparison of subpopulations of migratory birds sampled via different monitoring methods

Technique	Migratory Population Sampled
NEXRAD	Total mean densities of migratory animals passing over the site at higher altitudes during peak migratory activity (from two hours after sunset to two hours before sunrise)
Acoustics	Number of birds passing over the site that are emitting flight calls and are low enough to be heard on the microphone
Bird Banding	Number of birds landing at the site that are catchable in our nets

Table 6: Species detection totals for Fall 2011 acoustic monitoring

Island		EPFU	LABO	LACI	LANO	LUSO	MYLE	MYLU	MYSE	PESU	Total
Carleton	Count	66	67	12	75	42	2	22	0	0	**286**
	% Total	23%	23%	4%	26%	15%	1%	8%	0%	0%	
Grindstone	Count	135	67	11	86	15	0	39	2	2	**357**
	% Total	38%	19%	3%	24%	4%	0%	11%	1%	1%	
Grand Total		**201**	**134**	**23**	**161**	**57**	**2**	**61**	**2**	**2**	**643**

EPFU=Big brown, LABO=Red, LACI=Hoary, LANO=Silver-haired, LUSO=Indiana/Little brown (*Myotis* calls that could not be identified definitely to species level), MYLE=Eastern Small-footed, MYLU=Little brown, MYSE=Northern long-eared, PESU=Tricolor

Table 7: Species detection totals for spring 2012 acoustic monitoring

		EPFU	LABO	LACI	LANO	LU_SO	MYLU	MYSE	PESU	Total
Carleton Island	Count	178	3	5	52	7	2	1	0	**248**
	% Total	72%	1%	2%	21%	3%	1%	0%	0%	
Grindstone Island	Count	204	2	11	59	42	35	0	3	**356**
	% Total	57%	1%	3%	17%	12%	10%	0%	1%	
Grand Total		**382**	**5**	**16**	**111**	**49**	**37**	**1**	**3**	**604**

EPFU=Big brown, LABO=Red, LACI=Hoary, LANO=Silver-haired, LUSO=Indiana/Little brown (*Myotis* calls that could not be identified definitely to species level), MYLE=Eastern Small-footed, MYLU=Little brown, MYSE=Northern long-eared, PESU=Tricolor

Table 8. Mean estimated exodus activity (across all seasons and years) for island, mainland and open water sites. Exodus values are corrected for sites' elevation and distance from the radar station.

Location Type	N	Mean estimated exodus (dBη)	Standard Error (dBη)	95% Confidence Intervals
Island	5	18.983	0.806	17.342-20.624
Mainland	23	20.667	0.376	19.901-21.432
Open Water (Lake Ontario)	7	18.228	0.681	16.841-19.615

Table 9. MANOVA results: predicting avian migratory activity (as measured via banding, acoustics, and NEXRAD) based on environmental variables.

Variables in italics were statistically significant. All variables were nested within season, so P-values are the same for each factor across seasons. All wind direction parameter estimates are in comparison to western winds, so there is no parameter estimate for that wind direction.

Season	**Factor in MANOVA**	**Banding Parameter Estimate**	**Acoustics Parameter Estimate**	**NEXRAD Parameter Estimate**	**P value**
Fall	Julian Date	0.016	-0.006	0.016	*0.001*
	Front Passage=YES	0.406	-0.112	-1.881	*0.0325*
	Wind Direction, 850 mb=North	0.237	-0.08	2.11	*0.0380*
	Wind Direction, 850 mb =South	0.200	0.19	-1.372	*0.0380*
Spring	Julian Date	0.007	0.012	-0.058	*0.001*
	Front Passage=YES	-	-	-	*0.0325*
	Wind Direction, 850 mb = North	0.0935	0.218	-1.537	*0.0380*
	Wind Direction, 850 mb = South	0.271	-0.418	2.636	*0.0380*
	Wind Direction, 850 mb = East	-0.593	0.41	3.173	*0.0380*

Table 10. Partial correlation matrix for the three migratory monitoring response variables after correcting for important environmental variables

	Banding	**Acoustic**	**NEXRAD**
Banding	1		
Acoustic	0.33603	1	
NEXRAD	0.27765	0.03365	1

Figures

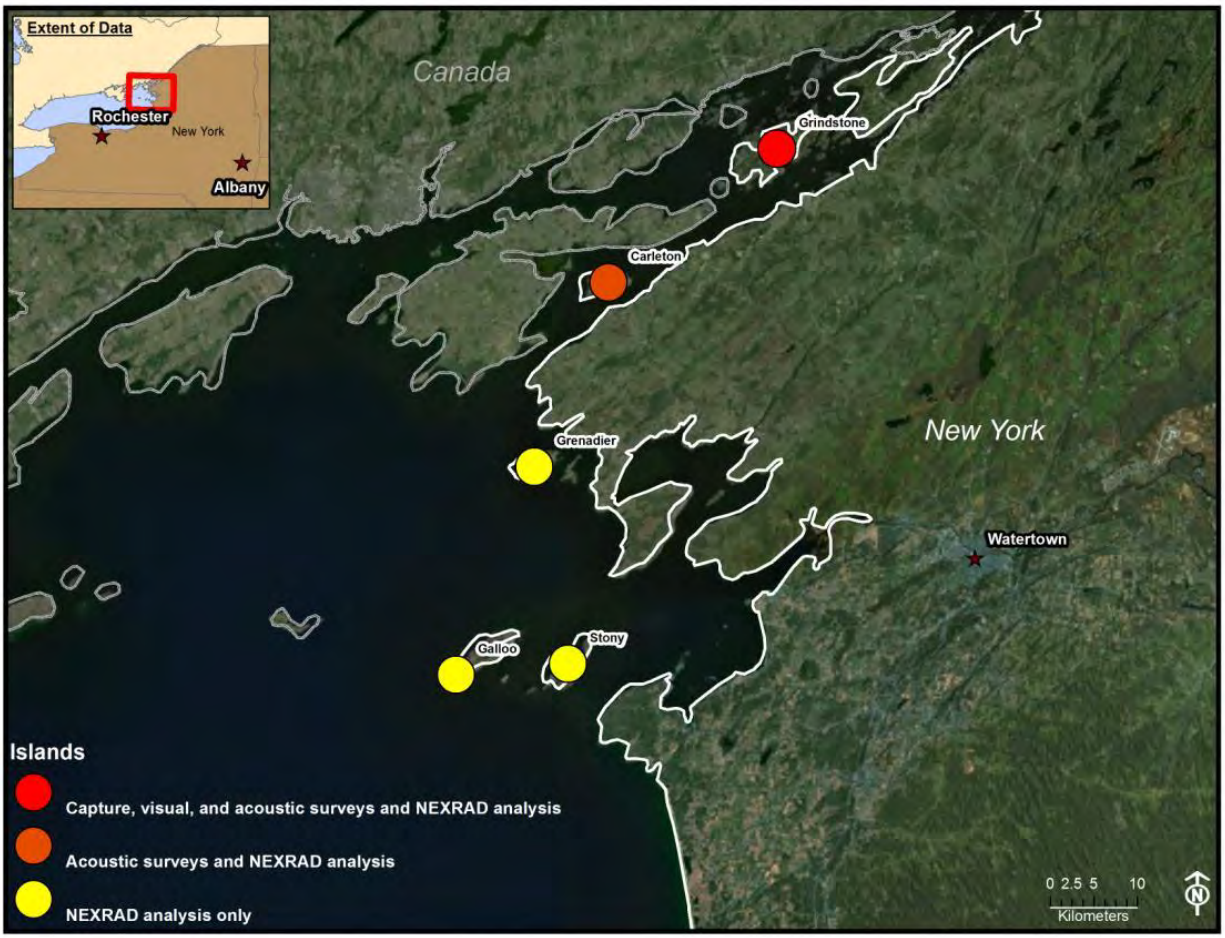


Figure 1. Study area in upstate New York

Grindstone Island (in red) was monitored simultaneously using all survey methods. Carleton Island (in orange) was monitored using nocturnal acoustics and NEXRAD, while Grenadier, Galloo and Stony Islands were monitored purely by NEXRAD (in yellow). The goal of this study design was to examine as many sites as possible, via the most wide-ranging and least expensive monitoring technique (NEXRAD), while maintaining sites where relationships between all monitoring methods could be quantified.

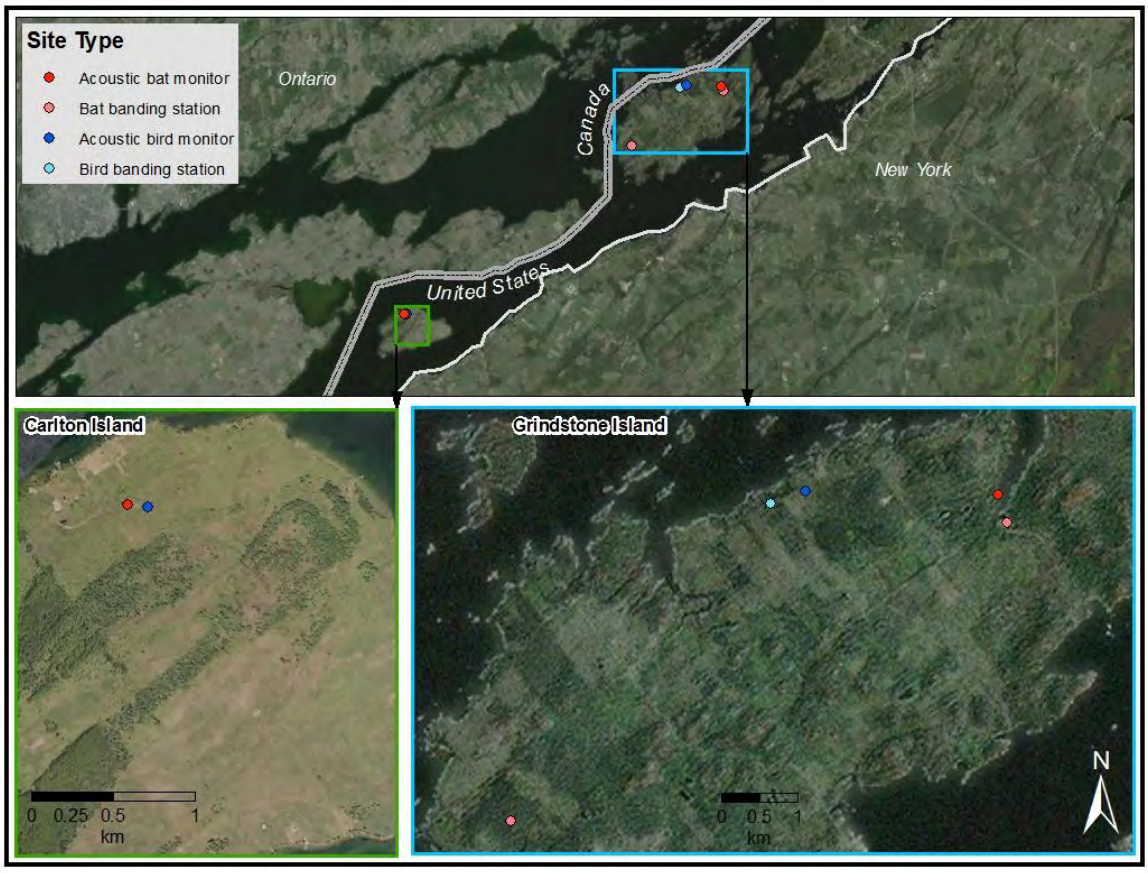


Figure 2. Bird and bat study locations on Grindstone and Carleton Islands, 2011-2012 (Jefferson County, New York)

Figure 3: Triple-high net coverage crossing wooded road on Grindstone (fall 2011, Site #1; photo by BRI staff)

Figure 4. Avian acoustic monitoring system on Grindstone Island (photo by BRI staff).

Microphone sits on top of a horizontal Plexiglas plate, which is affixed to the top of a 5.5m pole; the Song Meter recorder is located in a container at the base of the pole (not visible in this photo).

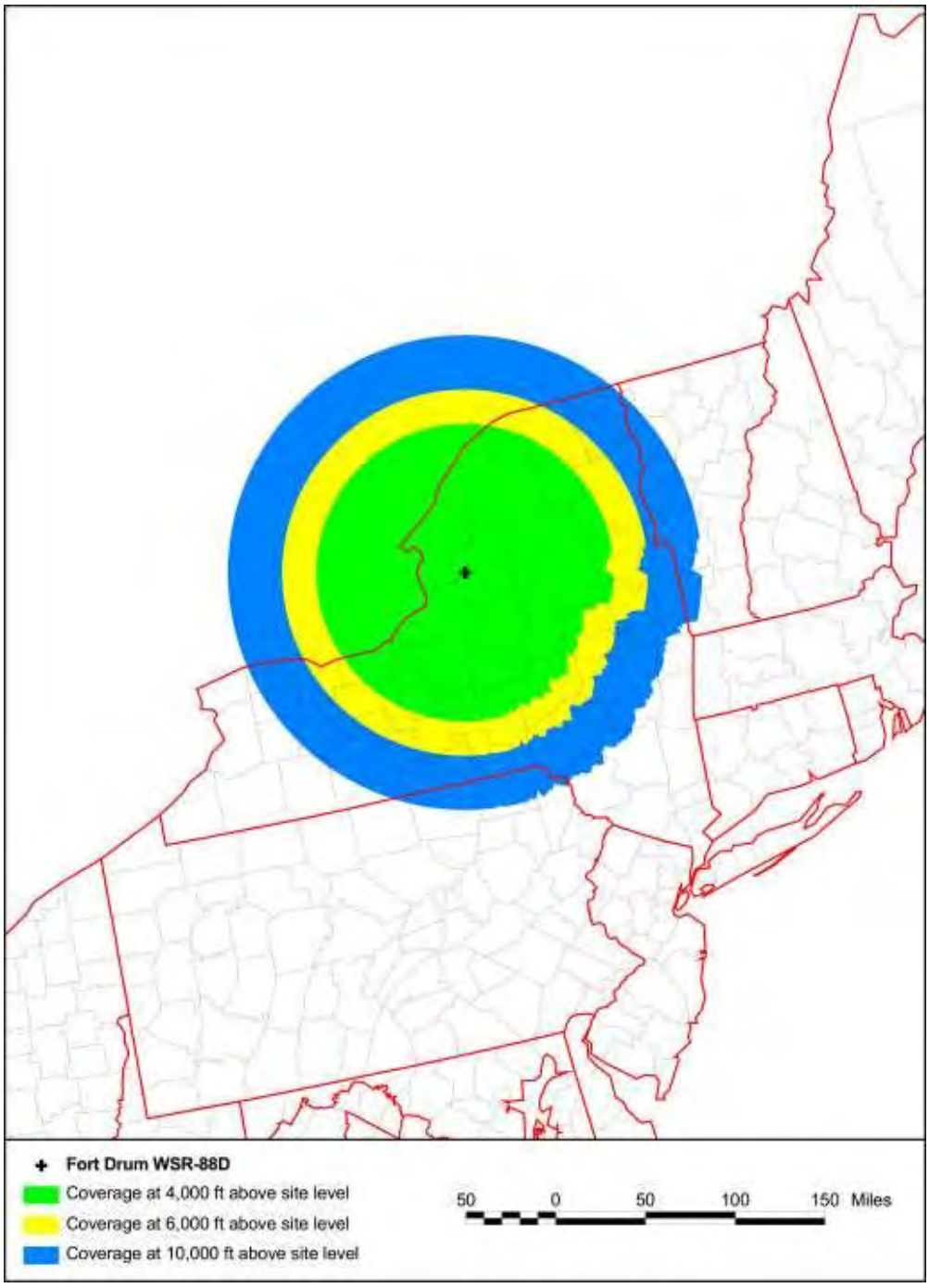


Figure 5. Coverage of the KTYX NEXRAD radar station based on Fort Drum, New York

From: http://www.ncdc.noaa.gov/nexradinv/covmaps.jsp?id=KTYX. One can observe at least down to 4,000 ft above sea level for locations within the green circle; down to 6,000 ft out to the edge of the yellow circle; and down to 10,000 ft out to the edge of the blue circle. Due in part to the altitude at which the radar was sampling in the vicinity of the study area, and a recent examination of the coverage area of this radar station for monitoring exodus (Appendix I), project collaborators chose to primarily examine peak migratory activity over the course of the night rather than exodus in this study area.

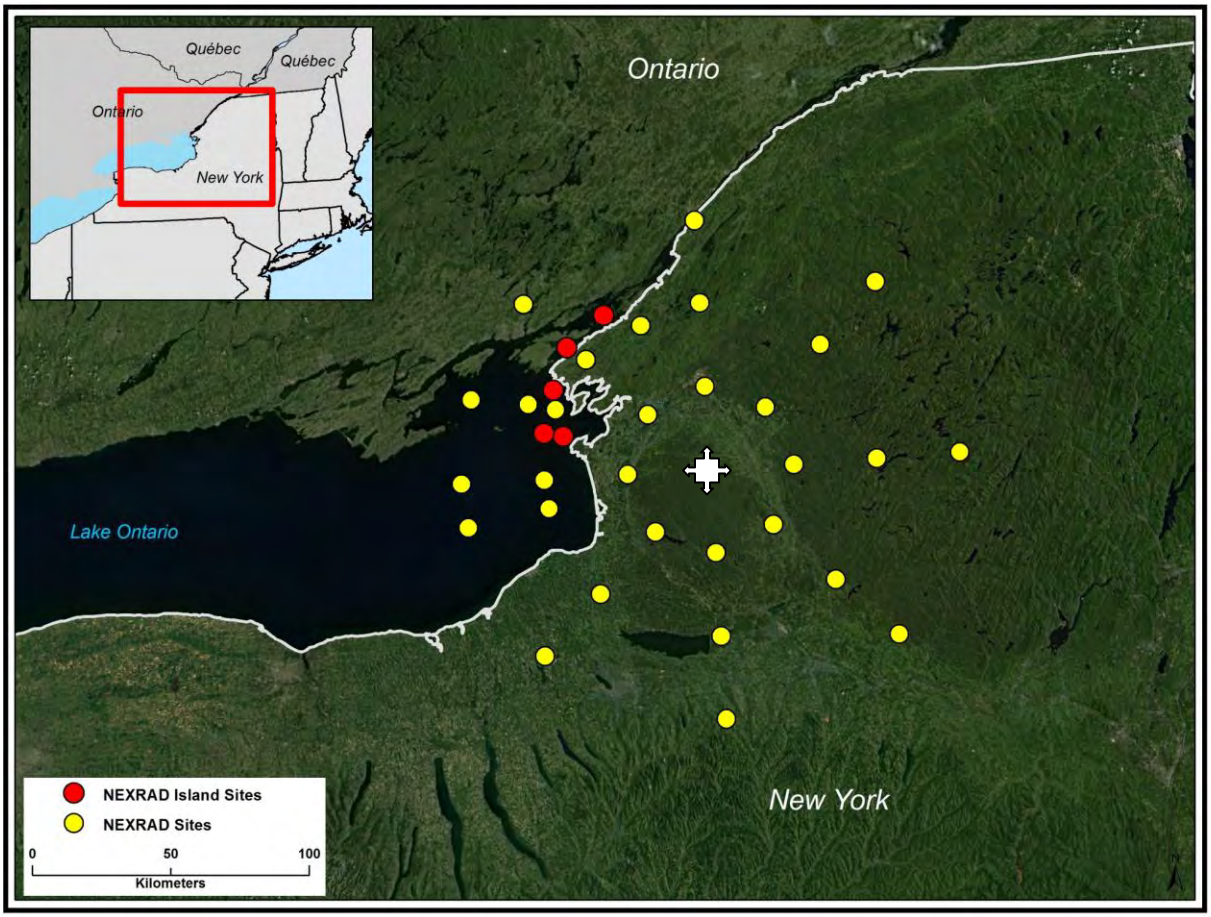


Figure 6. Sites used in NEXRAD spatial analyses

Locations of control sites (in yellow) and 5 focal islands (in red) used in NEXRAD spatial analyses. Sites were between 30 and 90 kilometers from the KTYX radar in Fort Drum (marked in white at the center of the control sites), and ranged from 74 to 450 meters in elevation.

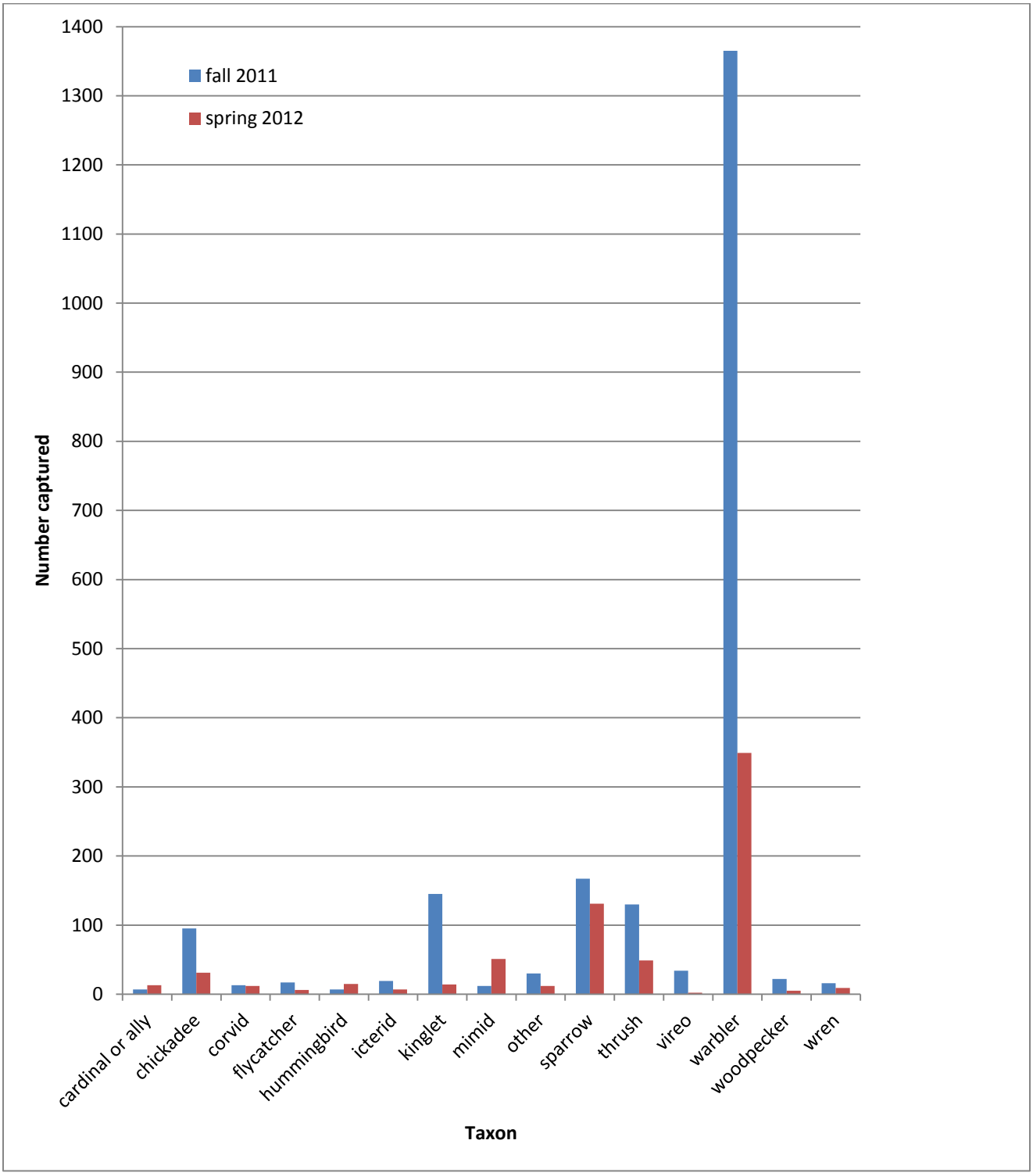


Figure 7. Total bird captures by season and taxon

A. B.

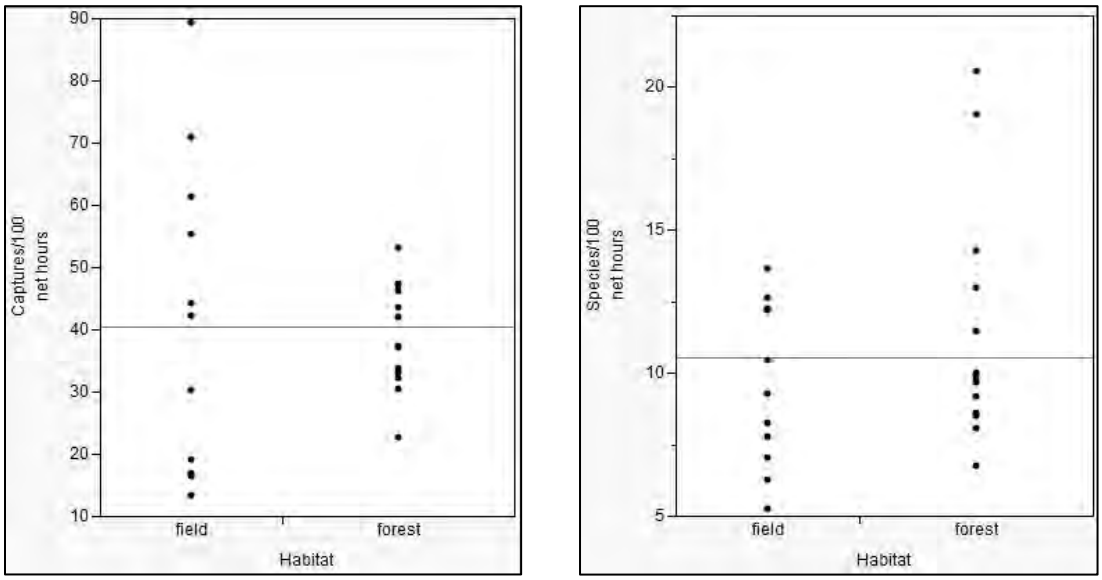


Figure 8. A. Bird captures per 100 net hours for nets placed in field habitats vs. forested habitats. B. Unique species captured per 100 net hours for nets placed in field habitats vs. forested habitats

Mean values across all nets (n=25) are indicated with a horizontal line.

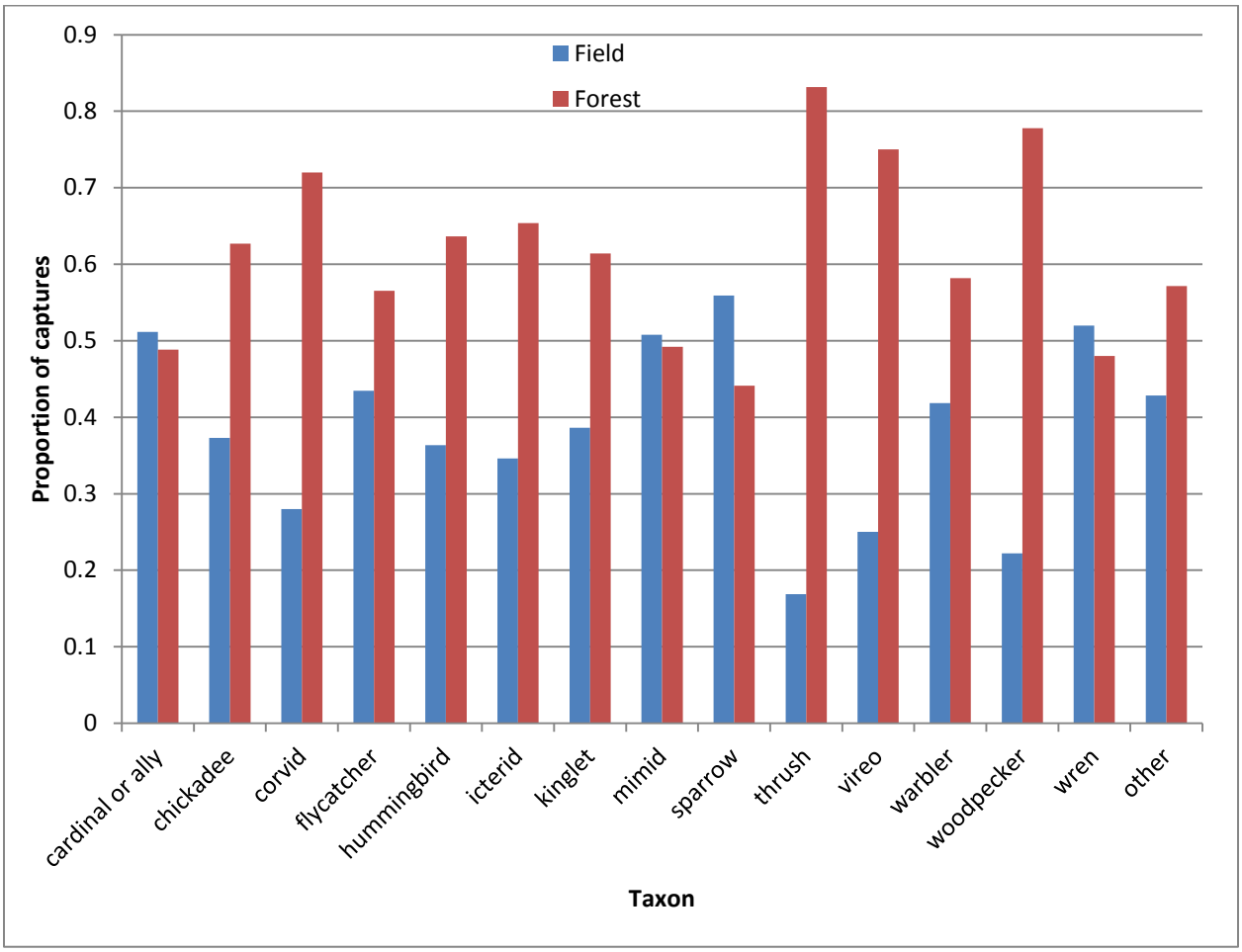


Figure 9. Proportion of bird captures that occurred in each habitat (corrected for effort)

Cardinal or ally = cardinals, tanagers, buntings and grosbeaks; chickadee = black-capped chickadee; corvid = jays; flycatcher = phoebes, wood-pewees, and flycatchers; hummingbird = Ruby-throated Hummingbird; icterid = orioles, cowbirds and grackles; kinglet = kinglets; mimid = thrashers and catbirds; sparrow = sparrows, juncos and towhees; thrush = thrushes and robins; vireo = vireos; warbler = warblers; woodpecker = woodpeckers, flickers and sapsuckers; wren = wrens; other = all taxa with <20 captures (finches, cuckoos, creepers, nuthatches, grouse, waxwings, hawks).

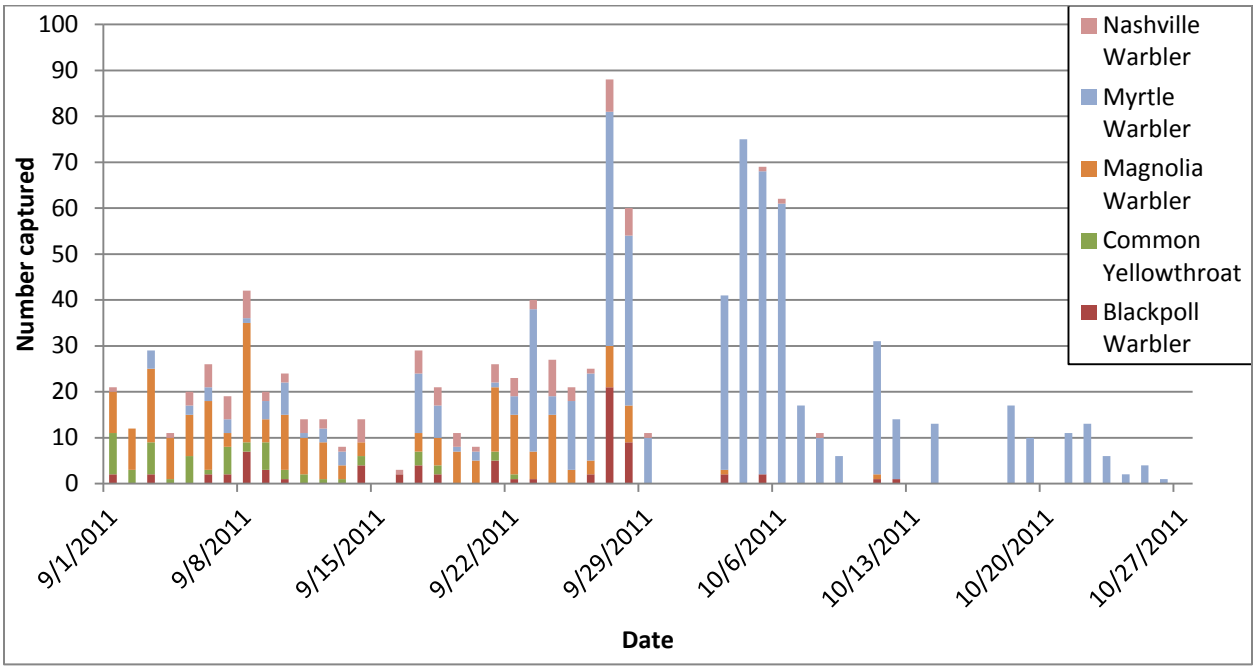


Figure 10. Temporal profile of fall 2011 captures for the five most common warbler species at the Grindstone Island banding station

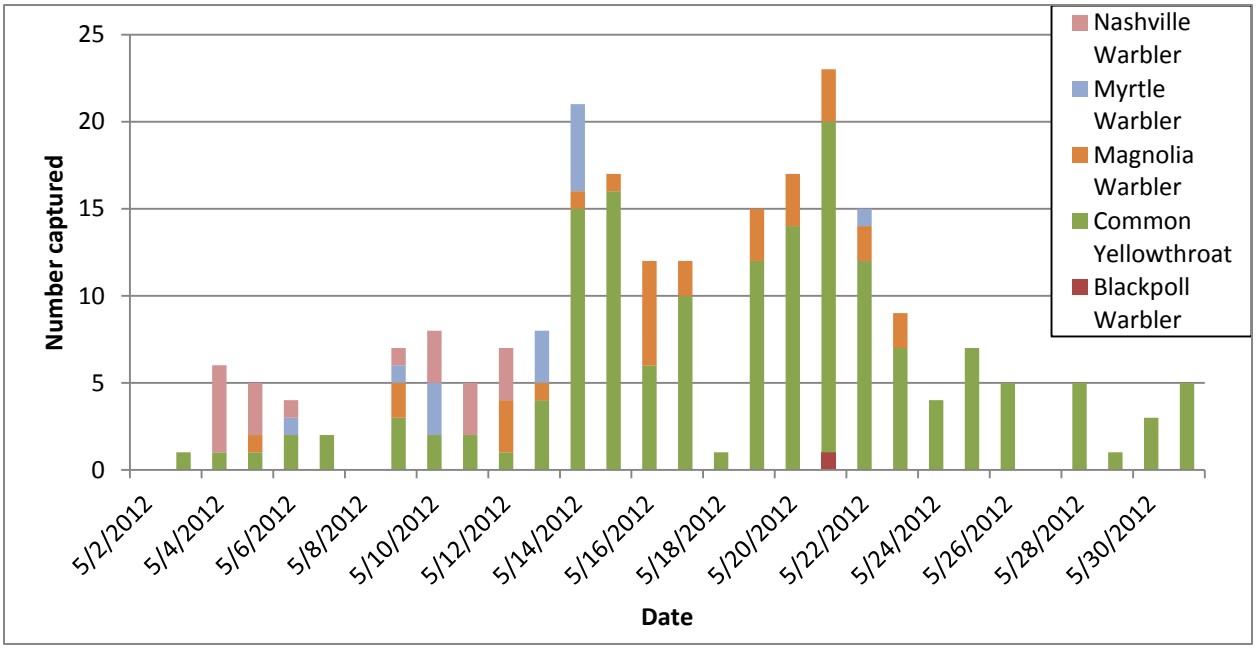


Figure 11. Temporal profile of spring 2012 captures for the five most common warbler species at the Grindstone Island banding station

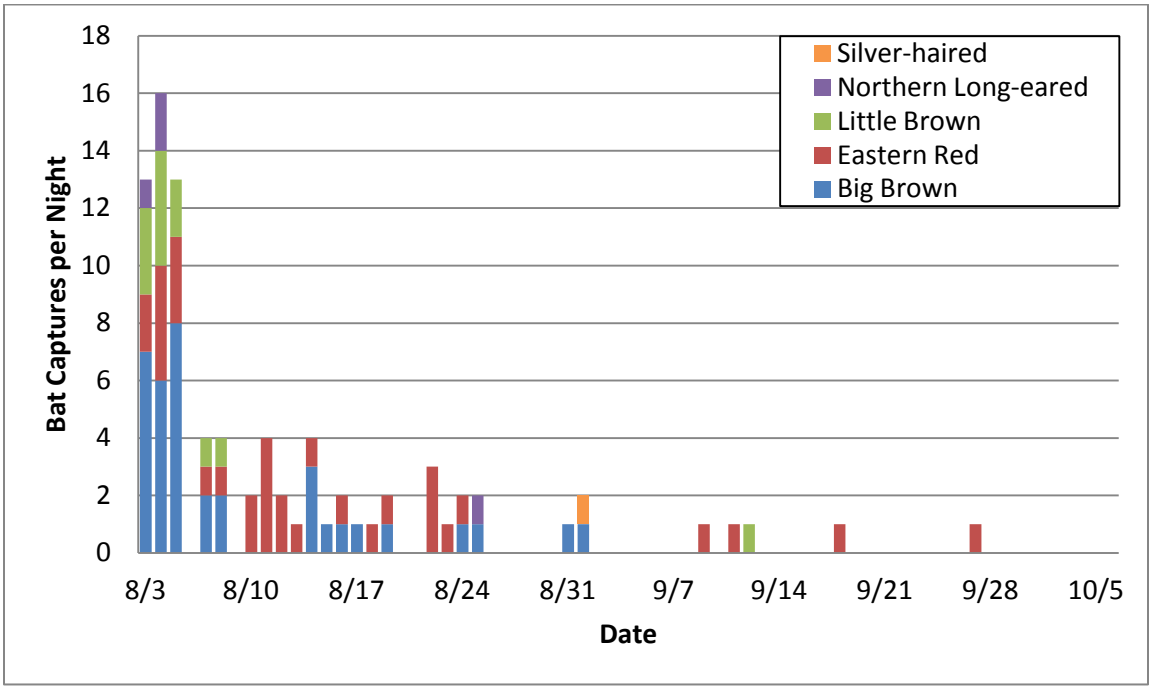


Figure 12. Fall 2011 Grindstone Island bat captures (new captures only)

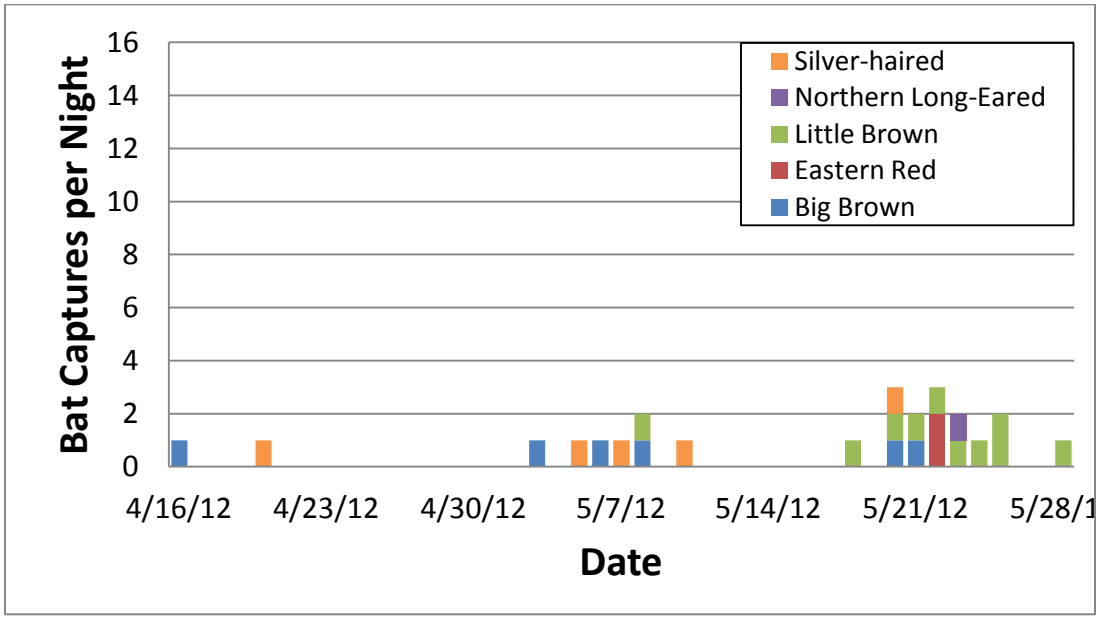


Figure 13. Spring 2012 Grindstone Island bat captures (new captures only)

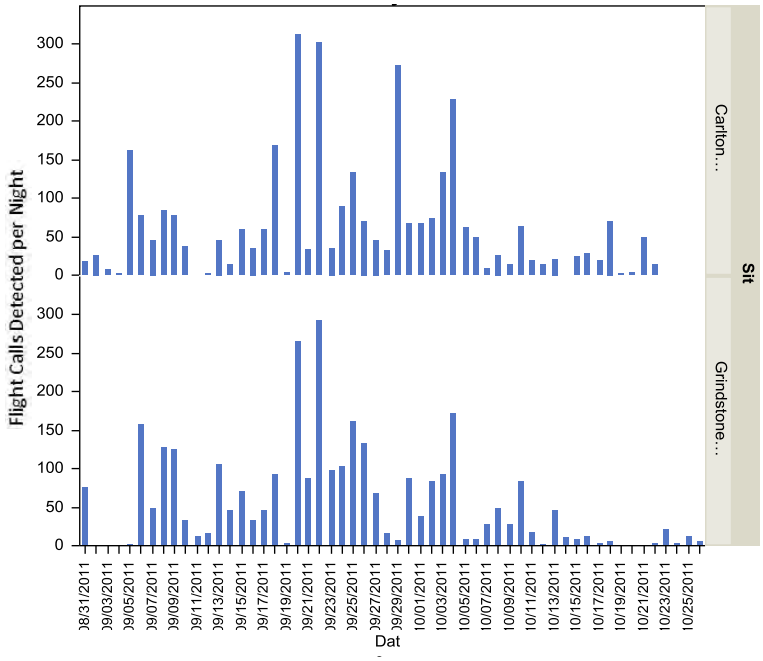


Figure 14. Frequency histogram of all bird calls at the two acoustic monitoring sites for fall 2011

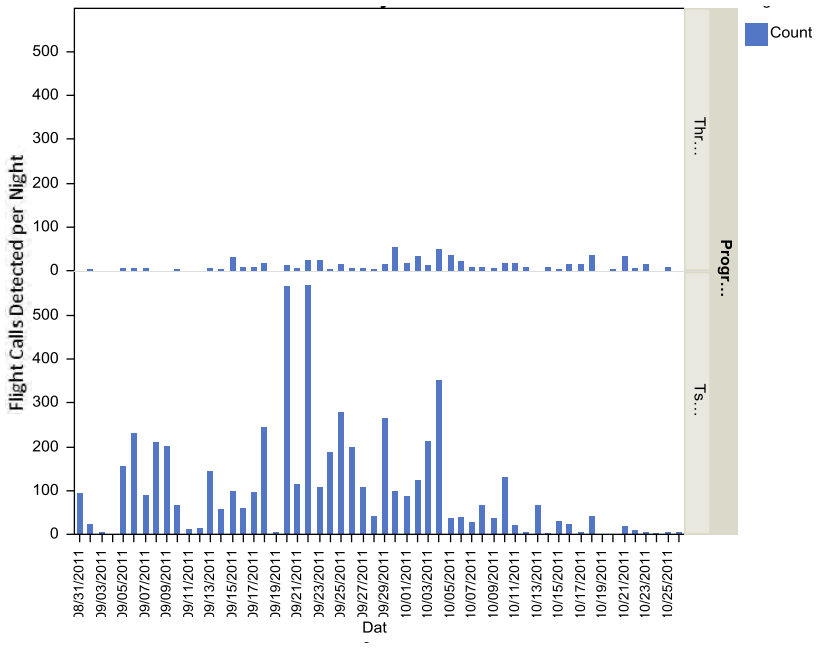


Figure 15. Frequency histogram of higher-pitched and lower-pitched flight calls picked up by both acoustic detectors throughout the fall 2011 field season

Higher pitched calls are between 6 and 10 KHz, and include most warblers and sparrows; lower-pitched calls (3-5 KHz) are primarily thrushes and waterbirds.

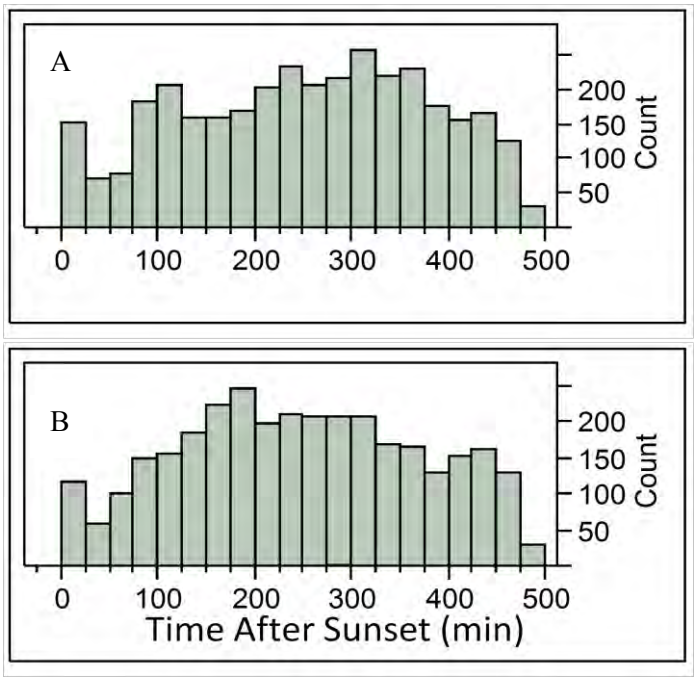


Figure 16. Frequency histogram of average number of flight calls throughout the nocturnal period of recording (fall 2011)

A is the detector on Carleton Island the B is Grindstone Island

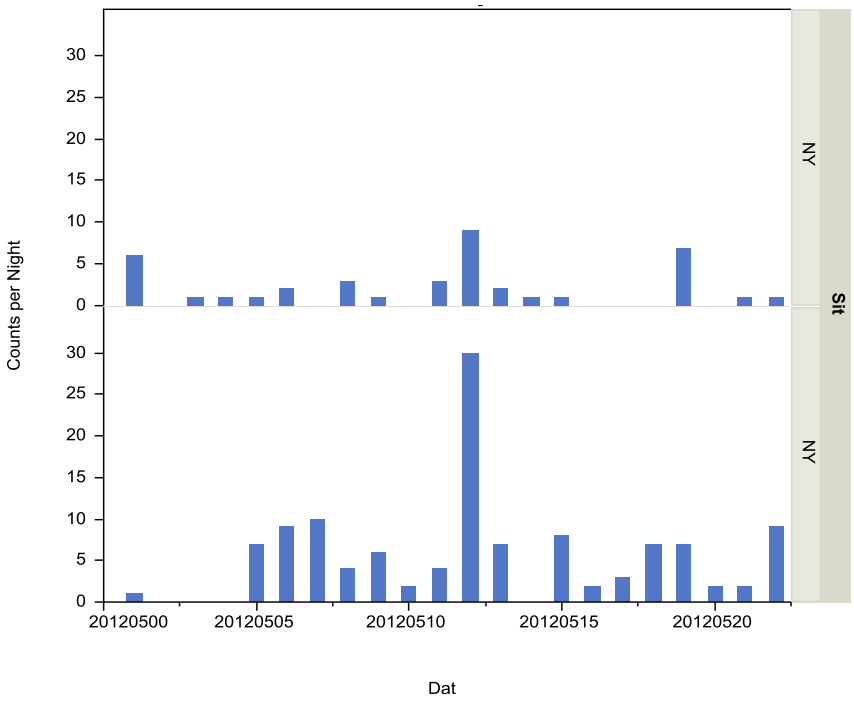


Figure 17. Frequency histogram of all bird calls at the two acoustic monitoring sites for spring 2012. Y-axis is number of calls per night

NY1 is the detector on Carleton Island the NY2 is Grindstone Island

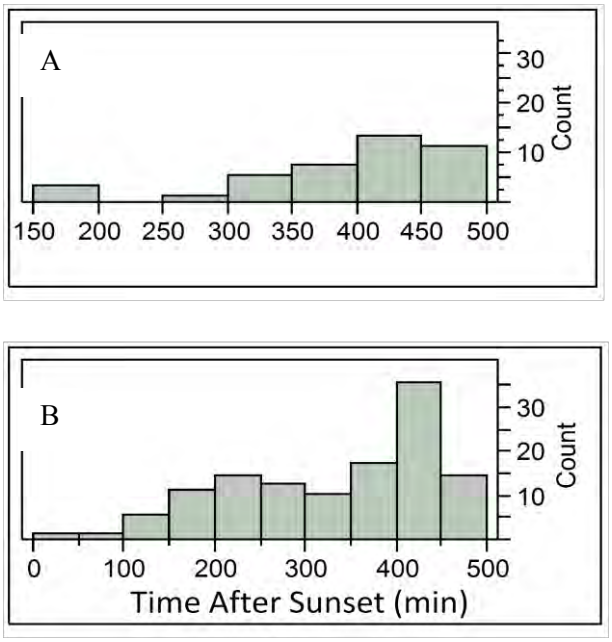


Figure 18. Frequency histogram of average number of flight calls throughout the nocturnal period of recording (spring 2012)

A is the detector on Carleton Island and B is Grindstone Island

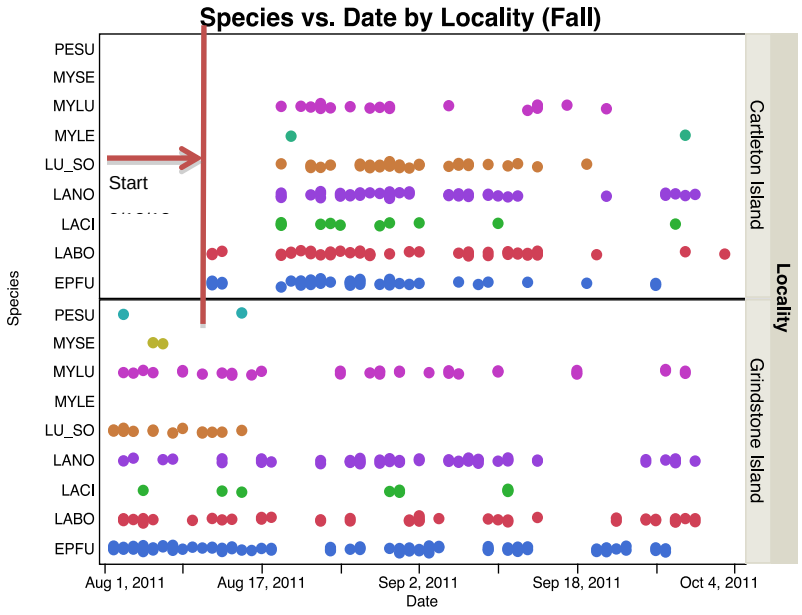


Figure 19: Acoustic bat detections through time during fall 2011 for Carleton (top) and Grindstone (bottom) Islands.

LU_SO=Indiana/Little brown (*Myotis* calls that could not be identified definitely to species level).

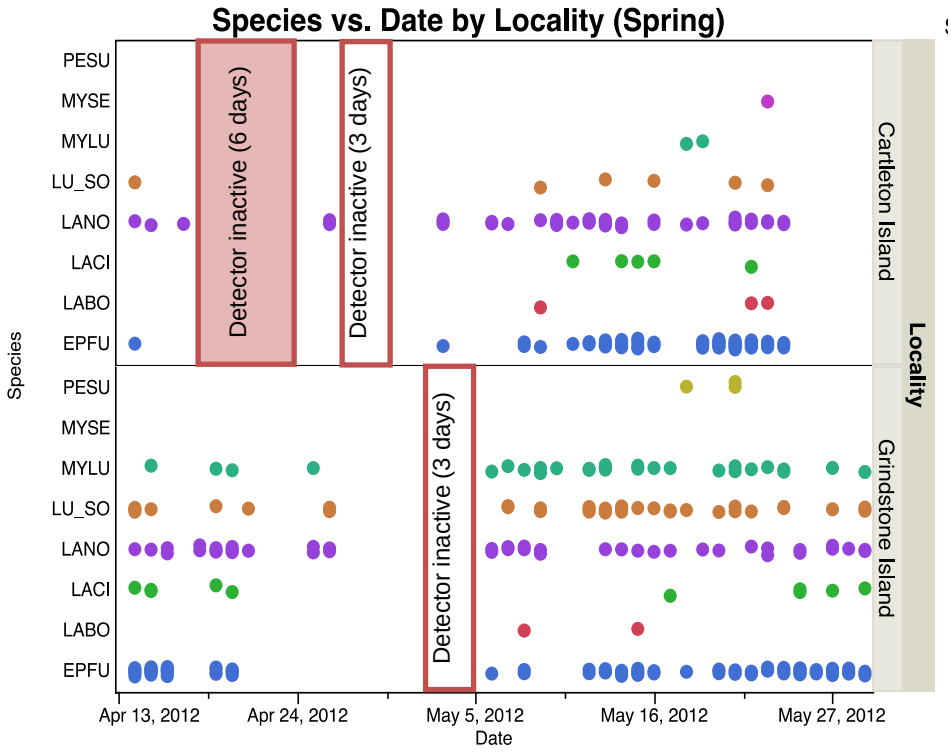


Figure 20: Acoustic bat detections through time during spring 2012 for Carleton (top) and Grindstone (bottom) Islands.

Time periods when the detector was inactive due to technical problems are blocked in red. LU_SO=Indiana/Little brown (*Myotis* calls that could not be identified definitely to species level).

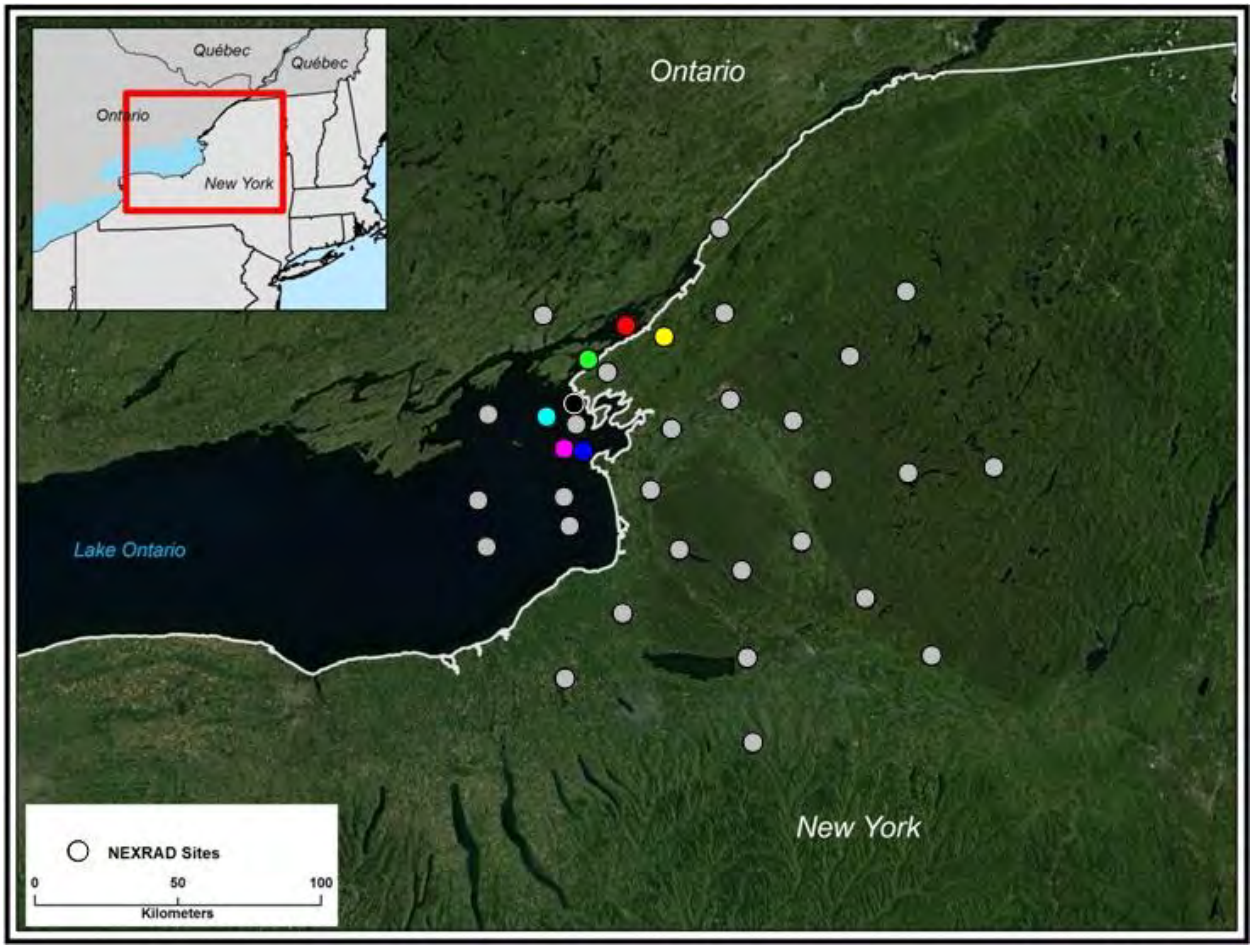


Figure 21A. Location of NEXRAD sites used in Figures 21B-C

Red = Island 1 (Grindstone); Green = Island 2 (Carleton); Black = Island 3(Grenadier); Dark Blue = Island 4 (Stony); Purple = Island 5 (Galloo); Ice Blue = Water Null site; Yellow = Land Null site.

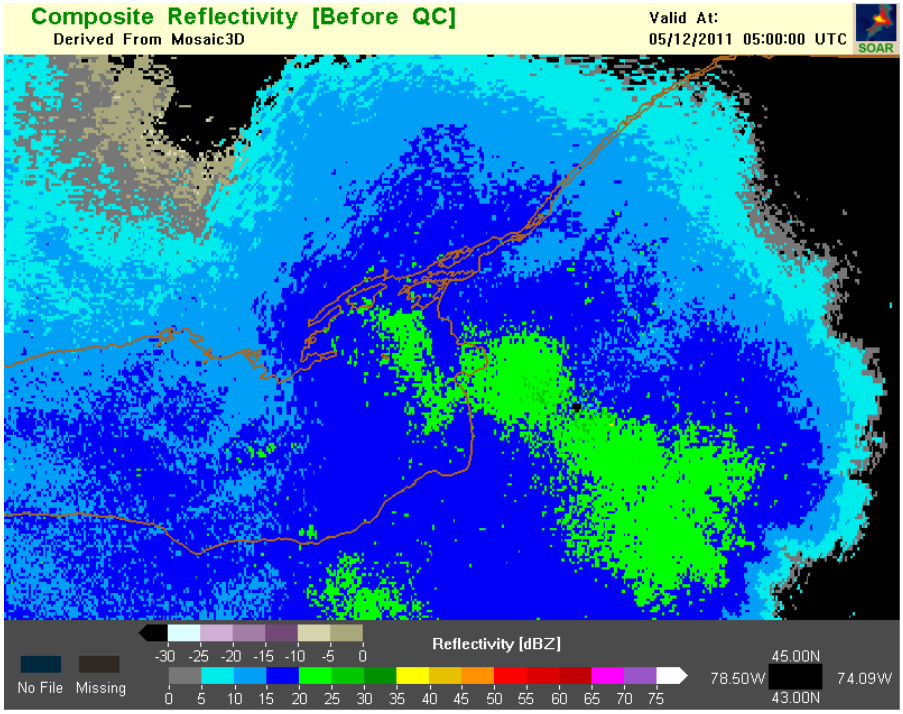


Figure 21B. Composite reflectivity map for the night shown in Figure 21C

This night has no weather interference. Radar image is from 05:00 UTC (1:00 AM), which is near the peak of biological activity as seen in Figure 21C.

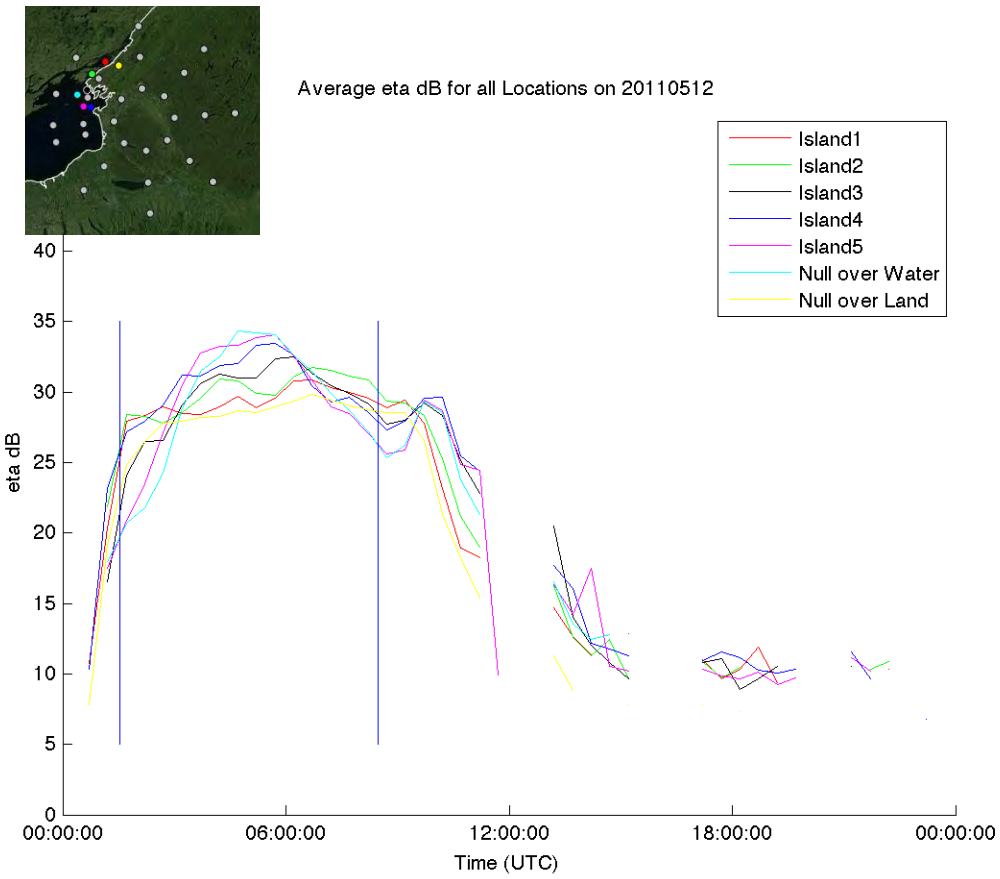


Figure 21C. Average dBη for seven sites from 12 May, 2011 (X-axis is time in UTC, or four hours ahead of east coast time for the period examined).

Vertical blue lines represent nautical sunset and sunrise, with the area between those two lines representing hours of darkness. Islands in Lake Ontario (Islands 3, 4, and 5) and the Water Null site in open water have higher peak migratory activity levels than the mainland null site or islands in the St. Lawrence (Islands 1-2).

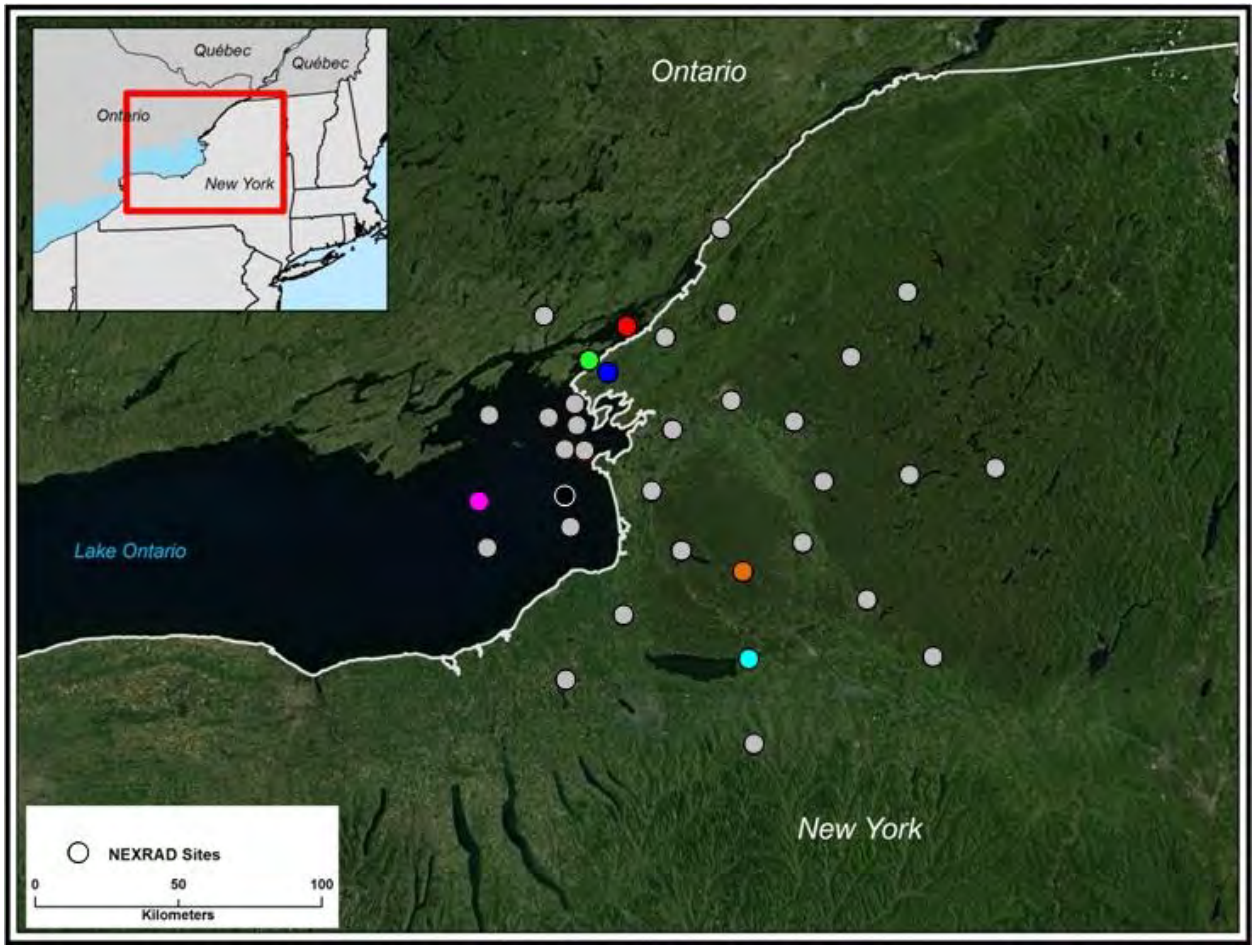


Figure 22A. Location of NEXRAD sites used Figures 22B-C

Red = Island 1 (Grindstone); Green = Island 2 (Carleton); Orange = Null Site 5; Ice Blue = Null Site 13; Black = Null Site 15; Dark Blue = Null Site 16; Purple = Null Site 23.

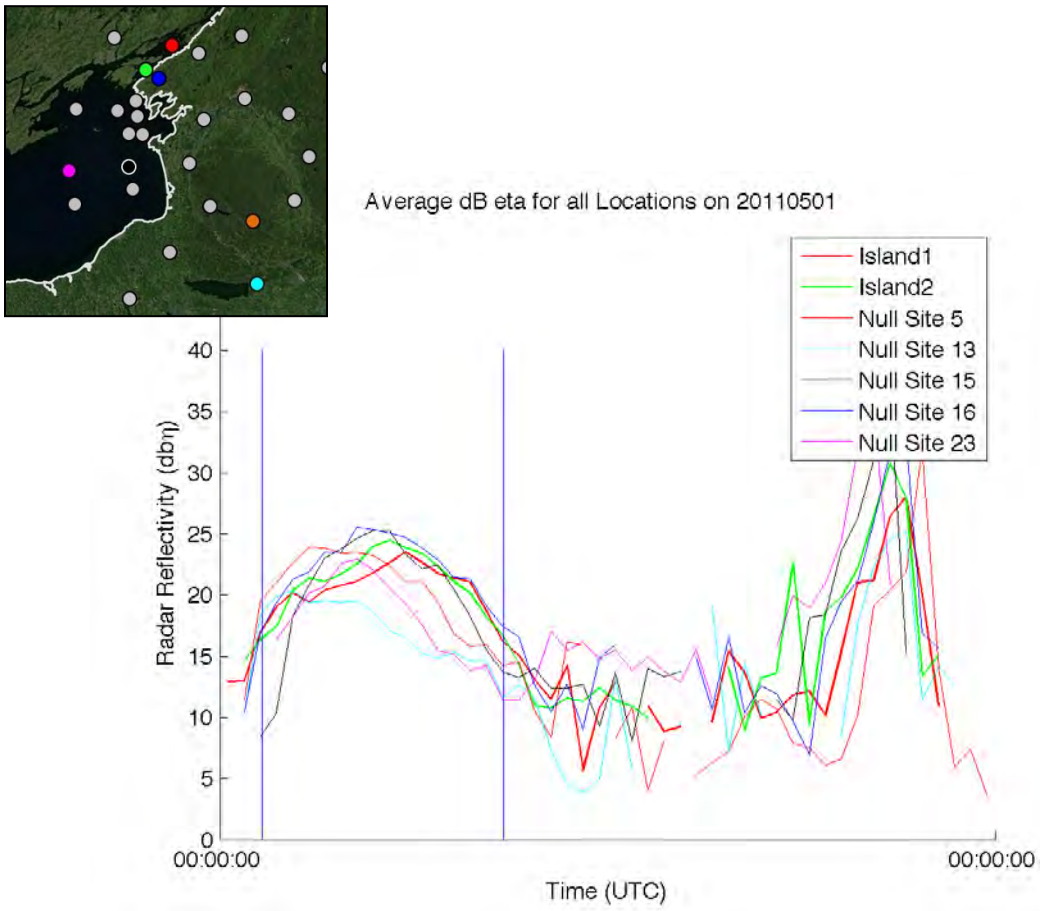


Figure 22B. Average dBη for seven sites from the night of 1 May, 2011

X-axis is time in UTC, or four hours ahead of east coast time for the period examined. Spikes to the far right of the graph represent weather interference. Vertical blue lines represent nautical sunset and sunrise, with the area between those two lines representing hours of darkness.

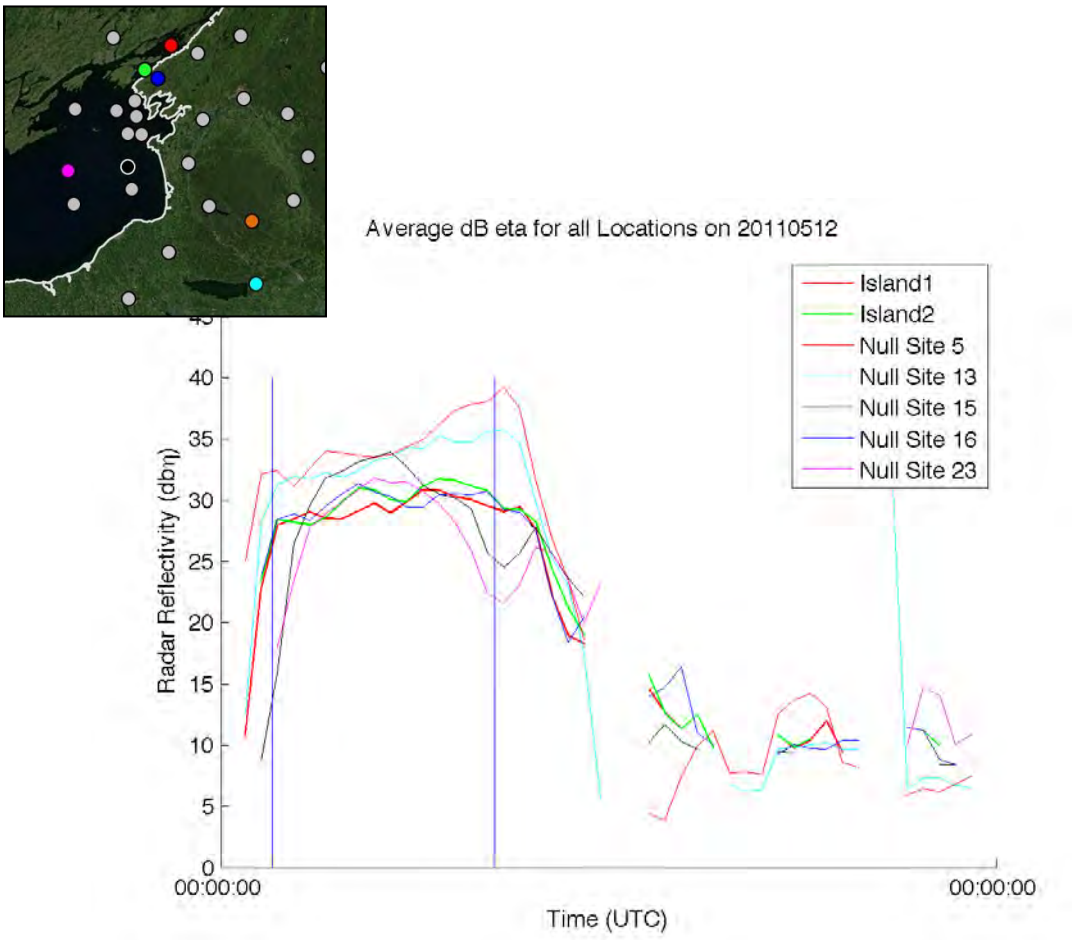


Figure 22C. Same as Figure 22B but for the night of 12 May, 2011

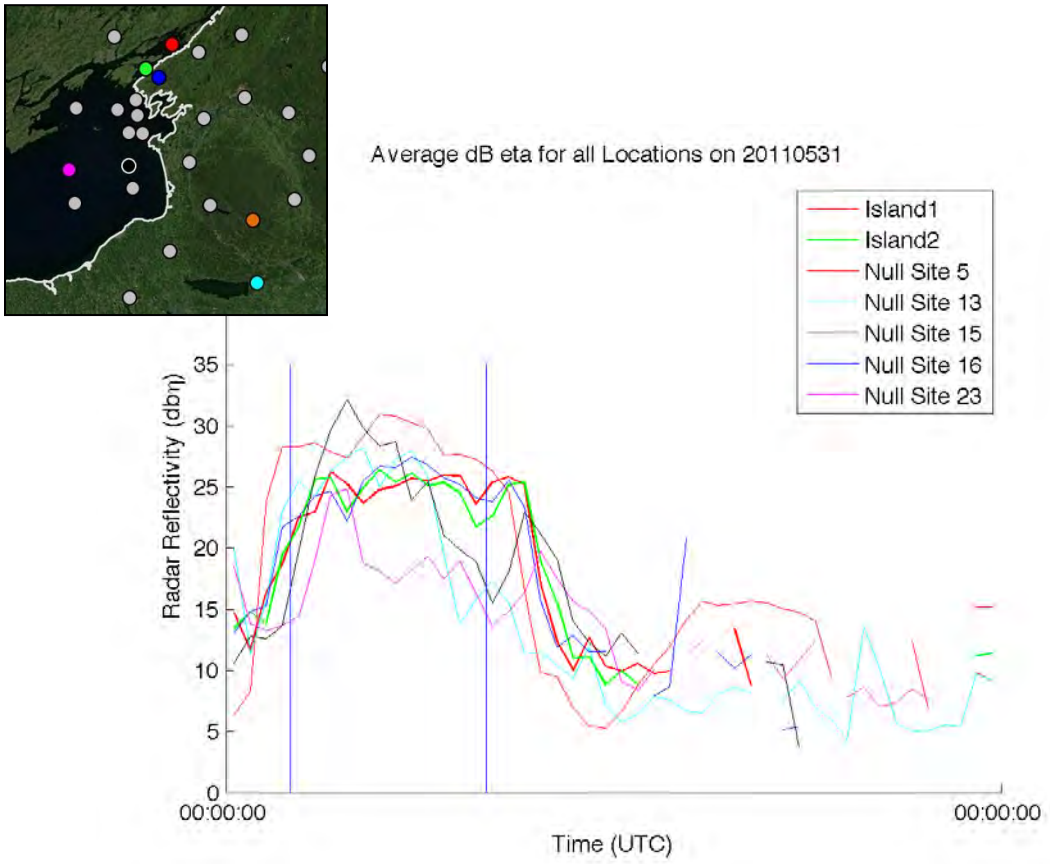


Figure 22D. Same as Figure 22B but for 31 May, 2011

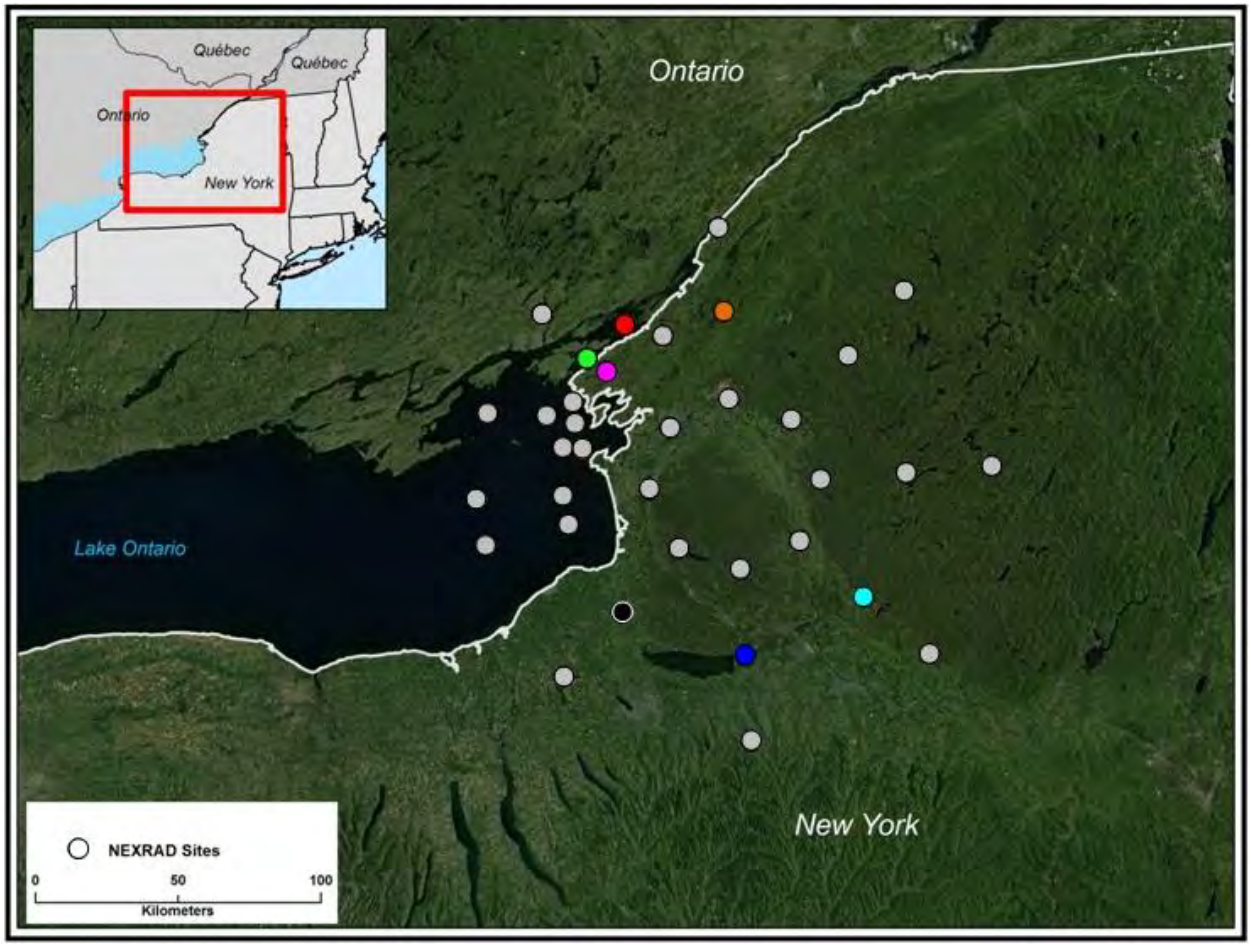


Figure 23A. Location of NEXRAD sites used in Figures 23B-C

Red = Island 1 (Grindstone); Green = Island 2 (Carleton); Orange = Null Site 9; Ice Blue = Null Site 12; Dark Blue = Null Site 13; Black = Null Site 14; Purple = Null Site 16.

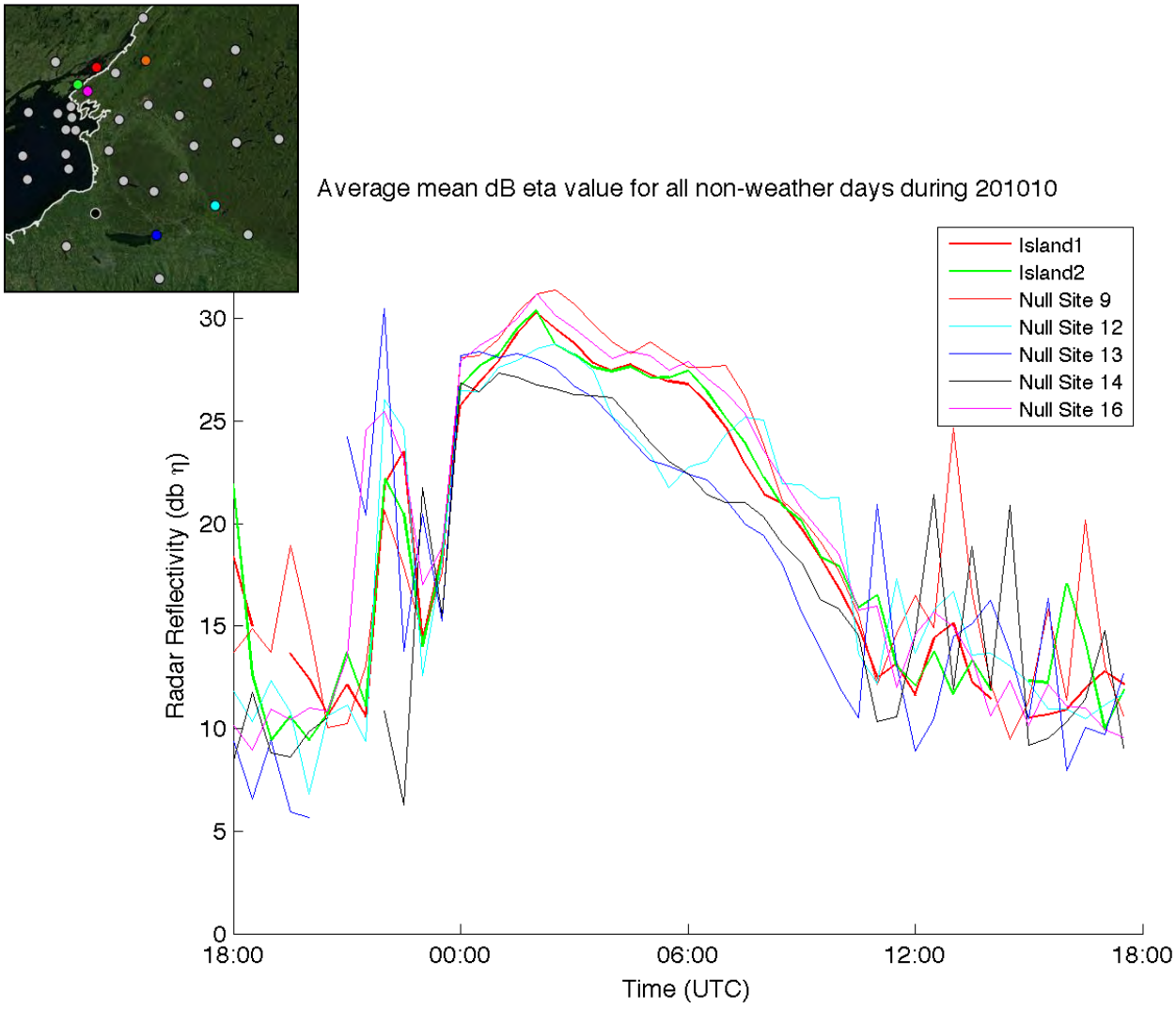


Figure 23B. Average dBη for seven sites from all days without weather interference during October 2010

X-axis is time in UTC, or four hours ahead of east coast time for the period examined. Nautical sunset occurred at approximately 23:00 UTC during this period, and nautical sunrise at approximately 11:00 UTC.

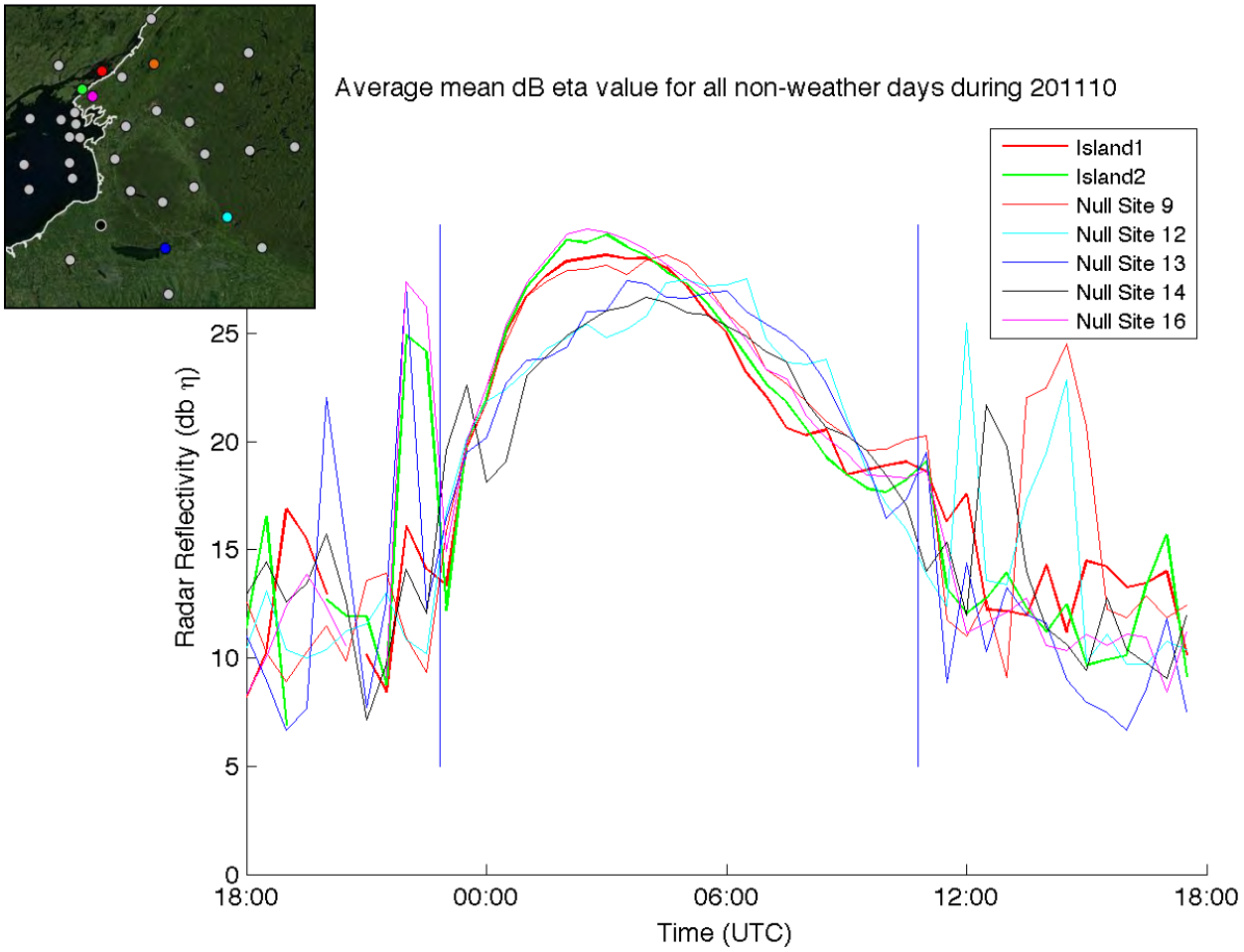


Figure 23C. Average dBη for seven sites from all days without weather interference during October 2011

X-axis is time in UTC, or four hours ahead of east coast time for the period examined. Vertical blue lines represent nautical sunset and sunrise, with the area between those two lines representing hours of darkness.

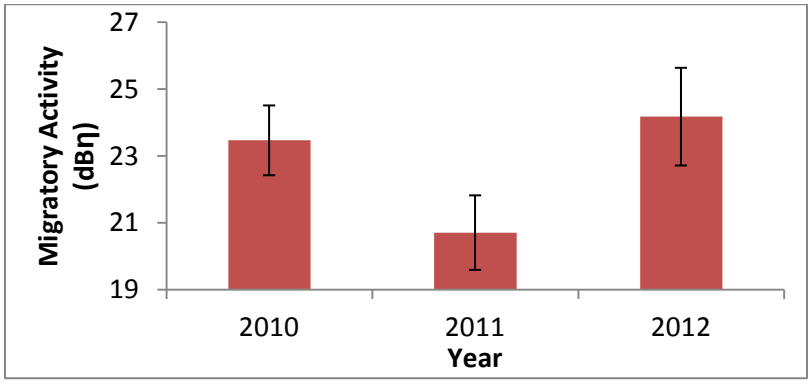
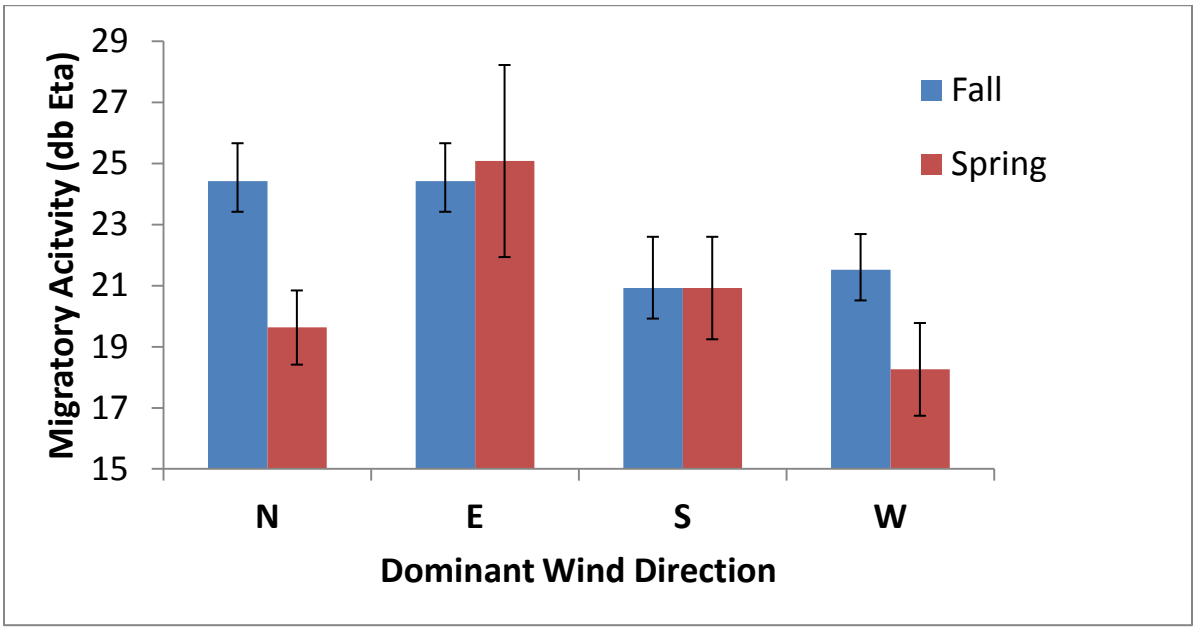


Figure 24. Model-derived least square means by year of NEXRAD migratory activity across all study sites.

A.



B.

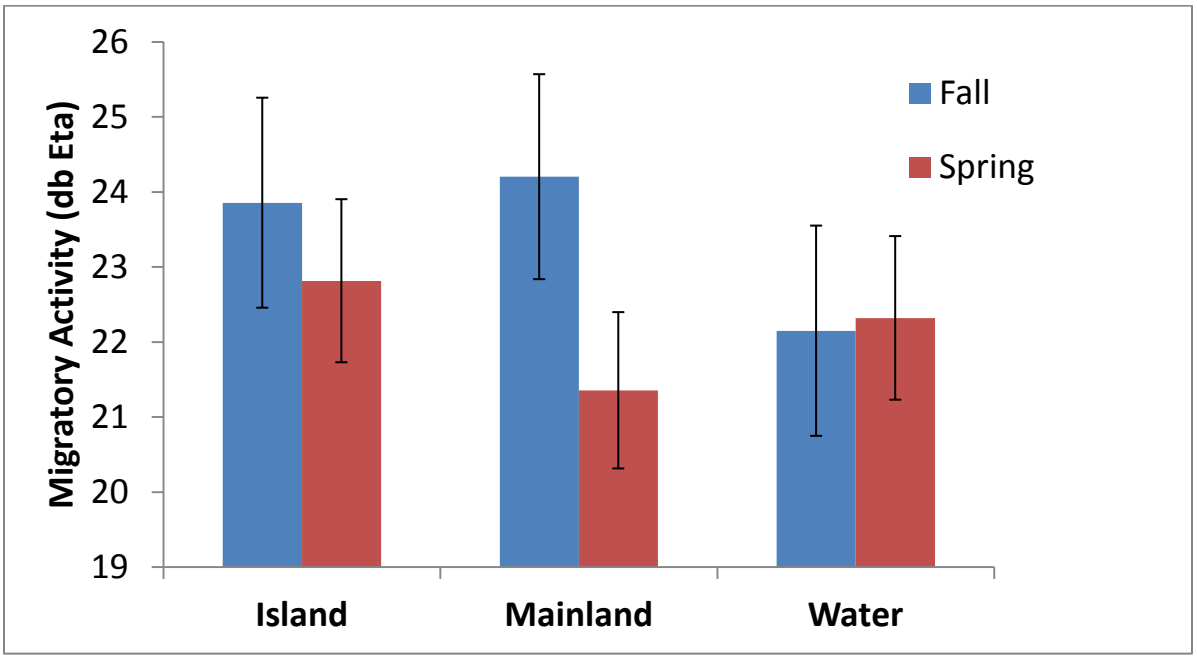


Figure 25: Model-derived least square mean of NEXRAD migratory activity across all study sites by wind direction and season (A) and site type and season (B)

"Water" sites are over eastern Lake Ontario.

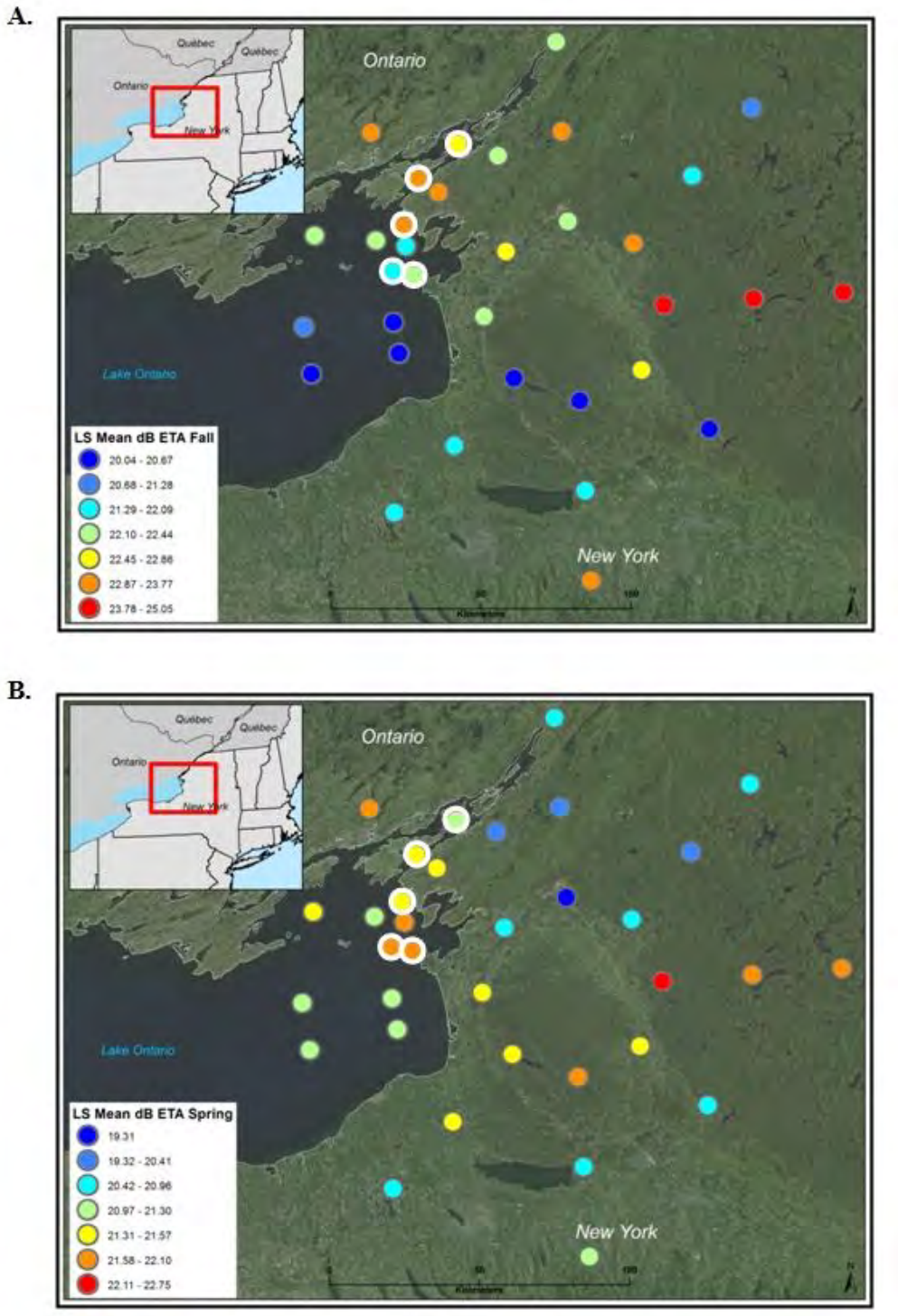


Figure 26. Model-estimated migratory activity at island study sites and standardized comparison sites across the study region.

Average values for fall (A) and spring (B) are shown; focal islands are outlined in white. Presented values are Least Squares Mean dBη estimates (pooled by season for 2010-2012) from a general linear model that accounts for elevation and distance from radar.

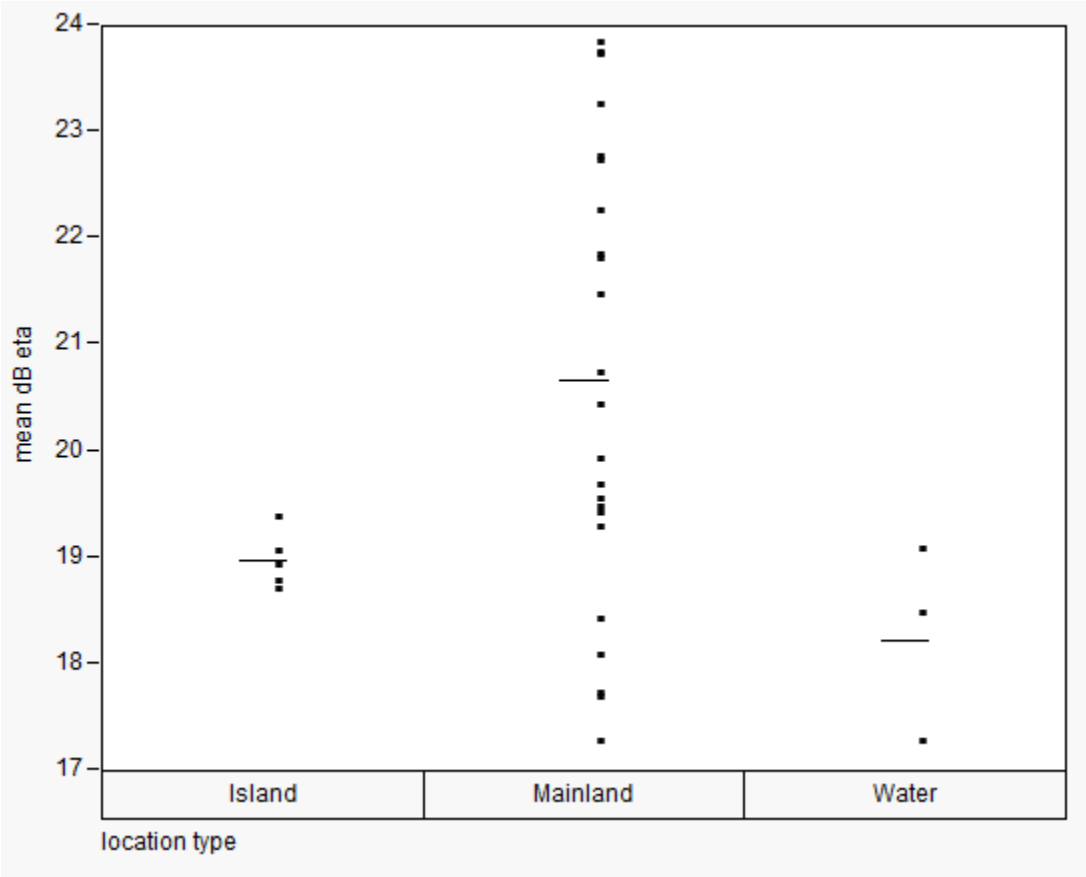


Figure 27. Predicted exodus by location type

Values are Least Square Mean dBη estimates for 35 mainland, island, and open water (Lake Ontario) locations, averaged across nights, seasons and years, from a GLM model controlling for distance from radar and elevation. Mean values for each location type are marked with a bar. There is no significant difference in mean dBη between island (n=5) sites and either mainland (n=23) or water (n=7) sites, although mainland and water locations types are significantly different from each other (p=0.0074).

Appendix I. Summary of Buler and Dawson 2012 report

Buler and Dawson (2012) conducted an analysis of NEXRAD radar stations throughout the northeastern United States for the U.S. Geological Survey. They used fall 2008 and 2009 data (all days without weather interference from 15 August to 7 November) from 16 NEXRAD stations in USFWS Region 5 (Figure I.1) to examine exodus of migratory birds within sampled areas, and used the results to predict important stopover areas across the region. The authors of this report used an algorithm based on mean profiles of reflectivity to extrapolate from radar-sampled air volumes to lower, unsampled altitudes, to account for data loss at low heights for regions far from the radar. Because the study included a large number of radar stations, the authors could develop statistical models based on landscape characteristics to predict the importance for stopover (based on predicted relative bird density) of geographic regions that were not sampled by radar.

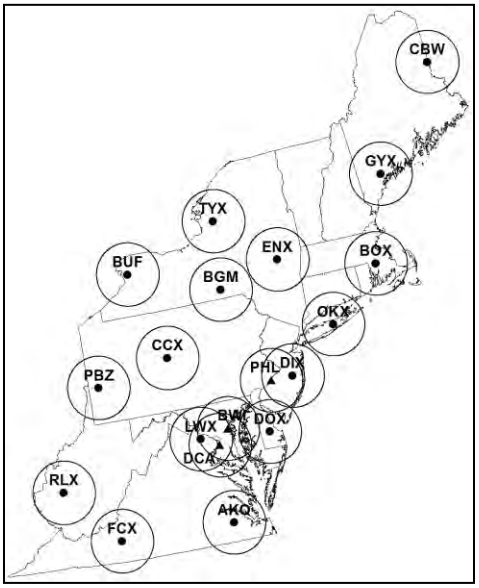


Figure I.1. Sixteen radar stations examined in the Buler and Dawson 2012 report.

An important first step in this effort was to determine the extent of radar-sampled volume for each station (Figure I.2). Some areas were "masked," or excluded from analysis, if something caused partial blockage of the radar beam at least a certain percentage of the time (a common problem in mountainous areas and areas with tall buildings); if the areas were located over open water; or if there was persistent ground clutter (often caused by highway overpasses, tall buildings, or wind farms) that made it difficult to use reflectivity values in comparison of exodus between sites. Some combination of these issues likely caused the comparatively sparse sampling volume for the KTYX radar in upstate New York (Figure I.2), which limited the geographic areas that could be examined for migration exodus using the authors' methods in this report.

For areas that the authors considered to be adequately sampled by radar, they examined mean bird densities during exodus and topographical or habitat characteristics for these locations via geographically weighted regression to develop a predictive model of stopover habitat use across the landscape. Important predictors in the best model (unadjusted $R^2 = 0.81$) included elevation (negatively associated with mean bird densities during exodus), distance from the coastline of a major water body (positive association), and the amounts of hardwood forest, agricultural lands, and human development within a 5-km radius (positive, neutral, and negative associations, respectively). Specifically, the report's authors found higher rates of stopover (and thus exodus) in coastal areas and in hardwood forest patches, particularly along rivers and when isolated among developed or agricultural landscapes. Areas along the St. Lawrence River and eastern Lake Ontario

were predicted to be highly important stopover locations during fall migration based on these criteria (Figure I.3). The report's authors called areas within 50 km of Lake Ontario "regionally important stopover areas."

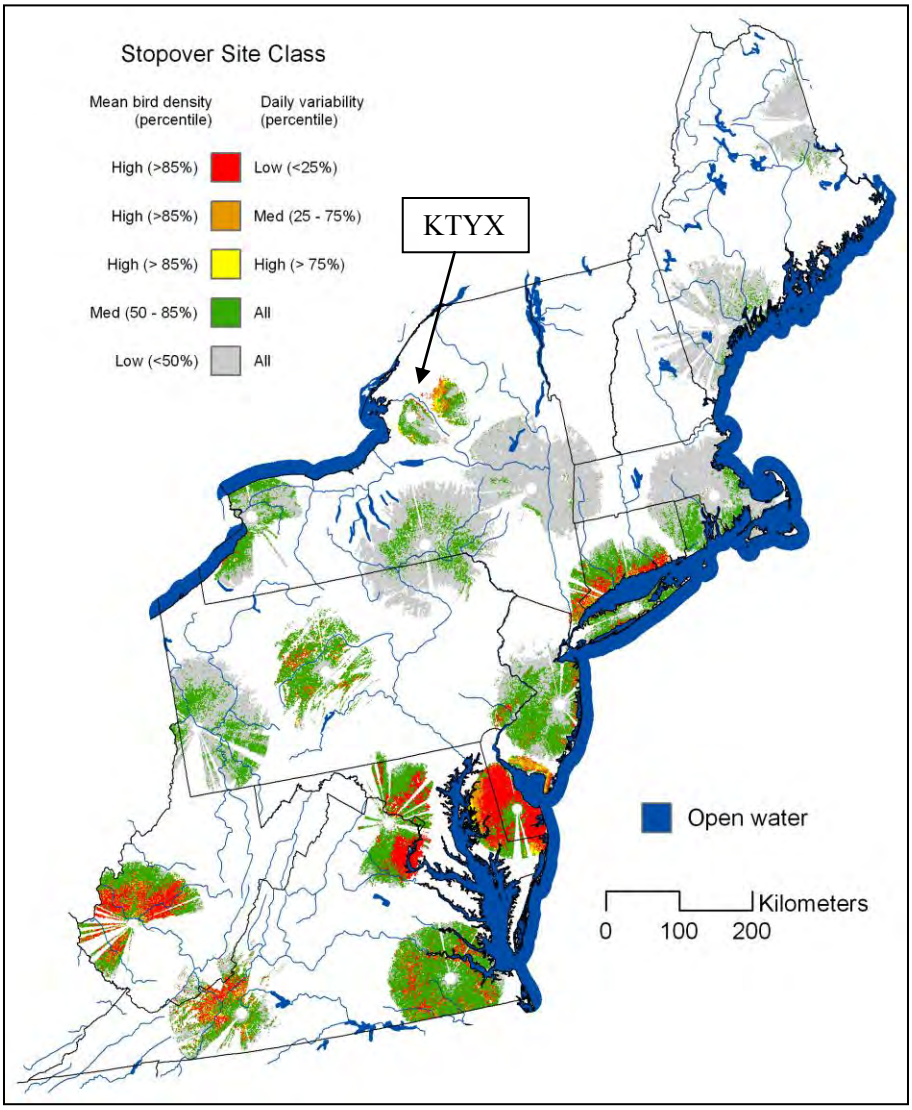


Figure I.2. Map of mean radar-observed bird stopover density during fall 2008 and 2009 seasons at 16 NEXRAD sites in the northeastern United States (from Buler and Dawson 2012; data are pooled across radars for calculation of percentiles). Poor coverage of the KTYX radar in upstate New York (label added) is likely attributable to some combination of radar beam blockage and ground clutter, which the authors felt limited the geographic area available for an examination of migratory exodus.

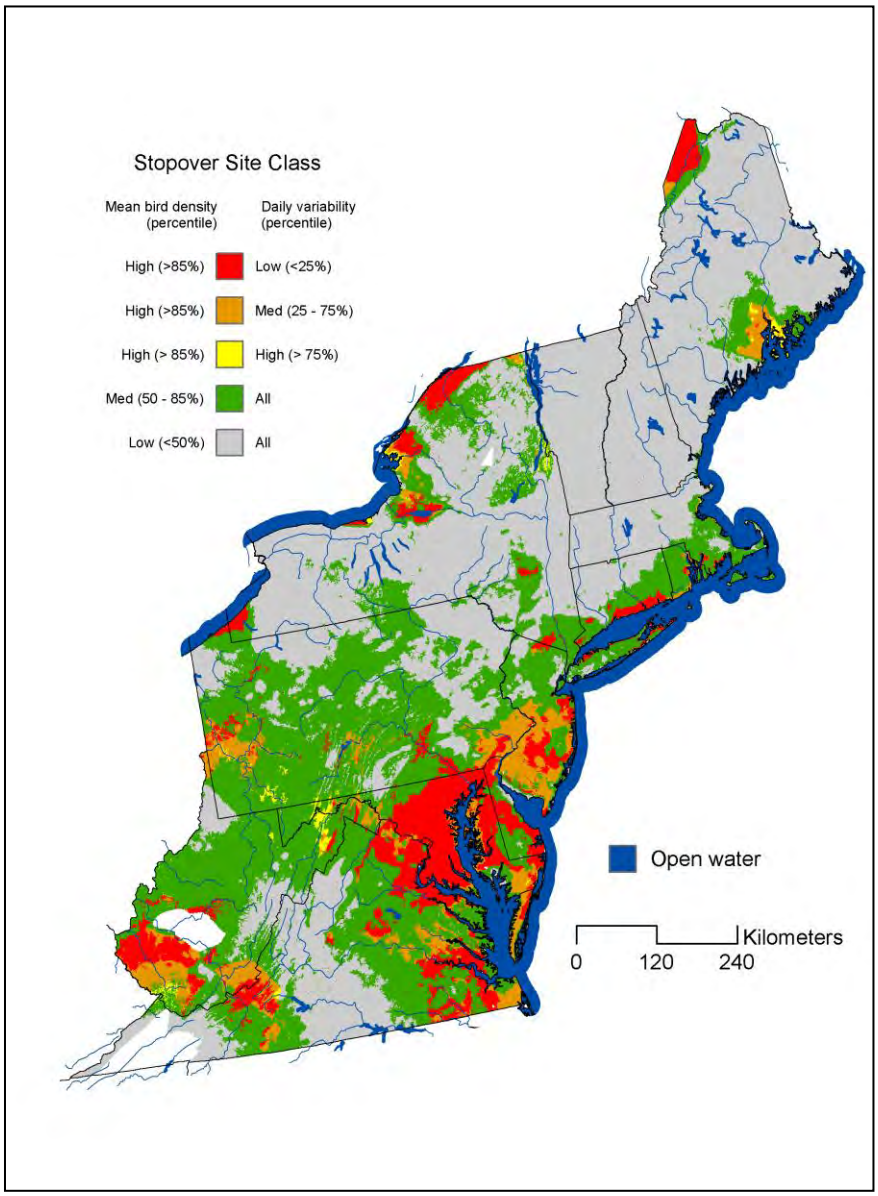


Figure I.3. Map of model-predicted mean bird stopover density during fall migration in 2008 and 2009 in the northeastern United States (from Buler and Dawson 2012; results are pooled throughout the region for calculation of percentiles). Important predictors of bird stopover density in the geographically weighted regression model included distance from the coastline of a major water body and the amounts of hardwood forest, agricultural lands, and human development within a 5 km radius. Despite the poor coverage provided by the KTYX radar in upstate New York (Figure I.1), areas along the St. Lawrence River and eastern Lake Ontario are predicted to be highly important stopover locations based on these criteria.

Appendix II. Species and numbers of birds caught at the Grindstone Island banding station in fall 2011 and spring 2012 (listed in order of total abundance)

Species	Fall 2011 (New captures)	Fall 2011 (Re-captures)	Spring 2012 (New captures)	Spring 2012 (Re-captures)	Grand Total	% of Total Captures
Yellow-rumped (Myrtle) Warbler	544	78	14	0	**636**	22.7%
Magnolia Warbler	199	35	30	0	**264**	9.4%
Common Yellowthroat	41	17	97	64	**219**	7.8%
Black-capped Chickadee	30	65	3	29	**127**	4.5%
Nashville Warbler	85	4	17	2	**108**	3.9%
Song Sparrow	37	8	21	41	**107**	3.8%
Hermit Thrush	61	23	8	0	**92**	3.3%
Golden-crowned Kinglet	82	5	0	0	**87**	3.1%
White-throated Sparrow	57	4	18	0	**79**	2.8%
Blackpoll Warbler	70	6	1	0	**77**	2.7%
Ruby-crowned Kinglet	52	6	13	1	**72**	2.6%
Tennessee Warbler	52	4	0	0	**56**	2.0%
Yellow Warbler	0	0	40	14	**54**	1.9%
Black-throated Blue Warbler	45	4	4	0	**53**	1.9%
Gray Catbird	9	0	39	5	**53**	1.9%
American Redstart	26	4	18	3	**51**	1.8%
Eastern Towhee	18	1	16	13	**48**	1.7%
Black-throated Green Warbler	42	0	0	0	**42**	1.5%
American Robin	23	0	14	3	**40**	1.4%
Ovenbird	32	3	3	0	**38**	1.4%
Black-and-white Warbler	14	2	13	2	**31**	1.1%
Red-eyed Vireo	25	0	1	0	**26**	0.9%
Blue Jay	13	0	8	4	**25**	0.9%
Dark-eyed (Slate-colored) Junco	25	0	0	0	**25**	0.9%
Swainson's Thrush	13	2	8	0	**23**	0.8%
House Wren	12	2	6	2	**22**	0.8%
Ruby-throated Hummingbird	7	0	15	0	**22**	0.8%
Chestnut-sided Warbler	4	1	12	3	**20**	0.7%
Common Grackle	19	0	0	0	**19**	0.7%
(Western) Palm Warbler	17	0	2	0	**19**	0.7%
Brown Creeper	15	2	0	0	**17**	0.6%

Species	Fall 2011 (New captures)	Fall 2011 (Re-captures)	Spring 2012 (New captures)	Spring 2012 (Re-captures)	Grand Total	% of Total Captures
Wood Thrush	4	0	11	1	**16**	0.6%
Wilson's Warbler	13	1	1	0	**15**	0.5%
Chipping Sparrow	5	0	7	2	**14**	0.5%
Cedar Waxwing	5	0	7	0	**12**	0.4%
Downy Woodpecker	8	3	0	0	**11**	0.4%
Bay-breasted Warbler	10	0	0	0	**10**	0.4%
Blue-headed Vireo	9	0	1	0	**10**	0.4%
Blackburnian Warbler	9	1	0	0	**10**	0.4%
Brown Thrasher	3	0	7	0	**10**	0.4%
Lincoln's Sparrow	3	0	6	0	**9**	0.3%
Field Sparrow	4	1	3	0	**8**	0.3%
Rose-breasted Grosbeak	1	0	7	0	**8**	0.3%
Hairy Woodpecker	5	1	1	0	**7**	0.2%
Least Flycatcher	5	0	2	0	**7**	0.2%
Northern Cardinal	1	0	4	1	**6**	0.2%
Veery	2	0	4	0	**6**	0.2%
Canada Warbler	2	1	2	0	**5**	0.2%
Eastern Phoebe	5	0	0	0	**5**	0.2%
Pine Warbler	3	0	1	1	**5**	0.2%
Scarlet Tanager	5	0	0	0	**5**	0.2%
Yellow-bellied Flycatcher	4	0	1	0	**5**	0.2%
Baltimore Oriole	0	0	3	1	**4**	0.1%
Cape May Warbler	4	0	0	0	**4**	0.1%
Gray-cheeked Thrush	3	1	0	0	**4**	0.1%
Sharp-shinned Hawk	2	0	1	1	**4**	0.1%
Yellow-bellied Sapsucker	3	1	0	0	**4**	0.1%
Brown-headed Cowbird	0	0	1	2	**3**	0.1%
Eastern Wood-Pewee	3	0	0	0	**3**	0.1%
Northern Waterthrush	2	0	1	0	**3**	0.1%
Ruffed Grouse	2	0	1	0	**3**	0.1%
Swamp Sparrow	1	0	2	0	**3**	0.1%
Traill's Flycatcher^	0	0	3	0	**3**	0.1%
White-crowned Sparrow	2	0	1	0	**3**	0.1%
Winter Wren	2	0	1	0	**3**	0.1%
Northern (Yellow-shafted) Flicker	0	0	2	1	**3**	0.1%
American Goldfinch	0	0	2	0	**2**	0.1%

Species	Fall 2011 (New captures)	Fall 2011 (Re-captures)	Spring 2012 (New captures)	Spring 2012 (Re-captures)	Grand Total	% of Total Captures
Black-billed Cuckoo	2	0	0	0	**2**	0.1%
Fox Sparrow	2	0	0	0	**2**	0.1%
Mourning Warbler	0	0	2	0	**2**	0.1%
Pileated Woodpecker	1	0	1	0	**2**	0.1%
Clay-colored Sparrow	0	0	1	0	**1**	0.0%
Gray-cheeked/Bicknell's Thrush*	1	0	0	0	**1**	0.0%
Golden-winged Warbler	0	0	1	0	**1**	0.0%
Hooded Warbler	0	0	1	0	**1**	0.0%
Indigo Bunting	0	0	1	0	**1**	0.0%
Northern Parula	1	0	0	0	**1**	0.0%
Orange-crowned Warbler	1	0	0	0	**1**	0.0%
Purple Finch	1	0	0	0	**1**	0.0%
Red-breasted Nuthatch	1	0	0	0	**1**	0.0%
White-breasted Nuthatch	1	0	0	0	**1**	0.0%
Grand Total	**1810**	**286**	**511**	**196**	**2803**	100.0%

***** Some individuals of Gray-cheeked Thrush and Bicknell's Thrush cannot be reliably identified to species in the hand.

^ Some individuals of Willow and Alder Flycatcher cannot be reliably identified to species in the hand, and are identified for banding purposes as Traill's Flycatchers (meaning the bird is one of those two species).

Appendix III. Species and numbers of birds detected during point counts on Grindstone Island in fall 2011 and spring 2012

Listed in order of total abundance; note that individuals may have been counted multiple times over the course of a season.

Species	Number Detected (Fall 2011)	Number Detected (Spring 2012)	% of Total Detections
Canada Goose	244	89	14.3%
Yellow-rumped (Myrtle) Warbler	256	20	11.9%
American Robin	120	34	6.6%
American Crow	119	33	6.5%
Cedar Waxwing	90	46	5.8%
Blue Jay	83	51	5.8%
Black-capped Chickadee	107	18	5.4%
White-throated Sparrow	105	1	4.6%
Song Sparrow	50	41	3.9%
Eastern Towhee	37	41	3.4%
Common Yellowthroat	26	49	3.2%
Herring Gull	63	11	3.2%
Gray Catbird	19	26	1.9%
Yellow Warbler	0	43	1.8%
American Goldfinch	23	10	1.4%
Black-and-white Warbler	1	31	1.4%
Unidentified Bird	0	29	1.2%
Common Loon	15	12	1.2%
Northern Cardinal	10	16	1.1%
Double-crested Cormorant	20	5	1.1%
Chestnut-sided Warbler	0	21	0.9%
Brown-headed Cowbird	0	18	0.8%
Black-throated Green Warbler	13	4	0.7%
Northern Flicker	8	7	0.6%
Chipping Sparrow	0	13	0.6%
American Redstart	5	7	0.5%
Downy Woodpecker	12	0	0.5%
Baltimore Oriole	1	9	0.4%
Red-tailed Hawk	9	1	0.4%
Red-winged Blackbird	0	10	0.4%
Unidentified Warbler	0	10	0.4%
Common Grackle	9	0	0.4%
Golden-crowned Kinglet	9	0	0.4%
House Wren	4	5	0.4%

Species	Number Detected (Fall 2011)	Number Detected (Spring 2012)	% of Total Detections
Magnolia Warbler	2	7	0.4%
Ruby-crowned Kinglet	4	5	0.4%
White-breasted Nuthatch	9	0	0.4%
Wild Turkey	5	4	0.4%
Black-throated Blue Warbler	2	6	0.3%
Hermit Thrush	5	3	0.3%
Turkey Vulture	3	5	0.3%
Common Merganser	0	7	0.3%
Red-eyed Vireo	6	0	0.3%
Osprey	0	5	0.2%
Pine Warbler	0	5	0.2%
Pileated Woodpecker	5	0	0.2%
Dark-eyed (Slate-colored) Junco	5	0	0.2%
Belted Kingfisher	3	1	0.2%
Bobolink	0	4	0.2%
Nashville Warbler	0	4	0.2%
Barn Swallow	3	0	0.1%
Eastern Phoebe	0	3	0.1%
Eastern Wood-Pewee	2	1	0.1%
Hairy Woodpecker	2	1	0.1%
Sharp-shinned Hawk	2	1	0.1%
Unidentified Gull	0	3	0.1%
Unidentified Woodpecker	0	3	0.1%
(Western) Palm Warbler	3	0	0.1%
Cooper's Hawk	0	2	0.1%
Common Raven	2	0	0.1%
Mourning Dove	1	1	0.1%
Rose-breasted Grosbeak	1	1	0.1%
Ruffed Grouse	1	1	0.1%
Unidentified Swallow	0	2	0.1%
Wood Thrush	0	2	0.1%
Yellow-bellied Sapsucker	2	0	0.1%
Bald Eagle	1	0	0.0%
Blackburnian Warbler	0	1	0.0%
Blackpoll Warbler	0	1	0.0%
Brown Thrasher	0	1	0.0%
Eastern Kingbird	0	1	0.0%
Great Blue Heron	0	1	0.0%

Species	Number Detected (Fall 2011)	Number Detected (Spring 2012)	% of Total Detections
Merlin	1	0	0.0%
Northern Parula	0	1	0.0%
Ring-billed Gull	0	1	0.0%
Scarlet Tanager	1	0	0.0%
Unidentified Duck	0	1	0.0%
Warbling Vireo	1	0	0.0%
Total	**1530**	**796**	**100.0%**

Appendix IV. Species identified from nocturnal passive acoustic recording of avian flight calls

Species	Detected Fall 2011	Detected Spring 2012
American Pipit	X	
American Redstart	X	X
American Robin	X	
American Woodcock	X	
American Tree Sparrow	X	
Black-and-White Warbler	X	
Bay-breasted Warbler	X	
Bicknell's Thrush	X	
Blackburnian Warbler	X	
Blackpoll Warbler	X	
Black-throated Blue Warbler	X	X
Black-throated Green Warbler	X	
Cackling Goose	X	
Canada Goose	X	
Canada Warbler	X	
Caspian Tern		X
Clay-colored Sparrow	X	
Chipping Sparrow	X	X
Cape May Warbler	X	
Common Yellowthroat	X	X
Chestnut-sided Warbler	X	X
Dark-eyed Junco	X	
Eastern Saw-whet Owl	X	
Eastern Towhee	X	
Fox Sparrow	X	
Great Blue Heron	X	
Gray-cheeked/Bicknell's Thrush		X
Gray-cheeked Thrush	X	
Great Horned Owl	X	
Greater Yellowlegs	X	
Henslow's Sparrow	X	
Hermit Thrush	X	
House Finch		X
Killdeer	X	
Louisiana Waterthrush	X	
Mallard	X	
Magnolia Warbler	X	
Nashville's Warbler	X	

Species	Detected Fall 2011	Detected Spring 2012
Nelson's Sparrow	X	
Northern Parula	X	
Northern Waterthrush	X	
Orange-crowned Warbler	X	
Ovenbird	X	
Palm Warbler	X	
Pine Warbler	X	
Prairie Warbler	X	
Rose-breasted Grosbeak	X	
Savannah Sparrow	X	X
Song Sparrow	X	X
Swamp Sparrow	X	X
Swainson's Thrush	X	X
Tennessee Warbler	X	
Veery	X	X
Vesper Sparrow	X	X
White-crowned Sparrow	X	
Wilson's Warbler	X	X
White-throated Sparrow	X	X
Yellow Warbler	X	
Yellow-rumped Warbler	X	X