STUDYING MIGRANT RAPTORS USING THE ATLANTIC FLYWAY.
BLOCK ISLAND RAPTOR RESEARCH STATION, BLOCK ISLAND, RI:
2012 - 2023 SEASON SUMMARY.

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INNOVATIVE WILDLIFE SCIENCE

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Biodiversity Research Institute (BRI) is a 501(c)(3) non-profit organization located in Portland, Maine. Founded in 1998, 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.

This report and numerous other materials related to this project are posted on the project webpage (http://www.briloon.org/raptors/blockisland) housed on the BRI website.

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FRONT PHOTO: *Rough-legged Hawk captured in fall 2023.* Photo credit: Chris Persico, BRI.

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DEDICATION

This report is dedicated to Deneb Sandack. Her never-ending enthusiasm, passion for nature, raptors and for every moment of life itself cannot be understated. She has left her mark on all of us; we will all do our best to carry it forward. She will be so dearly missed.

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1.0 EXECUTIVE SUMMARY

During fall seasons of 2012–2023, we operated the Block Island Raptor Research Station (BIRRS) on Block Island, Rhode Island to enable multiple ongoing research investigations on migrant raptors.

The primary objectives of our original study were to: (1) characterize the timing, intensity and species composition of the raptor migration at Block Island, Rhode Island (2) characterize spring and fall migration routes, overwintering locations and presumed origins of migrant raptors using Block Island during migration and (3) establish baseline mercury exposure levels in migrant raptors and make species comparisons, and (4) conduct educational outreach and contribute data to scientific endeavors/collaborations. As we have achieved these objectives, new objectives have been developed over time. The BIRRS enables unique opportunities to contribute to a wide variety of topics of conservation, management and regulatory relevance, including renewable energy development, climate change, disease prevalence, and migration ecology for a wide variety of organisms.

1. We captured 1,532 individuals of nine different raptor species on Block Island throughout the fall seasons, 2012–2023. Over three-quarters of raptors captured annually were falcons. In general, Merlins (*Falco columbarius*) comprised roughly one-half (48%) of total captures, while Peregrine Falcons (*Falco peregrinus*) (peregrine hereafter) comprised slightly more than one-quarter (30%) of total captures annually. Sharp-shinned Hawks (*Accipiter striatus*), Cooper's Hawks (*Accipiter cooperii*), Northern Harriers (*Circus cyaneus*) and American Kestrels (*Falco sparverius*) comprise the remaining quarter (21%) of total captures. To date, a single Red-tailed Hawk (*Buteo jamaicensis*), a single Northern Goshawk (*Accipiter gentilis*), and a single Rough-legged Hawk (*Buteo lagopus*) have been captured. The majority (97%) of raptors captured on Block Island were of the hatching year age class **(Figure 5 & Figure 6, pg 7, 9)**.
2. Captures on Block Island generally reflected known migration timing for peregrines and Merlins, with the bulk of the peregrine captures occurring during the first 7–14 days of October. The Merlin migration on Block Island was more protracted compared to peregrines, with the annual peak ranging from 17 September to 1 October **(Figure 7, pg. 10)**.
3. We fit numerous raptors with tracking devices along the Atlantic migration flyway to learn about use areas during migration, stopover sites, and habitat use in wintering and breeding areas. To date, we have fitted 49 peregrines with transmitters from the Block Island Raptor Research Station. Combined with two peregrines tracked from Monhegan Island and four from Cutler, Maine, these peregrines have generated the most extensive dataset available on peregrine migration in the Atlantic flyway **(Figure 11, pg. 15)**.
4. Satellite-tagged peregrines provided insights on spring migration routes and probable origins fall migrants using the Atlantic flyway. Spring destinations spanned from central Saskatchewan to Greenland. Satellite-tracked peregrines used little of the Atlantic flyway during their northward migration. **(Figure 15, p. 20)**.
5. This study is the first to our knowledge in which Merlins have been tracked using satellite telemetry. Sixteen satellite-tagged Merlins from Block Island (14 hatching year birds and 2 adult) and one adult fitted with a transmitter in Cutler, ME provided information on fall amd spring migration routes along the Atlantic flyway. Merlins used both coastal and offshore

habitats during migration. Two adult Merlins were tracked to Quebec and Newfoundland after overwintering in Puerto Rico and Cuba, respectively **(Figure 17 & Figure 18, pgs. 23-24)**.We also tagged Merlins with digitally encoded VHF radio transmitters in 2014 – 2016 to study fine-scale migratory habits of a greater sample size of Merlins (see Appendix A).

6. To address a significant literature data gap, we estimated home range area of peregrines and Merlins in wintering areas ranging from Block Island to Argentina. Mean wintering area home range areas (at 50% and 95% isopleth levels) for individuals in our study were variable but smaller than limited reports for peregrines documented elsewhere **(Table 1, pg. 25, Figure 19, Figure 20, pgs.26-27)**.
7. We fitted three hatching year Northern Harriers with satellite transmitters. Individuals in this small sample suggest Northern Harriers using Block Island in the fall maintain relatively local/regional movements versus long-distance movements observed in other migrant species. A hatching year male migrated north to Connecticut prior to spending nearly six weeks north of Buzzard's Bay in the Cape Cod region of MA, while a hatching year female migrated west to Long Island, NY. **(Figure 21, pg. 29)**.
8. We have evaluated mercury (Hg) exposure in eight species of migrant raptors using the Atlantic Flyway. Overall patterns of Hg exposure among species were similar in blood and feather indices. Feather Hg concentrations were highest in Sharp-shinned Hawks, followed by the three falcon species. Mean blood Hg concentrations were greatest Merlins. Raptor sampling provided perspectives on Hg exposure in both natal areas and during migration. We evaluated Hg risk to peregrines and Merlins **(Figure 22 & Figure 23, pgs. 31 & 32).**
9. Samples were collected to evaluate the prevalence of wildlife pathogens such as avian influenza (i.e., "bird flu"), avian malaria, and other blood-borne parasites. We also evaluated exposure of migrant raptors to PFAS chemicals (i.e., 'forever chemicals') in migrant raptors. Preliminary findings of those analyses are presented in this report.
10. We evaluated relationships between Hg exposure and oxidative stress with partners from URI, EPA and Hawk Ridge Bird Observatory in Duluth, MN. Findings of those studies are still underway.
11. The BIRRS is uniquely suited to help inform numerous data gaps with significant conservation, management and regulatory implications. The location of the station in the northern portion of the U.S. Atlantic Flyway is important because birds captured at northern latitudes provide information on habitat use along a large portion of the Atlantic flyway. Such information has become important in efforts to understand exposure risk of migrant raptors such as peregrines and others relative to proposed offshore wind energy areas along the Atlantic U.S. coast. Tracking data has additional relevance to conservation efforts in raptor breeding and non-breeding/wintering areas spanning from the arctic to South America.
12. The Block Island Raptor Research Station has provided exceptional opportunities for conducting environmental education and outreach programs. During the 2012–2019 and 2023 seasons, BRI and TNC partnered to conduct educational outreach programs focusing on the ecology and natural history of raptors, migration, contaminant exposure, and other environmental issues. Target audiences were of all ages including school groups, conservation professionals, ecotourism groups and government decision-makers. We will continue to report on project findings at professional scientific conferences and to promote conservation through science and education.

2.0 INTRODUCTION

Many species of migratory birds travel thousands of miles twice a year between breeding areas and wintering areas. Some species of birds travel *en masse* in spectacular migration events, while others travel inconspicuously on an individual basis. Many bird species use relatively well-documented continental-scale migration corridors, or flyways, to travel between breeding and wintering areas. The Atlantic Flyway along the eastern seaboard of the U.S. represents a major migratory throughway for tens of thousands of birds originating from arctic and temperate portions of eastern and central North America and elsewhere. Even species originating from Greenland, such as *tundrius* Peregrine Falcons, cross the Atlantic at high latitudes and use the Atlantic migration flyway to reach wintering areas in the Caribbean or Central and South America.

Information documenting the migratory habits of birds is important in developing effective conservation strategies. Conservation biologists recognize that many bird populations face threats in their breeding areas, wintering areas, and during migration, and that effective conservation measures can protect populations at each stage of their annual life cycle. Flight routes used by many species remain poorly charted, links between populations in breeding areas and wintering areas remain poorly established, and key stopover sites used by individuals to rest and refuel during migration are poorly documented. These notable data gaps stem from significant challenges in collecting information about birds that travel vast distances through remote areas.

Notable developments in animal tracking technologies are rapidly advancing our understanding of the migratory ecology of birds. While traditional research approaches relied upon banding and opportunistic band encounters that occurred infrequently (i.e., 1–3% of birds banded were encountered), tracking technologies now offer the possibility of documenting daily – even hourly – movement patterns of individual birds continuously over time. Animal tracking data are increasingly being used by conservation biologists and regulators to fill-in substantial data gaps in our understanding of species needed to inform management and conservation decisions. Animal tracking data is routinely used to map migration routes, identify wintering and stopover habitats, and to inform wildlife risk assessments. The ability to use tracking datasets retrospectively toward multiple and widely differing conservation and research applications quickly helps justifies the additional costs of many types of transmitters.

In 2009, BRI began searching for a suitable site from which migrant raptors using the Atlantic migration flyway could be captured and studied to aid in migration studies, contaminant exposure assessments, and offshore wind energy wildlife risk evaluations. Relatively few sites exist in which raptors using coastal migration routes can be captured efficiently along the Atlantic coast; however, the majority were located in the Mid-Atlantic region (i.e., Cape May, NJ, Assateague Island, MD/VA, Kiptopeke, VA). Raptor research stations located in the northern portion of the Atlantic migration flyway are especially needed to learn about movements of raptors relative to proposed or existing offshore wind energy facilities because individuals need to be captured well before they encounter proposed facilities.

Over the last decade, the need for a raptor research station north of the Mid-Atlantic U.S. states has become evident as offshore wind energy facilities are being built or considered in state (< 3 nautical mi from shore) and federal (>3 nautical mi from shore) waters throughout the Atlantic Flyway (BOEM 2021), and the risks these facilities pose to migrating birds remain unknown. While raptors are a primary bird group associated with collision risks at terrestrial-based wind energy projects, they are generally overlooked when considering potential impacts of wind energy projects in offshore settings. Peregrine Falcons, Merlins, and several other raptors are capable of enduring lengthy over-water flights; however, and they commonly use offshore habitats. With an increasing number of offshore wind energy facilities being proposed along the U.S. Atlantic coast, further evaluations of the degree to which migrating raptors might encounter or collide with these facilities are warranted.

Starting in 2009, BRI initiated efforts to locate a site suitable for establishing a long-term raptor research station along the north Atlantic coast. Once established, the station would serve as the foundation for annual raptor research and monitoring efforts for migrant raptors using the Atlantic migration flyway. Those efforts led to explorations of several site options along the Maine coast, including Isle Au Haut in 2009, Monhegan Island in 2010 (DeSorbo et al. 2012), and Richmond Island in 2011. In 2011, BRI received a grant from the U.S. Department of Energy (DOE) to estimate wildlife densities, distribution and movement patterns relative to offshore wind energy areas in federal waters in the Mid-Atlantic U.S. (Delaware, Maryland and Virginia). To support that study, BRI established the first raptor research station on Block Island, RI (the Block Island Raptor Research Station; BIRRS) in 2012 to collect information on Peregrine Falcon movement patterns relative to the DOE Mid-Atlantic study area. Block Island was a strategically attractive place to establish a migration research station because it is situated north of the DOE Mid-Atlantic study area, and the majority of other areas likely to be proposed for offshore wind energy development along the U.S. Atlantic coast in the future. More details on the other components of the DOE study can be found at: www.briloon.org/mabs, including individual project technical reports, the technical report summarizing findings of the Peregrine Falcon study (DeSorbo et al. 2015), an overview summary report (Williams et al. 2015), and other information.

BRI's first-year field efforts on Block Island revealed that the BIRRS was not only an optimal location in which migrating Peregrine Falcons could be studied, but also that it presented unique opportunities to study other species such as Merlins, American Kestrels, Northern Harriers, and several accipiter hawks in various respects. As the field component of the DOE Peregrine Falcon study concluded in 2013, BRI met with The Nature Conservancy (TNC) and University of Rhode Island (URI) to strategize about how to continue operating the BIRRS. The BIRRS has since continued to operate in the fall due to generous support over the years from TNC, The Bailey Wildlife Foundation, the Ocean View Foundation, the Bluestone Foundation, the Overlook Foundation, the William C. Young Family Foundation and a few individual donations. In this report, we summarize a portion of the data collected over the 2012 to 2023 seasons at BIRRS, and we continue to expand the number of research collaborations enabled by the operation of the station.

3.0 STUDY AREA

Block Island is located 13 miles (21 km) south of Point Judith, Rhode Island and 14 miles (23 km) due east from Montauk, NY. The island is approximately 9.7 square miles (52.2 km^2). Just over 47 percent of the island is protected from development. The northern three-quarters of coastline consists of sand dunes and beaches broken up by low clay-based bluffs. Coastlines in the southern portion of the island are characterized by high clay-based bluffs and extensive beaches. The Block Island Raptor Research Station is situated on private conservation land in the southwest corner of Block Island. The banding station is surrounded from the south and west by pasture land sectioned by hedgerows, and to the north and east by forests and small open spaces interspersed with conifers.

4.0 OBJECTIVES

New research objectives are being developed and incorporated into our field efforts annually. Some of the ongoing long-term objectives of this study are to:

1. Characterize the timing, intensity, and species composition of the raptor migration at Block Island.
2. Determine raptor migration routes, overwintering locations, migratory stopover areas, range and presumed origins of migrant raptors captured on Block Island during migration.
3. Collect baseline information on contaminant exposure (particularly Hg, PFAS and other compounds) in raptor migrants using the Western Atlantic Flyway.
4. Collect baseline information on wildlife pathogens and parasites in raptor migrants using the Western Atlantic Flyway.

5.0 METHODS

In fall 2011, BRI explored Block Island to find a location suitable for establishing a raptor research station. Many factors were considered, including property ownership, public use, habitat type, topography, and location relative to the presumed flightpath of fall migrant raptors. With these considerations in mind, we selected a privately owned property in the southwestern portion of Block Island and we initiated trapping in 2012. Annual trapping operations typically occurred over a 3–5 week period. The station was generally modeled after stations elsewhere (i.e., Cape May, NJ, Monhegan Island, ME [BRI]; DeSorbo et al. 2012), which capture migrant raptors using a combination of mist nets, bow nets, and dho-gaza nets (Figure 1).

Figure 1. Removing a Merlin from a dho-gaza net.

Upon capture, we removed raptors from nets, banded them using U.S. Geological Survey (USGS) leg bands, and collected standard morphometric data (natural wing cord, tarsus width, body mass, tail, and culmen) following standard protocols (Pyle 2008) (Figure 1, Figure 2, Figure 3). Each bird was given a rudimentary health evaluation which included classifying both the crop and body index condition (BIC) into four qualitative classes (0–3). We plucked 3–4 feathers from the breast, back and/or rump of all individuals. Feathers are used for analyses of mercury (Hg), and will be further considered for analyses of other metals, stable isotopes, genetics, and/or archival. We collected blood samples from a portion of captured individuals following standard protocols (Fair et al. 2010). Additional biological samples (i.e, oral/cloacal swabs, blood smears) were collected and are outlined in relevant sections below. Many birds were photo-documented.

Figure 2. Banding a Peregrine Falcon using a lock-on band (left), and banding a Merlin with a butt-end band (right).

Figure 3. Measuring wing chord of a Peregrine Falcon (left) and examining wing molt on an adult female Merlin (right)

We tracked daily station operating hours each season and totaled hours to get season operating hours. We calculated trap effort by dividing the total number of raptors trapped during a season by the total station operating hours.

6.0 RESULTS

6.1 Annual Capture Totals, Species Composition, Age Class and Timing

We captured a total of 1,532 individual diurnal raptors representing nine species during fall capture efforts in the years 2012–2023. Capture totals were often relatively similar within species annually, with a few exceptions such as a notable Peregrine Falcon peak in 2014 that was detected at other Atlantic sites, and three recent consecutive years of generally lower Merlin captures (Figure 5).

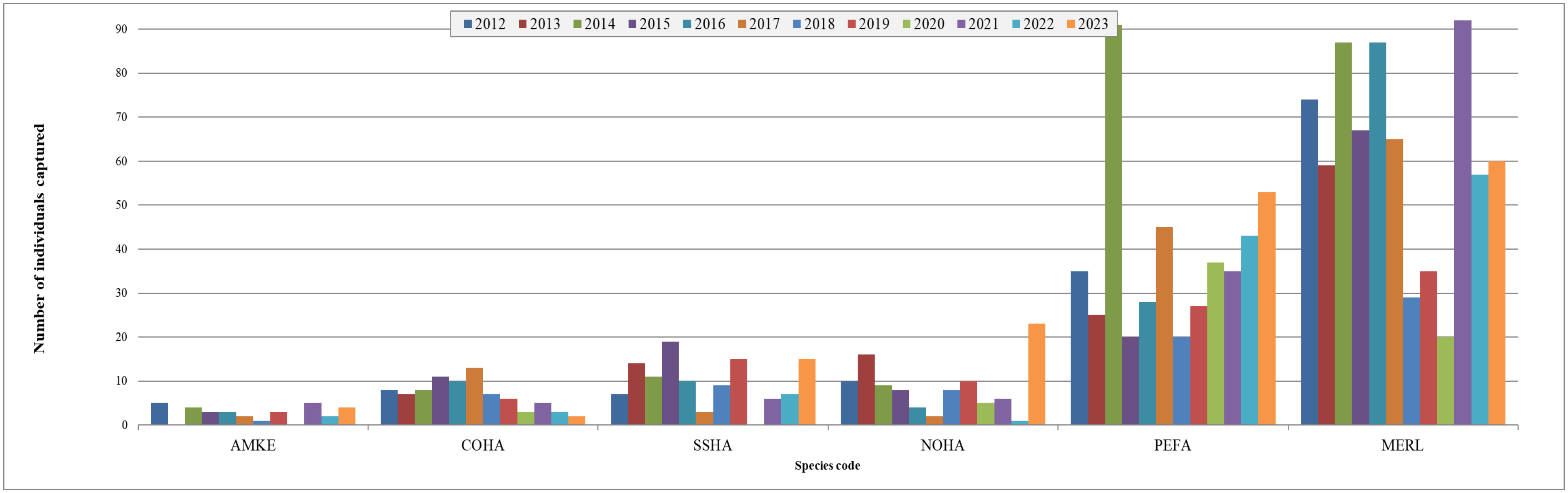

Figure 4. Total number of diurnal raptors trapped by species and year at BIRRS, 2012–2023. A single RTHA and NOGO were captured in 2012 and are not represented on this figure. A single RLHA was captured in 2023 and is not represented on this figure.

* Species codes follow American Ornithologist Union convention: Northern Goshawk (NOGO), Red-tailed Hawk (RTHA), American Kestrel (AMKE), Cooper's hawk (COHA), Sharp-shinned Hawk (SSHA), Northern Harrier (NOHA), Peregrine Falcon (PEFA), and Merlin (MERL).

Annual capture totals for each species can be notably affected by a variety of factors, including prevailing wind direction and wind speed, high vs. low production years and prey abundance in natal/breeding areas of migrants, and differences in capture effort among years. The average number of raptors captured (all species) (2012-2023) was 0.64 / hr. The average number of Merlins captured was 0.29/hr and average Peregrine Falcons was 0.20/hr (Figure 4). Merlins were the most consistent raptor captured each year, with only one spike in 2021. The number of captures varied more annually for Peregrine Falcons than for Merlins (Figure 4).

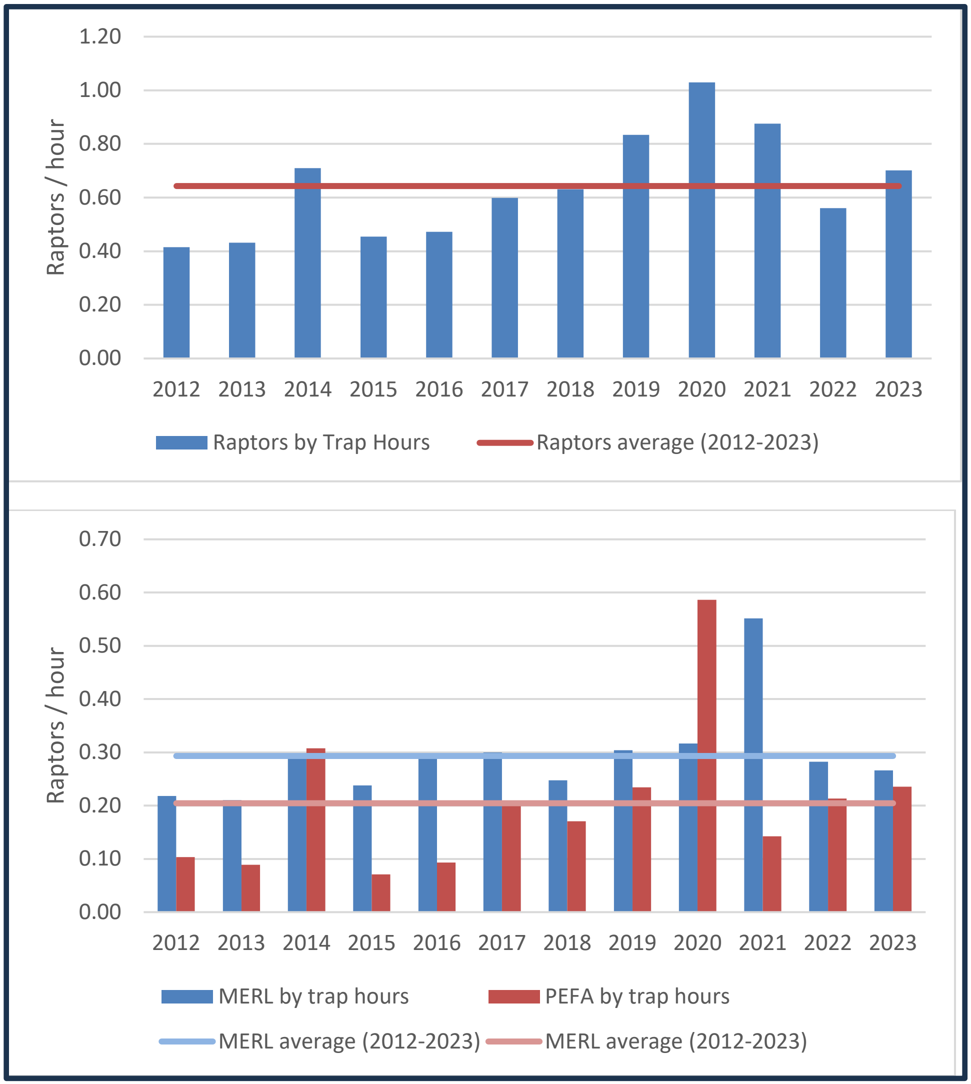

Figure 5. (Top) Total number of raptors captured annually adjusted for effort. (Bottom) Total number of Peregrine Falcons and Merlins captured per year adjusted for effort. The solid lines on graphs represent 2012-2023 average capture totals adjusted for effort

Overall, annual species composition measures were similar among years. As noted above, 2014 was noteworthy for an unusual increase in the total number and relative proportion of Peregrine Falcons captured compared to other years. Over all years, 48% of annual captures were Merlins, 30% were Peregrine Falcons, and the remaining 21% are comprised of Northern Harriers, Sharp-shinned Hawks, Cooper’s Hawks, American Kestrels, Red-tailed Hawk, Northern Goshawk, and Rough-legged Hawk (Figure 6).

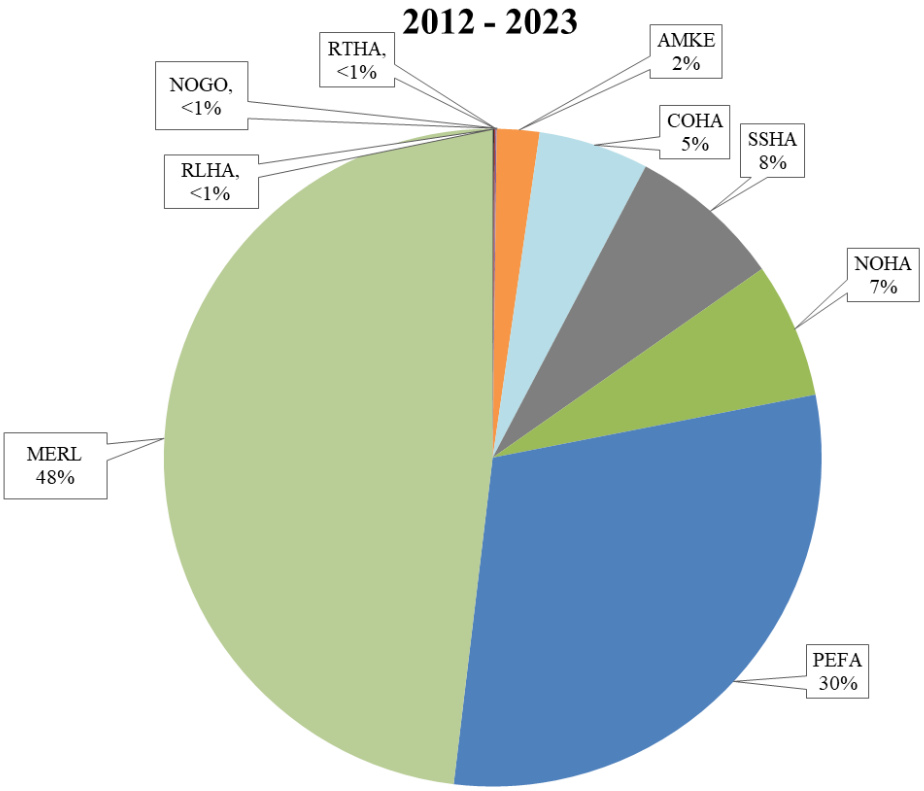

Figure 6. Average species composition of diurnal raptors captured at BIRRS, 2012–2023 (n = 1532).

Age Class: The vast majority (96.67%) of all raptors captured on Block Island were young of the year (hatching year age class). Adults were captured in all species except Northern Goshawks, Red-tailed Hawks, and Rough-legged Hawks; 27 adult Merlins (3.66% of all Merlins captured), 13 adult Peregrine Falcons (2.83%), two adult American Kestrels (6.25%), three adult Coopers Hawks (3.61%), one adult Sharp-shinned Hawk (0.86%), and five adult Northern Harriers (4.9%).

Timing: The bulk passage periods for Peregrine Falcons and Merlins were generally evident in capture data. The peak days of Peregrine Falcon captures during the 2012–2017 seasons (daily averages) occurred between 4–13 October (Figure 6). This ten-day range accounted for 56% of all Peregrine Falcons captured. Over 80% percent of all Peregrine Falcon captures occurred from 27 September to 13 October. The timing of the Merlin flight as indicated by capture data was notably more consistent and seasonally protracted compared to Peregrine Falcons. Peak Merlin captures occurred between 18 September and 2 October (Figure 7). This 15-day time span accounted for 61% of all Merlins trapped during the 2012–2023 seasons. Seventy-five percent of all Merlin captures occurred between 18 September and 5 October (18 days). Capture timing was variable for other species, and sample sizes preclude powerful conclusions about migration timing.

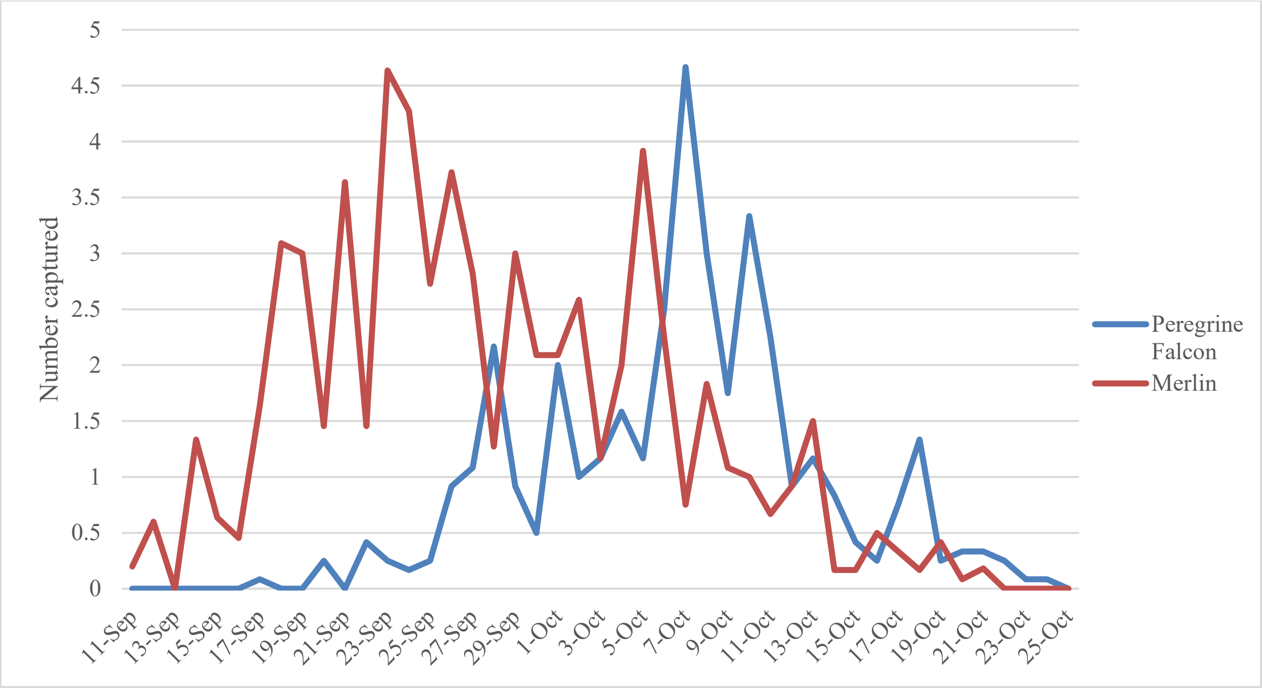

Figure 7. Average daily number of Peregrine Falcons and Merlins captured by date 2012-2023.

In general, hourly migration count data, rather than daily capture data is likely more accurate in characterizing the timing and intensity of raptors passing through an area during migration. Standardized migration counts have not been conducted on Block Island. Here, we use capture totals as a surrogate for some information that might be better understood through standardized counts. The Hawk Migration Association of North America (HMANA) provides regularly updated annual hawk count information for over 275 North American hawk watch sites (www.hawkcount.org). Site-specific information on this website can be of value to the general public and researchers in placing local migration patterns in a broader regional context. Overall, migration timing patterns for raptors captured on Block Island were consistent with general knowledge of migration timing for each species; however, migration count data from other offshore sites is rare (DeSorbo et al. 2012).

7.1 Migratory Connectivity: Migration Routes, Wintering Areas, Origins

7.1.1 Transmitters, attachment and filtering

Animal tracking has revolutionized our understanding of animal movements by providing a means of tracking movements of animals traveling vast distances and in remote regions that were otherwise impossible or impractical (Seegar et al. 1996). In brief, transmitters attached to animals transmit information on individual bird movements to circumpolar orbiting satellites that relay information to users (Douglas et al. 2012). More recently, GPS-GSM transmitters were developed, enabling GPS locations to be relayed to users over the cellular network.

We attached satellite transmitters (a.k.a.: Platform Transmitter Terminals, PTTs) and cellular / GSM transmitters to a subset of captured raptors from research stations. We often prioritized birds that were visibly healthy and heavier, such that the transmitter package remained ≤3.9% of bird body mass (Peregrine Falcon) or ≤3.0% (Merlins). Transmitters were instrumented to individuals with backpack-style harnesses made of 0.25 in (6.35 mm; Peregrine Falcon) or 0.1875 in (4.76 mm; Merlin) Teflon® ribbon (Bally Ribbon Mills, Bally, PA) or Spectra® sewn with Spiderwire Dyneema® thread (Kenward 2001, Steenhof et al. 2006, Walls and Kenward 2007, Fair et al. 2010) (Figure 4). All satellite transmitters (GeoTrak Inc., Apex, NC) fixed 'Doppler' (or 'Argos') locations, while some also fixed GPS locations, which exhibit notably higher accuracy compared to Argos locations (Douglas et al. 2012). The location error for GPS locations typically ranges from 5 to 15 m. Argos locations are classified into seven different location classes by CLS America according to their associated error (Douglas et al. 2012, CLS 2016). We removed implausible locations from our dataset using the Douglas Argos Filter (DAF) prior to analysis (Douglas et al. 2012). Cellular, or GSM tags (Cellular Tracking Technologies, Rio Grande, NJ) fixed GPS location estimates, which were relayed over the cellular network.


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Figure 8. Left: Example of 22g solar GPS PTT unit, 12g solar PTT and 5g solar PTT unit used to track movements of Peregrine Falcons, Merlins and Northern Harriers. Right: A hooded Peregrine Falcon being fitted with a transmitter (right).

A modest number of transmitters are deployed annually as allowed by annual funding support. Between the years 2012–2020, we fitted individuals of the following three species with tracking devices at BIRRS and other research stations:

> **Peregrine Falcons:** Data from 54 Peregrine Falcons tracked along the U.S. Atlantic flyway were analyzed in this report. Of these Individuals, three were adult females, 26 were hatching year males, and 25 were hatching year (HY) females. Of these 54 transmitters, four were deployed on HY males from BRI's Cutler Raptor Research Station in Cutler, ME in 2020 (Christopher P. Persico et al. 2021), two were deployed on HY females from Monhegan Island, ME in 2012 (DeSorbo et al. 2012), and the remaining 48 were deployed on three adult females, 23 HY females, and 22 HY males from the BIRRS over the period 2012-2022 (Figure 9).

Merlins: We fitted 17 satellite transmitters to Merlins on Block Island in 2014, 2017, and 2019 (Figure 8). All transmitters were 5g units, fit to three adult females and 14 hatching year females. One adult female fitted with a transmitter in Cutler, ME in 2018 is also included in analyses in this report.

Northern Harriers: We fitted one 6g satellite transmitter to a hatching year male Northern Harrier in 2014. In 2017, we fitted one 5g satellite transmitter to a hatching year male and one 5g satellite transmitter to a hatching year female (Figure 10).

Figure 9. Female hatching year Merlin fitted with a 5g satellite transmitter (left), male hatching year Peregrine Falcon (right) fitted with a 12g solar satellite transmitter at BIRRS.

Figure 10. Male hatching year Northern Harrier fitted with a 5g satellite transmitter in 2014 (left), female hatching year Northern Harrier fitted with a 5g satellite transmitter in 2017 (right).

7.1.2 Determining Migration Routes, Wintering Areas and Presumed Origins

We used individual raptor tracking data to chart migration routes of raptors using the Atlantic migration Flyway. We determined wintering areas for individuals based upon date and changes in directional patterns of movement and travel rates. Spring migration routes were plotted for individuals surviving through their first winter. Individuals fixing multiple fall or spring migration routes were plotted independently. Areas visited by northbound migrants during the spring were used to infer information about potential source populations of tracked individuals. When identifying wintering areas, we distinguished complete migrants (individuals deemed to have completed migration to their wintering area) and incomplete migrants (individuals from which transmissions ceased before migration could be confirmed as complete) generally following the approach outlined in Fuller et al. (1998), which distinguished between these groups using observed patterns of localized (i.e., non-directional) and uni-directional movements.

7.1.3 Estimating Winter Home Range

Habitat use of raptors in their wintering areas is poorly studied. We used individual raptor tracking data to characterize Peregrine Falcon and Merlin space use patterns in wintering areas (sample sizes remain limited for other species). We define wintering area home range as the density of animal use across the landscape in the wintering area calculated from animal location estimates. We delineated migratory movements from those occurring in wintering areas by manually identifying a change in behavior from large, unidirectional long-distance movements (migration) to localized multi-directional movements in a single area for >1 day (winter). We determined the end of wintering area use when location estimates indicated continuous directional movement away from the wintering area polygon for >1 day. Only transmitters deployed in 2012 – 2018 that transmitted for a complete winter (i.e., through 2019) were used in this analysis. Dates used to delineate wintering area use for individuals are listed in Appendix C.

We used a Dynamic Brownian Bridge Movement Model (Kranstauber et al. 2012) to generate utilization distributions (UDs) and we present 50% and 95% isopleth home range estimates for wintering areas. Satellite PTT data were filtered for poor quality positions by applying a speed check filter (max. speed 150 km/hr) to the movement data. Dynamic Brownian bridge movement analysis was conducted for each animal in every winter where there were at least 31 valid locations, the minimum number required for analysis. Three birds had data for two winters; these individuals were considered independent in analyses.

7.2 Peregrine Falcons: Fall Migration Routes and Wintering Areas

The datasets of the 54 Peregrine Falcons fitted with tracking devices along the Atlantic migration flyway (48 on Block Island, RI, 2 on Monhegan Island, ME, and 4 from Cutler, ME) comprise the most substantial information to date on Peregrine Falcon movement patterns along the Western Atlantic Flyway. This dataset is especially unique in that hatching year Peregrine Falcons have otherwise been minimally studied using tracking technologies.

Routes: Overall, migration routes used by fall migrants tended to follow a coastal route along the Atlantic coastline (Figure 11). Over land migration routes of Peregrine Falcons originating in areas north of Hudson Bay or west of the Great Lakes in Figure 10 reflect *second* fall migration fight paths of individuals. Analyses of limited subsets of this data to assess use of offshore wind energy areas along the Atlantic coast can be found in DeSorbo et al. (2015) and more extensive analyses are currently underway.

Wintering areas: Fall migrant Peregrine Falcons overwintered in locations across a wide geographic range, spanning throughout the Bahamas, Central America, and South America (Figure 10). Of the 54 Peregrine Falcons tracked along the Atlantic flyway, 33 were considered to have reached wintering areas (Figure 12), while transmitters on 20 individuals ceased transmitting during migration (Figure 13). Causes for ceased transmissions are often unknown, and could be from mortality, transmitter failure or solar panel obstruction. First year mortality is notably high in raptors, particularly during migration (Newton 1979, 2008).

Preliminary patterns suggest that males captured during our study may use more southerly wintering areas than females. For example, while the majority of females (60%; 12 of 20 individuals) overwintered in Florida, the Bahamas, Cuba, and other islands in the Caribbean, 85% (11 of 13) of males traveled to Central and South America (Figure 11). A male (HYM12) migrated to Argentina in 2017, travelling further south than any other individual in this study. An adult Peregrine Falcon (ADF03) instrumented with a transmitter in 2018 travelled to southeastern Brazil, the furthest south of any female tracked to date.

Incomplete migration tracks: Of the twenty transmitters fitted to Peregrine Falcons that stopped transmitting prior to reaching wintering areas, the majority (16 of 20 individuals, 80%), were within the latitudinal span of the continental U.S. between Rhode Island and Florida (Appendix B). Some of the individuals in this cohort demonstrate the notable challenges facing birds during migration; including hurricanes, starvation and predation. Of these individuals, 65% were males, and 35% were females. One noteworthy male traveled on an impressive and unique transoceanic journey, 1500 km to the east into the Atlantic, following release (Figure 14). Travel speeds by this individual as indicated by transmitter location estimates suggest this individual was resting on offshore vessels before transmissions ceased.

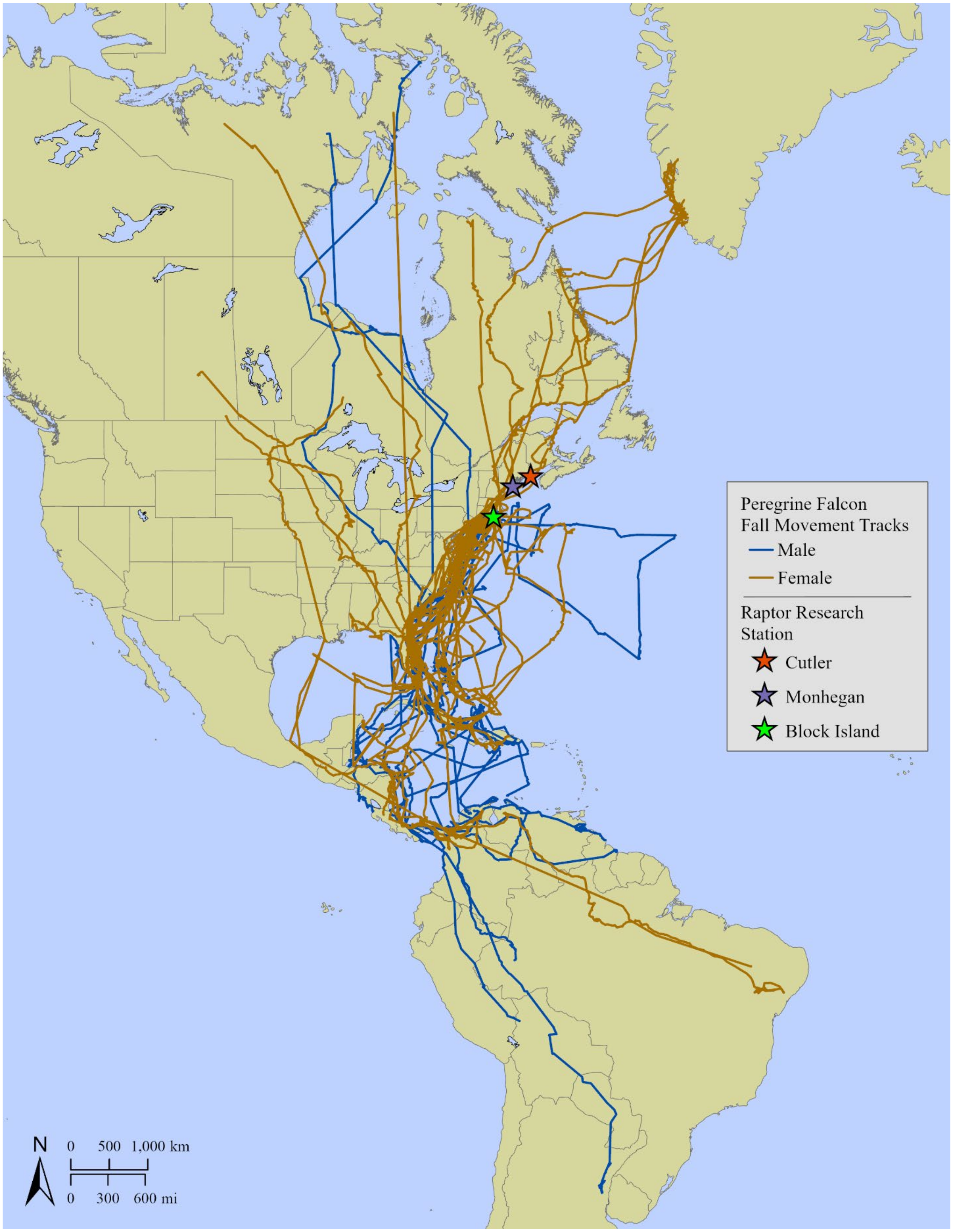

Figure 11. Fall migration routes of Peregrine Falcons fitted with tracking devices at three raptor research stations 2010–2023.

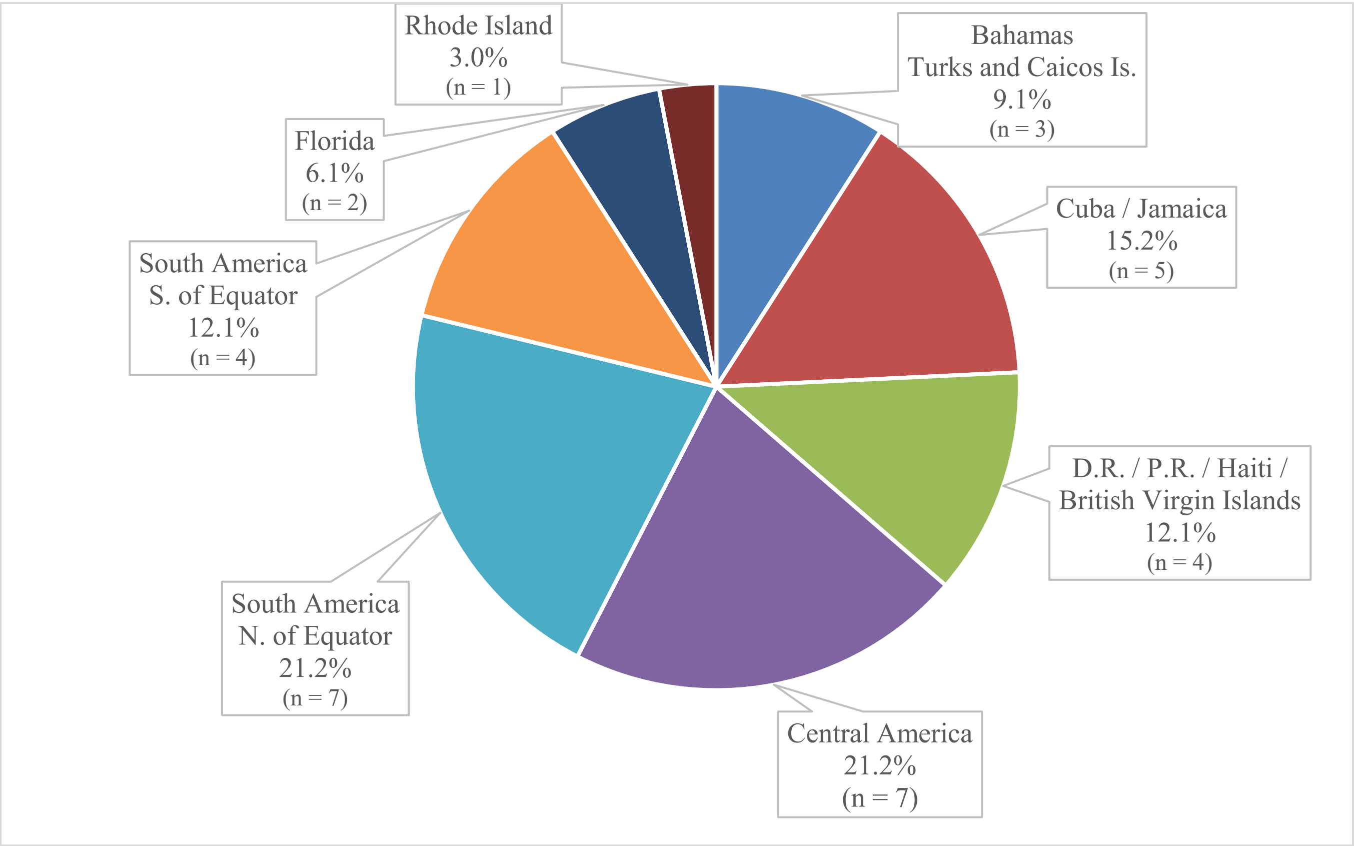

Figure 12. Wintering areas for 27 fall migrant Peregrine Falcons tracked from Block Island, RI (n = 33; 2012–2022) and Monhegan Island (n = 2; 2010) using tracking devices.

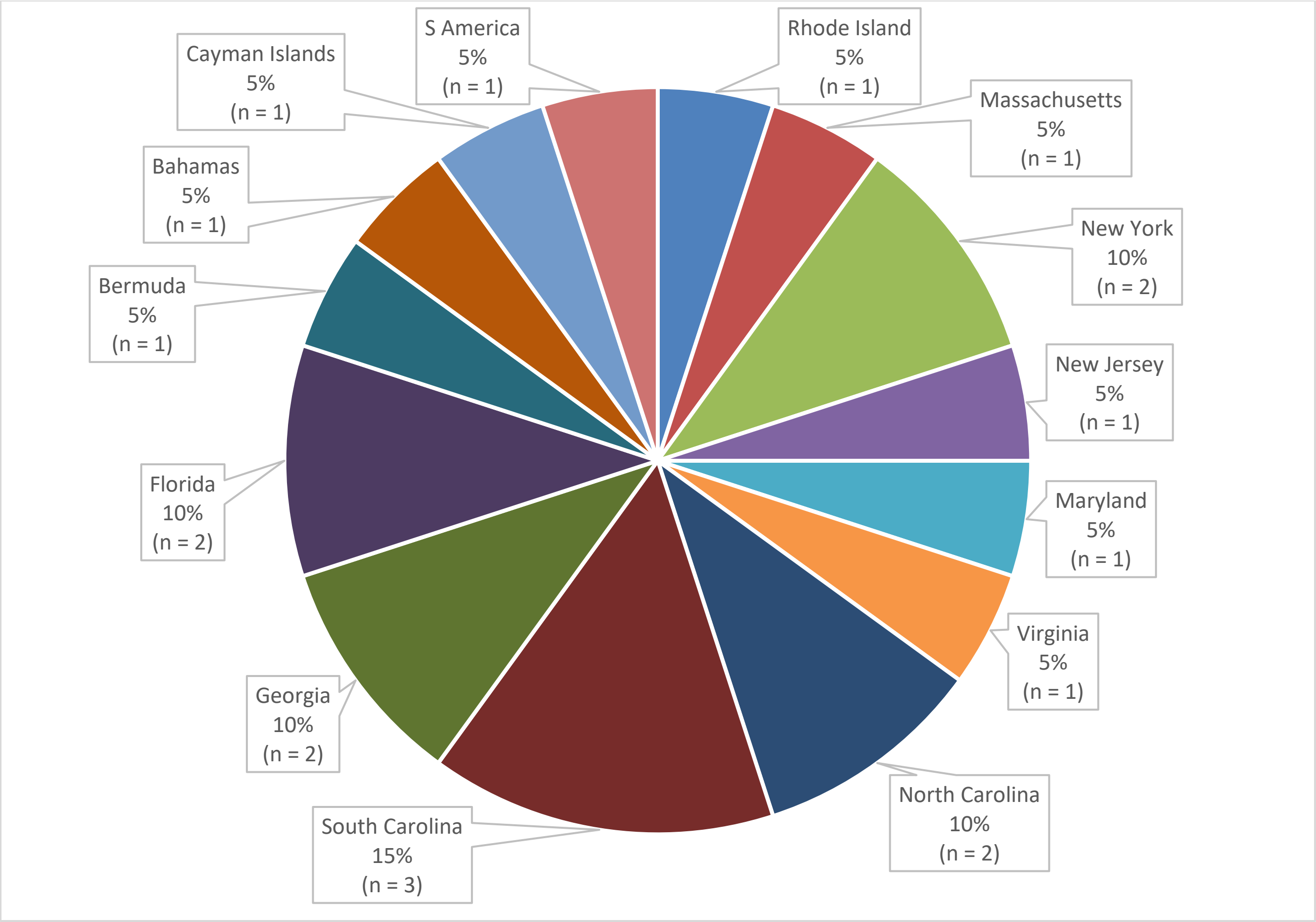

Figure 13. Last known locations of Peregrine Falcons fitted with tracking devices with presumed incomplete fall migration paths (2012–2020).

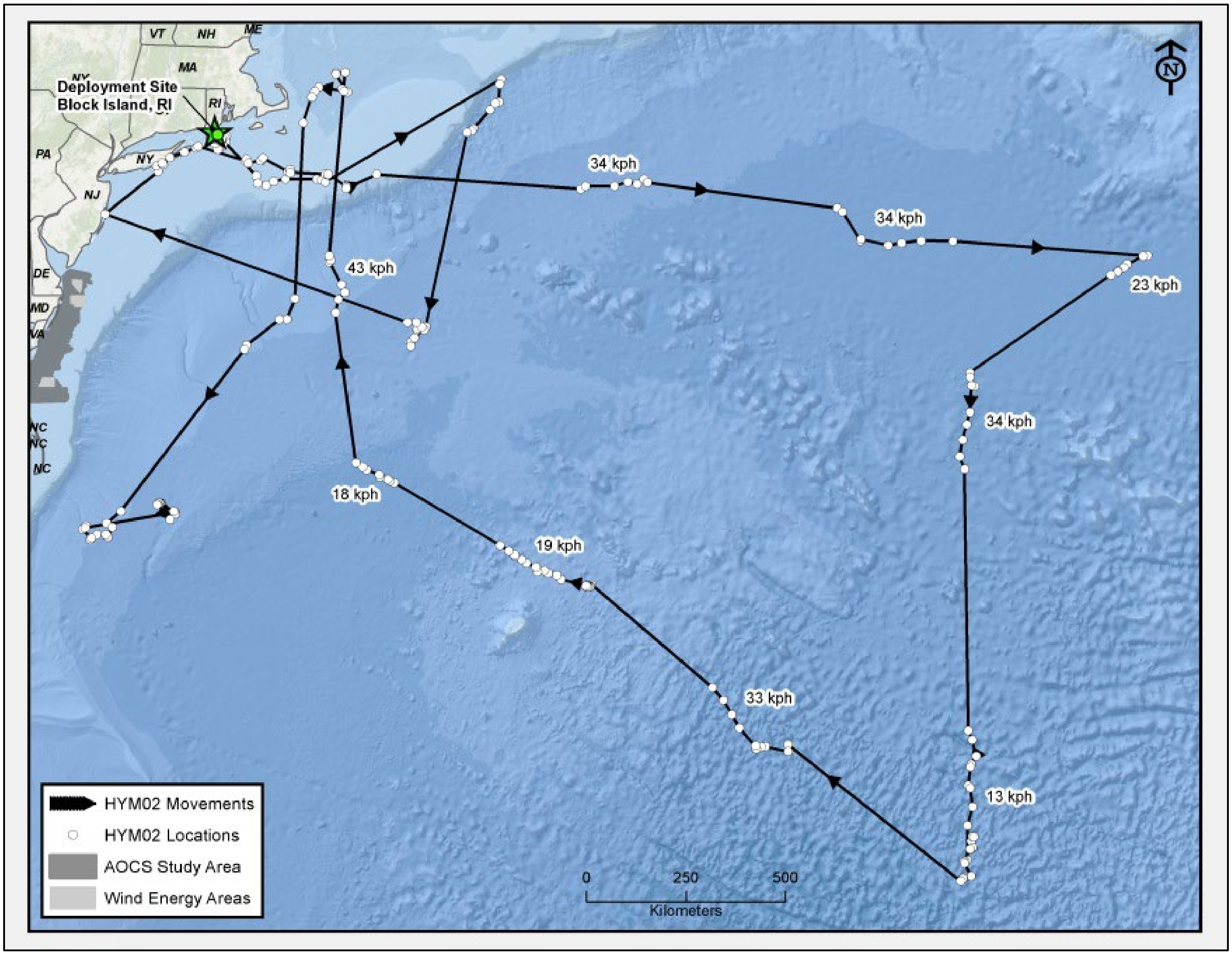

Figure 14. Fall migratory movement of Peregrine Falcon HYM02 after departure from BIRRS, as indicated by satellite telemetry.

* Speeds presented in figure measured between first and last location of daily clusters of locations.

7.2.1 Fidelity to Wintering Areas

Of the Peregrine Falcons instrumented between 2012 and 2019 seasons, six (four females and two males) enabled evaluations of inter-annual fidelity to wintering areas. Of these six individuals, five returned to the same specific wintering areas used during consecutive winter seasons in the following areas: Aklins Island, Bahamas; Turks and Caicos; the Dominican Republic; western Haiti, and Miami, FL. The single Peregrine Falcon that did not show winter site fidelity (HYM12) traveled further south than any other bird tracked during this study during its first winter (to Argentina, see Figure 11), but stayed in northwest Columbia during its second winter (Figure 15). While poorly documented overall, high between-year winter site fidelity has been previously noted in Peregrine Falcons (McGrady et al. 2002, DeSorbo et al. 2018*b*).

7.3 Insights on Natal Origins and Spring Migration Routes – Peregrine Falcons

Insights on Natal Origins: Of the 54 Peregrine Falcons instrumented between 2012 and 2022 seasons, roughly one-quarter (n = 11) provided information on spring migration. These individuals offer insights on the potential natal origins of individuals (assuming second-year birds return to their natal areas), as well as information linking use of breeding areas, wintering areas and migration stopover sites. Since first-year birds may not necessarily return to their natal area, the strongest evidence clearly linking wintering and breeding populations of individuals captured during fall migration derives from adults. Of the three adult female Peregrine Falcons captured on Block Island, ADF01 migrated to Saskatchewan, Canada (after overwintering in Jamaica), ADF02 migrated to eastern Greenland (after overwintering in the vicinity of Block Island) and ADF03 migrated to Saskatchewan (after overwintering in eastern Brazil) (Figure 15). Overall, these regions roughly span the longitudinal range of areas visited by spring migrating Peregrine Falcons captured as hatching year birds in our study. Several Peregrine Falcons captured during their first year of life in our study migrated to regions across much of Canada including Saskatchewan, Nunavut, Quebec, Newfoundland, and Labrador; some have travelled annually to Greenland (Figure 15).

Spring Migration Routes: Of the 14 Peregrine Falcons tracked northward in the spring, a minority used travel routes along the Atlantic coast during their northward migrations (Figure 15). The majority of spring migrating Peregrine Falcons travelled through the central U.S. west of the Great Lakes. Peregrine HYF07, who was tracked northward during two consecutive spring seasons, migrated through the central U.S. and spent the summer in southern Saskatchewan, but during its second spring migration migrated through Ontario and Hudson Bay (where it appeared to be riding ice flows) to northern Quebec. After capture during fall 2016, Peregrine Falcon HYF15 has been tracked for five consecutive spring migrations to date. HYF15 spent her first summer (2017) in northern Quebec, and the following summer seasons (2018, 2019, 2020) at a presumed breeding site in southwest Greenland (Figure 15). All travel routes were along the Atlantic coast.

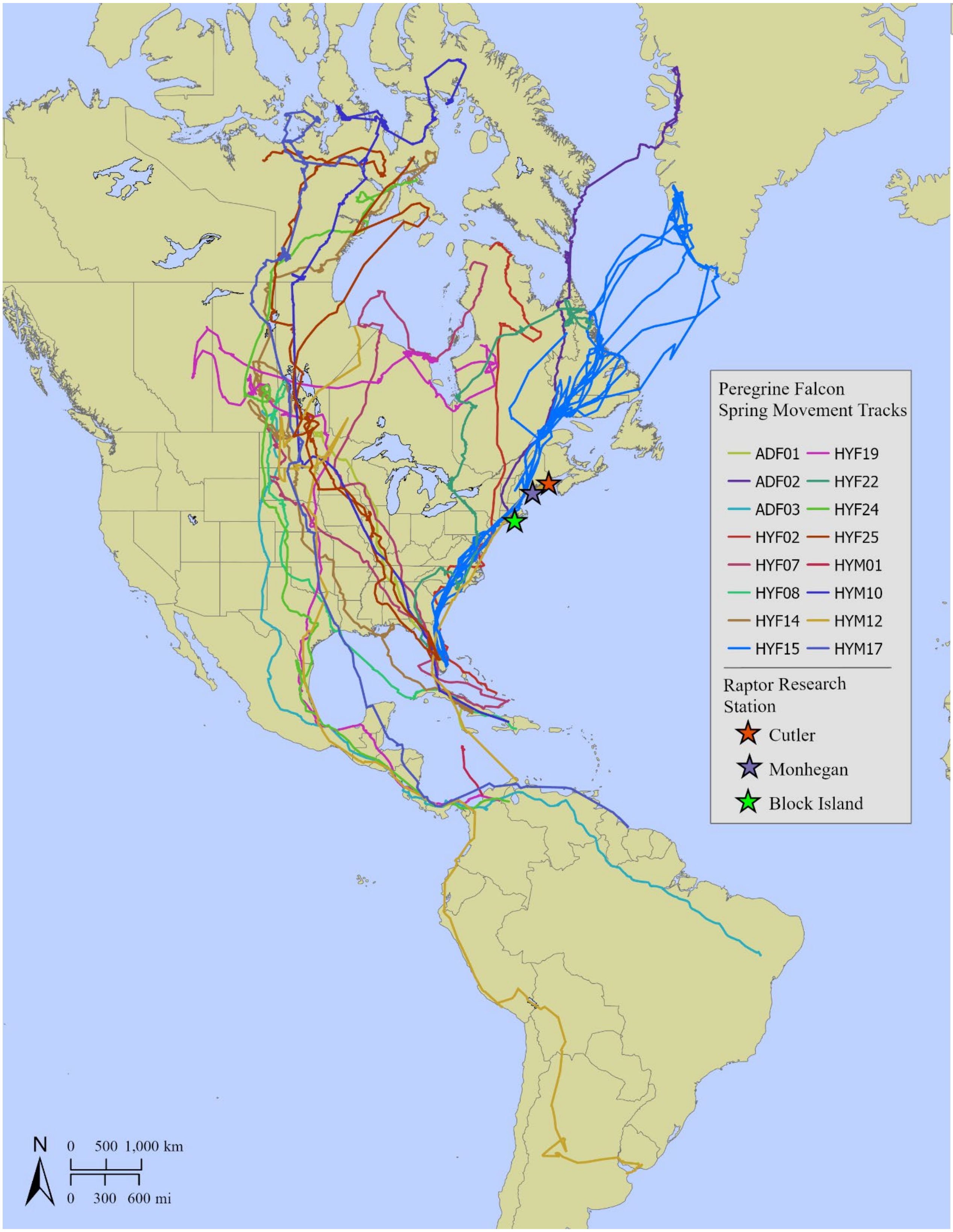

Figure 15. Spring migration routes of eleven female and three male Peregrine Falcons fitted with tracking devices 2013 - 2023. Individuals with multiple spring tracks are grouped by a single color (ADF03, HYF07, HYF15, HYF25, HYM12).

7.4 Merlins: Migration Routes, Wintering Areas, and Presumed Origins

To date, we have instrumented 17 migrating Merlins (all females; 3 adult, 14 hatching year) with 5g solar satellite transmitters. These individuals might represent the only individuals of this species to be tracked to date using satellite telemetry. Of these individuals, 12 revealed information about wintering areas (3 adult, 9 hatching year individuals). Of these, just under half (42%; n = 6) overwintered south of the continental U.S. in either Cuba (n = 5) or Puerto Rico (n = 1) (Figure 16 and Figure 17). All three tagged adults overwintered south of the Continental U.S. (two in Cuba, one in P.R.). The six Merlins that overwintered in the U.S. were distributed between New England and the Mid-Atlantic U.S. One overwintered on coastal islands on the southern end of Pamlico Sound, North Carolina; one overwintered in the Great Dismal Swamp National Wildlife Refuge in Virginia; two overwintered on the Delmarva Peninsula; one overwintered in Stonington, Connecticut; and one overwintered on Conanicut Island in Rhode Island (Figure 16, Figure 17).

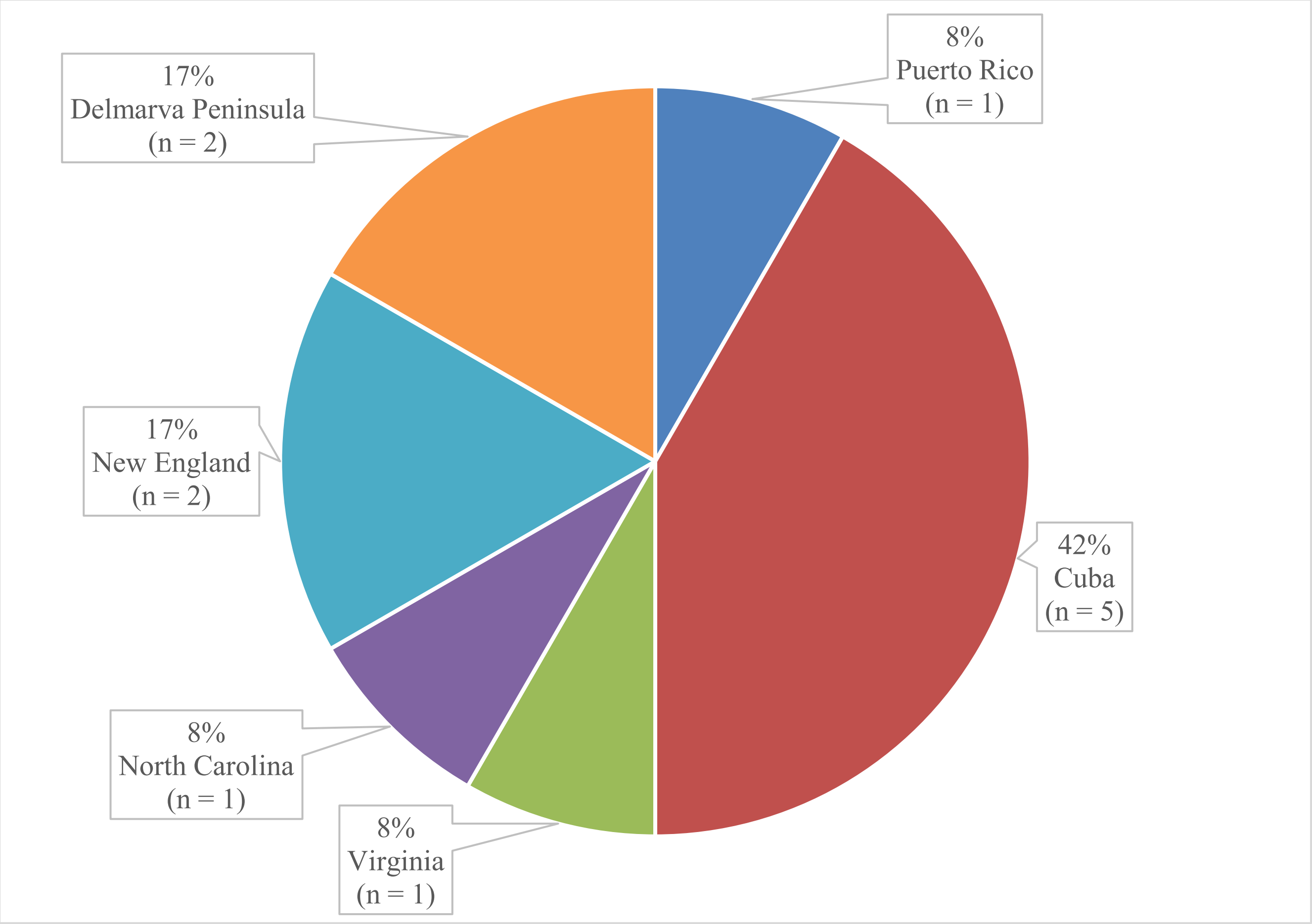

Figure 16. Wintering areas for 12 female Merlins tracked from Block Island, RI and Cutler, ME 2014–2018.

Of the 17 Merlins instrumented with satellite transmitters, four did not complete migrations prior to the cessation of transmissions. The causes of ceased transmissions often cannot be verified; such cases are typically considered due to either mortality or transmitter failure. Of these four; two last transmitted in southern Florida; one last transmitted near Virginia Beach, VA; and one last transmitted over the Atlantic Ocean off Long Island, NY.

Use of Offshore Habitats: Of the Merlins tracked down the Atlantic coast in our efforts thus far, several showed clear indications of offshore habitat use (Figure 17). This finding has relevance to ongoing efforts to understand movement patterns of birds in relation to offshore wind energy facilities being proposed in both state and federal waters along the Atlantic coast (BOEM 2021). Indications that Merlins use offshore habitats is consistent with limited indications elsewhere along the Atlantic seaboard. Standardized raptor migration counts on Monhegan Island, ten miles east off the Maine coast, documented that Merlins were the most abundant diurnal raptor observed offshore in that region during migration (DeSorbo et al. 2012). Merlins are also the most commonly observed, and dominant species captured at BIRRS (this study).

Spring Travel Routes: Five Merlins fitted with satellite transmitters in the present study provided insights on spring travel routes and possible natal origins of Merlins along the Atlantic coast. Of these, several used sections of both inland and coastal habitat to reach their destinations, but it would appear that the dominant migration corridor is along the coast (Figure 18).

Origins: Adult Merlins provide more reliable speculations on origins than hatching year birds. Both of the adults fitted with transmitters spent their summer months in eastern Canada. Merlin ADF01 travelled to Petit-Mecatina, Quebec, while ADF02 travelled to southwestern Newfoundland (Figure 17). Of the three hatching year Merlins fixing spring migration tracks (HYF08, HYF12, HYF14), two travelled to Newfoundland, Canada, while one travelled to western New Brunswick. Interestingly, Merlin HYF14 fixed a location on Block Island during its northward journey, and then initiated a sizeable open water crossing to get from Maine to Nova Scotia before continuing on to Newfoundland.

Additional insights on Merlin migration movements were obtained during a nanotag study conducted during 2014–2016, in collaboration with University of Rhode Island and TNC. A summary of this study and findings can be found in Appendix A.

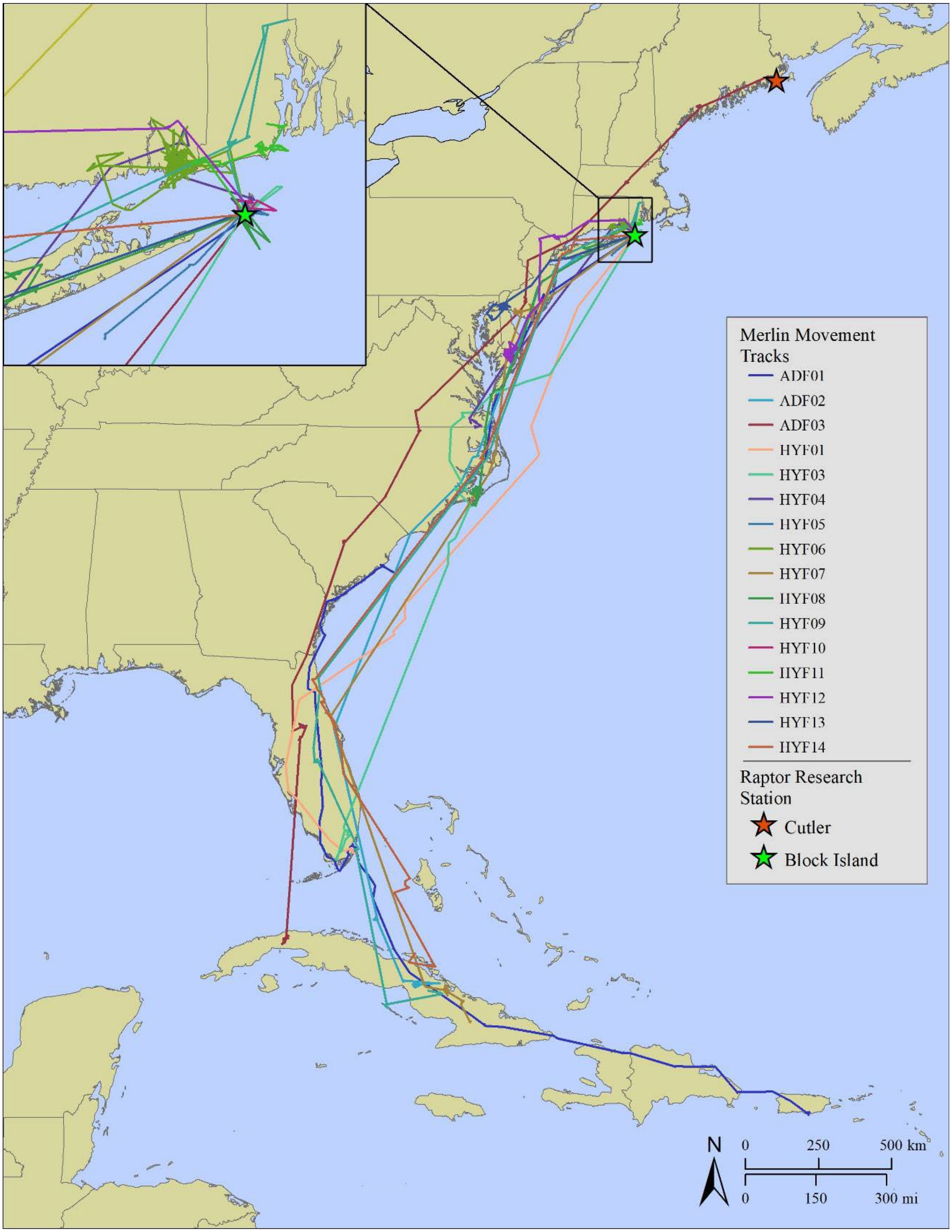

Figure 17. Fall migration routes of fourteen hatching year female and three adult female Merlins tracked from the Block Island Raptor Research Station, RI and the Cutler Raptor Research Station, ME, using satellite telemetry.

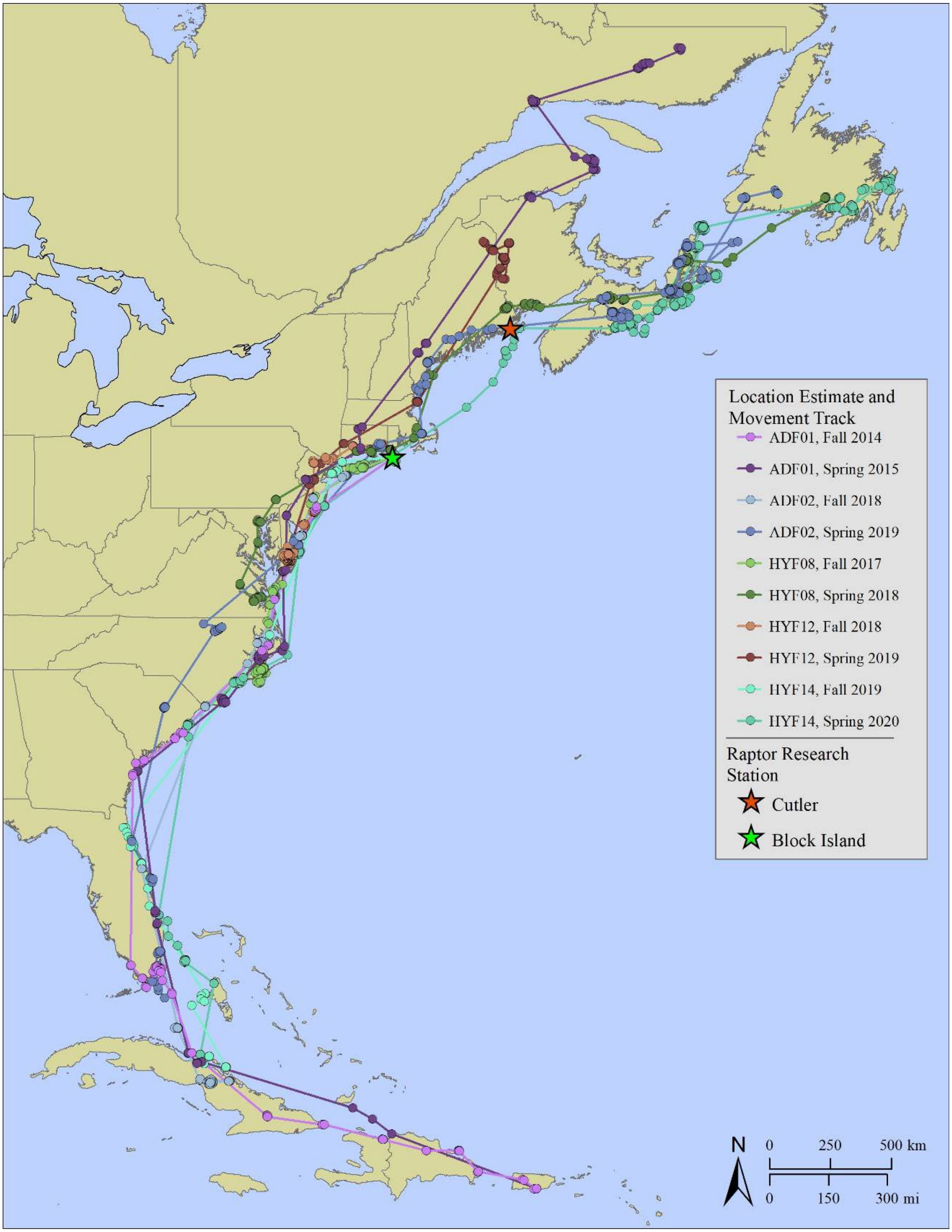

Figure 18. Fall and spring migration routes of two adult (AD) and three hatching year (HY) female Merlins tracked from the Block Island Raptor Research Station, RI, and the Cutler Raptor Research Station, ME, using satellite telemetry (2014-2020).

7.5 Peregrine Falcon and Merlins: Winter Home Range Estimates

Few studies have attempted to estimate winter home range of Merlins or Peregrine Falcons (Palmer 1988, Ratcliffe 1993, McGrady et al. 2002, DeSorbo et al. 2018*b*, Sokolov et al. 2018). To our knowledge, this study is the first to estimate the winter home range size of Peregrine Falcons or Merlins wintering in the Caribbean and South America.

Peregrine Falcons: We estimated winter home range size for 11 Peregrine Falcons (14 winters) and one Merlin (Figure 19, Figure 20, Table 1). The winter home range size of Peregrine Falcons at 50% (core use area) and 95% isopleth levels ranged from 69–1,441 km^2 at the 50% level (mean ± SD: 425 ± 331 km^2) and 1,038–30,353 km^2 (mean ± SD: 6,579 ± 7,132 km^2) at the 95% isopleth level. The mean of 425 km^2 at the 50% isopleth level in our study was notably smaller than the mean reported for Peregrine Falcons wintering in the Gulf of Mexico (3,918 km^2 for 50%). Similarly, the 95% isopleth winter home range in our study (6,579 km^2) was also substantially smaller than the 90% level reported for Peregrine Falcons in the Gulf of Mexico (16,953 km^2) (McGrady et al. 2002). Mean wintering home range areas found in our study were also smaller than those reported for breeding New Hampshire Peregrine Falcons overwintering in Pennsylvania (1,083 km^2 for 50%; 14,493 km^2 for 95%; DeSorbo et al. 2018). Home range size is likely inversely correlated with food availability; that is, when food availability is high, individuals do not need to travel as far to find food. Our findings may reflect higher food availability in wintering areas in our study compared to those reported elsewhere. Preliminary comparisons did not suggest that mean winter home range size varied by sex or age class.

Three Peregrine Falcons (HYF07, HYF15, and HYM12) provided home range data for two consecutive winter seasons. In all three of these individuals, mean use areas were smaller in the second winter compared to the first winter at both 50% and 95% isopleth levels. The winter home range size contracted by 68% in the second winter compared to the first winter in the core use area, and the 95% isopleth home range contracted by 67% in the second winter compared to the first winter. Limited sample sizes currently preclude powerful statistical comparisons of these data. Only one other study to our knowledge reported consecutive winter home ranges of individuals (DeSorbo et al. 2018*b*). In that study, all but one individual exhibited a reduced utilization distribution (UD), i.e. “use area”, in its second winter compared to the first.

Merlins: The home range areas of Merlins fell within the range of those reported for Peregrine Falcons; the mean wintering area home range for HY female Merlins were 287 km^2 (50%) and 1,827 km^2 (95%), respectively (Table 1).

Table 1. Wintering home range area (km^2) at 50% (core use area) and 95% isopleth levels for 12 Peregrine Falcons and three Merlins instrumented with satellite transmitters. Consecutive annual winter ranges fixed by three female Peregrine Falcons were considered independently in summary.

	50% Isopleth				95% Isopleth			
	n	Mean	SD	min - max	n	Mean	SD	min - max
Merlin	3	287	59	204 - 339	3	1,827	216	2,254 - 2,782
Peregrine	16	426	399	33 - 1,382	16	7,763	9,593	358 - 32,256

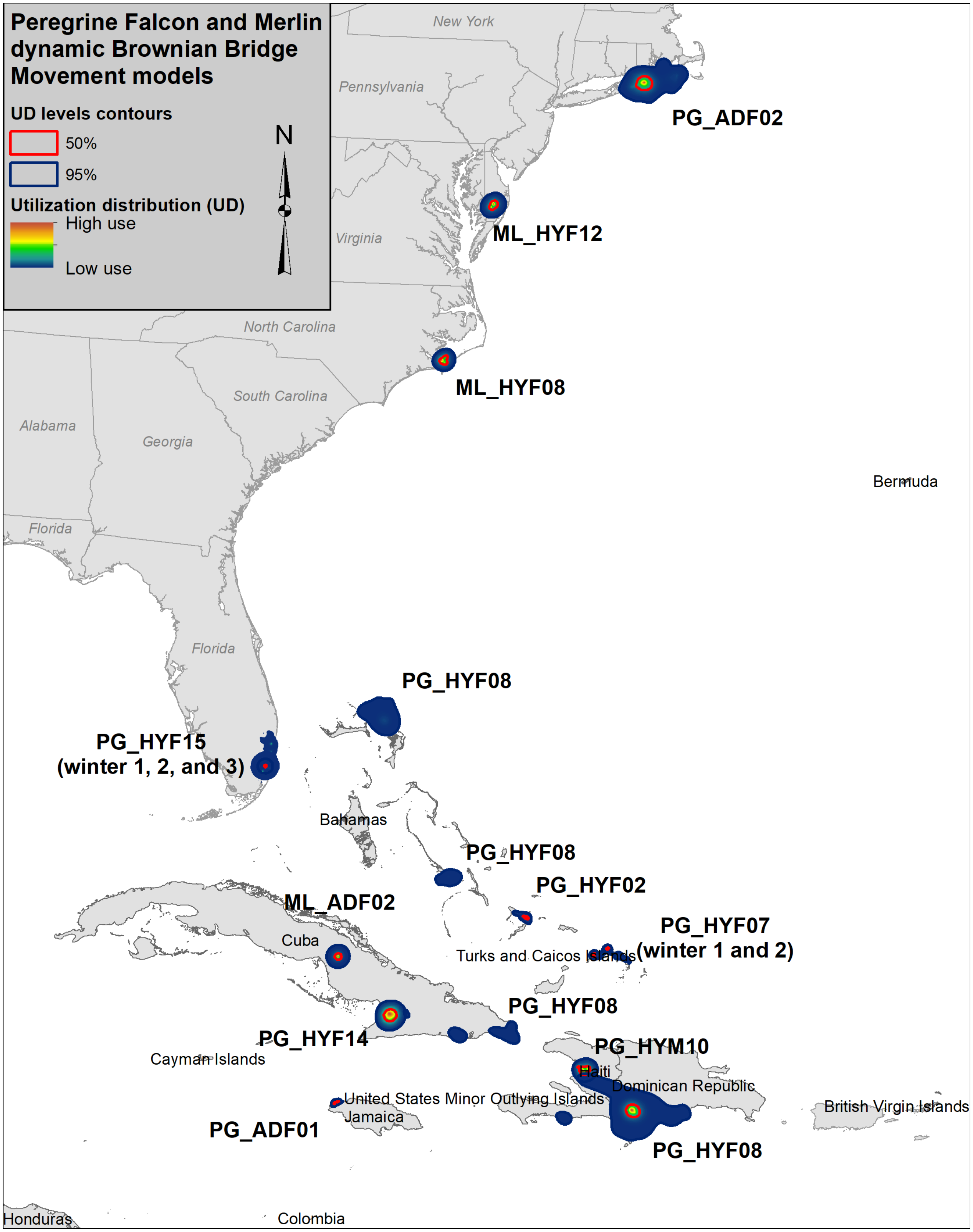

Figure 19. Winter home range estimates of nine Peregrine Falcons and three Merlins in North America and the Caribbean.

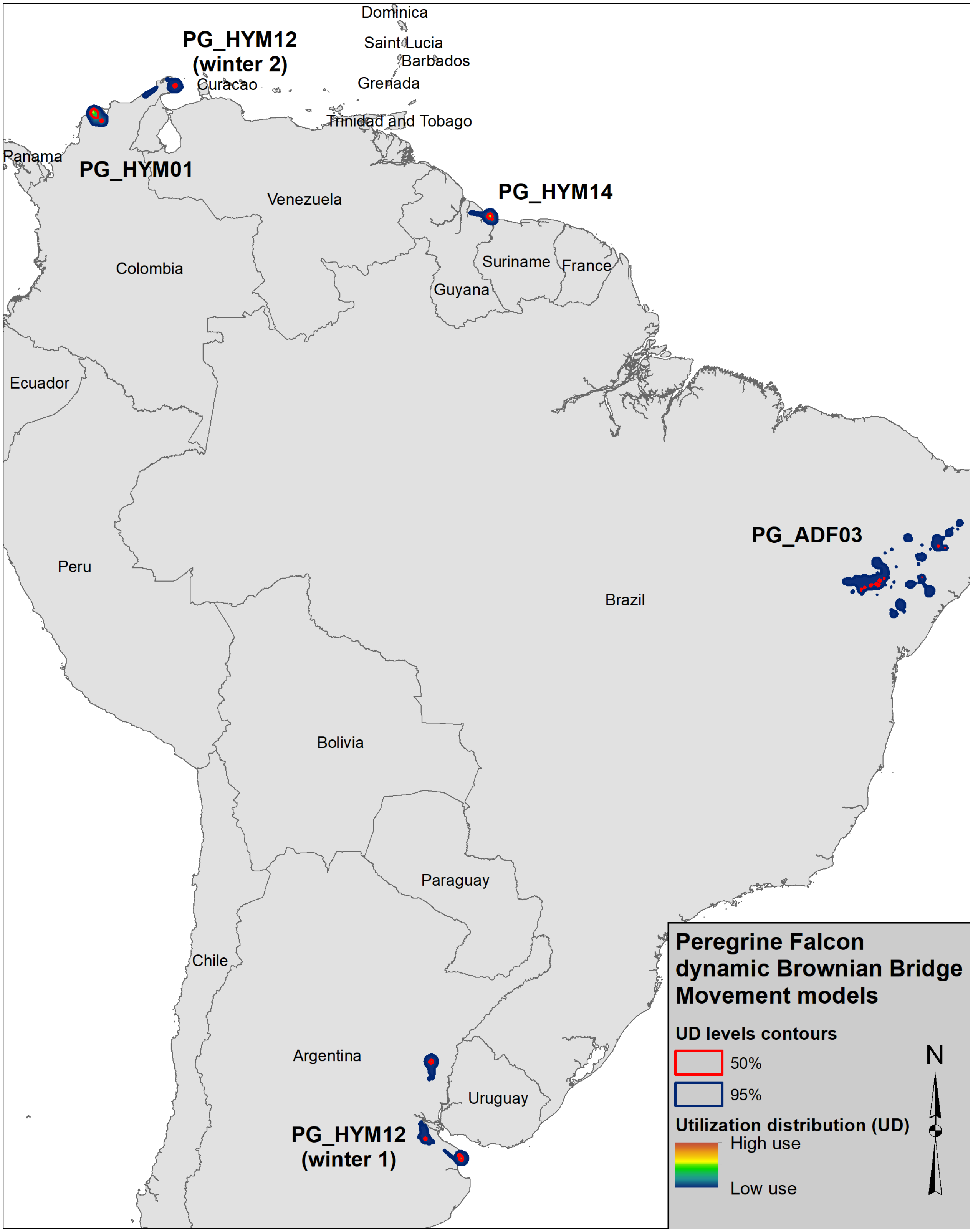

Figure 20. Winter home range estimates of four Peregrine Falcons in South America.

7.6 Northern Harriers: Perspectives on Migration

Northern Harriers are among the most poorly studied raptors in the eastern U.S. Northern Harriers are listed as state-endangered in five of the northernmost Atlantic states (RI, NH, CT, NJ, and DE) and are classified as either threatened or of special concern status in five other northeastern states in their breeding range (ME, VT, MA, NY, and PA). To our knowledge, no published studies have attempted to study Northern Harrier migratory movements using satellite telemetry.

We fitted three hatching year migrant Northern Harriers captured on Block Island with satellite transmitters in 2014 (n = 1) and 2017 (n = 2). These individuals exhibited regionally localized movement patterns; and movements were not biased directionally south like other migrants tracked from BIRRS (Figure 21). For example, Northern Harrier HYM01 departed the island from the southwestern corner, traveled down a portion of Long Island, NY, and then moved northward through central Connecticut, where it spent roughly 5 days before continuing on to Carver, MA just north of Buzzard's Bay. HYM01 transmitted from the general vicinity of Carver, MA until its last transmission on 28 November 2014. In 2017, a hatching year female Northern Harrier (HYF01) fitted with a satellite transmitter appeared to leave the north end of the island and traveled to Connecticut, then flew south again, crossing Long Island Sound and then traveling southwest along the coast towards New York City before it turned back to Short Beach Island along the south coast of Long Island, where it stayed until its last transmission on 19 November 2017 (Figure 20). A third Northern Harrier in our study fitted with a transmitter died in a region of Block Island with dense thickets shortly after instrumentation. Our limited observations of satellite tracked Northern Harriers suggests the species exhibits highly regionalized and non-directional movements compared to other raptors tracked from BIRRS using telemetry. Findings may also reflect notably high mortality among the hatching year age class in this species.

On 4 February 2019 an adult female Northern Harrier was found caught in a cable-restraint snare (intended set for red fox) near Gam's Crest, DE. This bird was banded as a hatching year on Block Island in 2013. The bird was released unharmed and reported to the USGS Bird Banding Laboratory (BBL) by the person who found it. Of the 57 harriers banded at BIRRS to date, this is the first band encounter.

Figure 21. Fall movements of a hatching year male (2014) and a hatching year female (2017) Northern Harrier tracked from BIRRS, using satellite telemetry.

8.0 Evaluating Contaminant and Pathogen Exposure in Migrant Raptors Sampled on Block Island, RI

8.1 Mercury Exposure

8.1.1 Background: Mercury Exposure in Wildlife

Mercury (Hg) pollution is prevalent in our environment and levels are increasing globally. Mercury occurs naturally in our environment, but it is also produced through a wide variety of industrial activities. It can be deposited into ecosystems directly, or more commonly, through atmospheric deposition. Once deposited, Hg readily accumulates in organisms and biomagnifies up food webs to top predators. Mercury is increasingly being shown to be highly persistent in ecosystems over time (DeSorbo et al. 2018*a*). Bird tissues are commonly sampled and analyzed to monitor geographic and temporal patterns of Hg exposure, and to evaluate potential for adverse impacts of Hg on populations. Concentrations of Hg in blood reflect recent dietary exposure, while feathers can reflect a combination of recent dietary exposure and cumulated body burdens over the time of feather growth (Evers et al. 2005). Elevated Hg exposure in birds is associated with a wide variety of adverse effects on animal behavior, reproduction and physiology (Evers 2018). Traditionally, toxicologists predominantly considered Hg a risk to fish-eating wildlife; however, recent studies are increasingly revealing that: (1) species vary widely in their sensitivity to Hg (Heinz et al. 2008), and (2) Hg can also pose health risks to organisms associated with terrestrial habitats, including passerine songbirds (Rimmer et al. 2005, Jackson et al. 2011), which comprise the diet of some raptor species. These findings therefore raise concerns that some raptor species could be sensitive to Hg effects and impacted by exposure. Here, we summarize findings of Hg analyses of raptor tissues sampled at five sites – particularly the BIRRS – along the Atlantic migration flyway[1].

8.1.2 Mercury Exposure in Migrant Raptors

Feather Hg - HYs: Mercury concentrations differed across the six raptor species groups ($p < 0.0001$; Wilcoxon test). Mean concentrations of Hg in breast feathers, which reflect dietary exposure during nestling development, were lowest in Cooper's Hawks and Northern Harriers (which were statistically similar), and greatest in Sharp-shinned Hawks. Mean Hg concentrations in feathers sampled from the three falcon species – American Kestrels, Merlins, and Peregrine Falcons – were statistically similar and this group was intermediate between the aforementioned groupings (Figure 22).

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[1] Isle Au Haut: 2009; Monhegan: 2010 [DeSorbo et al. 2012]; Richardson 2011; Cutler: 2018 and 2020 [Persico et al. 2021]; BIRRS: 2012-2022 . BIRRS predominated sample sizes. Only Cutler, Isle Au Haut and BIRRS sites were included in blood Hg analysis (blood was not sampled at other sites).

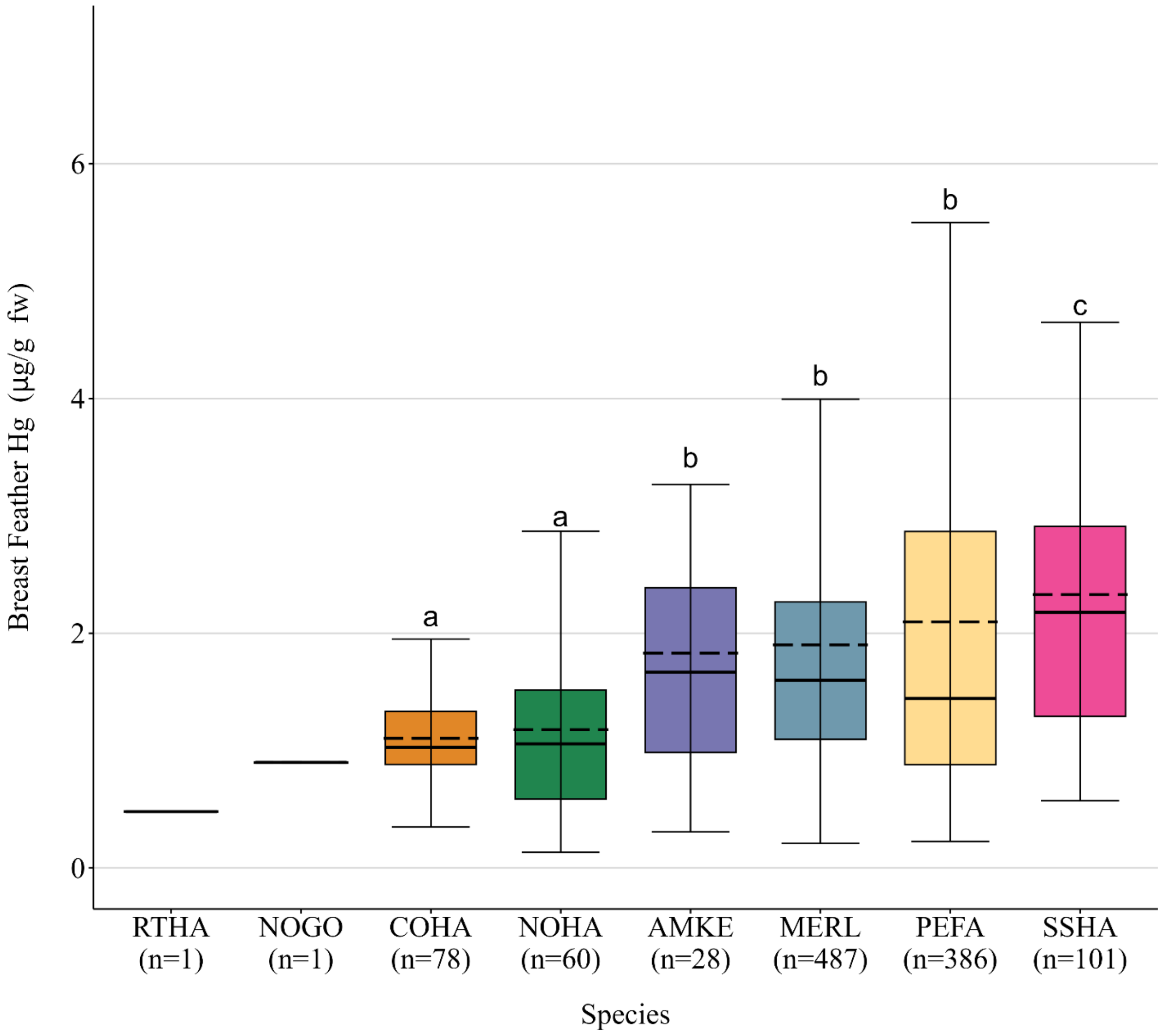


Figure 22. Breast feather Mercury concentrations (µg/g) in eight species of hatching year migrant raptors sampled at five raptor research stations (predominantly BIRRS; see text) along the Atlantic coast, 2009-2022.

* Box shows interquartile range. Whiskers show 95% confidence intervals. Solid line indicates median and dashed line indicates mean. Species are ordered by mean values in ascending order. Pairs of species that share the same letter were not significantly different using a Wilcoxon Multiple Comparison Procedure. Species codes follow American Ornithologist Society convention: Red-tailed Hawk (RTHA), Northern Goshawk (NOGO), Cooper's Hawk (COHA), Northern Harrier (NOHA), American Kestrel (AMKE), Merlin (MERL), Peregrine Falcon (PEFA), and Sharp-shinned Hawk (SSHA).

Blood Hg - HYs: Mean Hg concentrations in hatching year blood, which reflects recent dietary uptake, differed across six migrant raptor species ($p< 0.0001$) (Figure 23). Species exposure patterns in blood were slightly different than those observed in nestling feathers. The mean concentration of Hg in blood was lowest in Cooper's Hawks and American Kestrels (which were statistically similar), slightly greater in Northern Harriers (which were similar to kestrels, but greater than Cooper's Hawks), intermediate in Sharp-shinned Hawks and Peregrine Falcons (which were statistically similar) and greatest in Merlins (Figure 23).

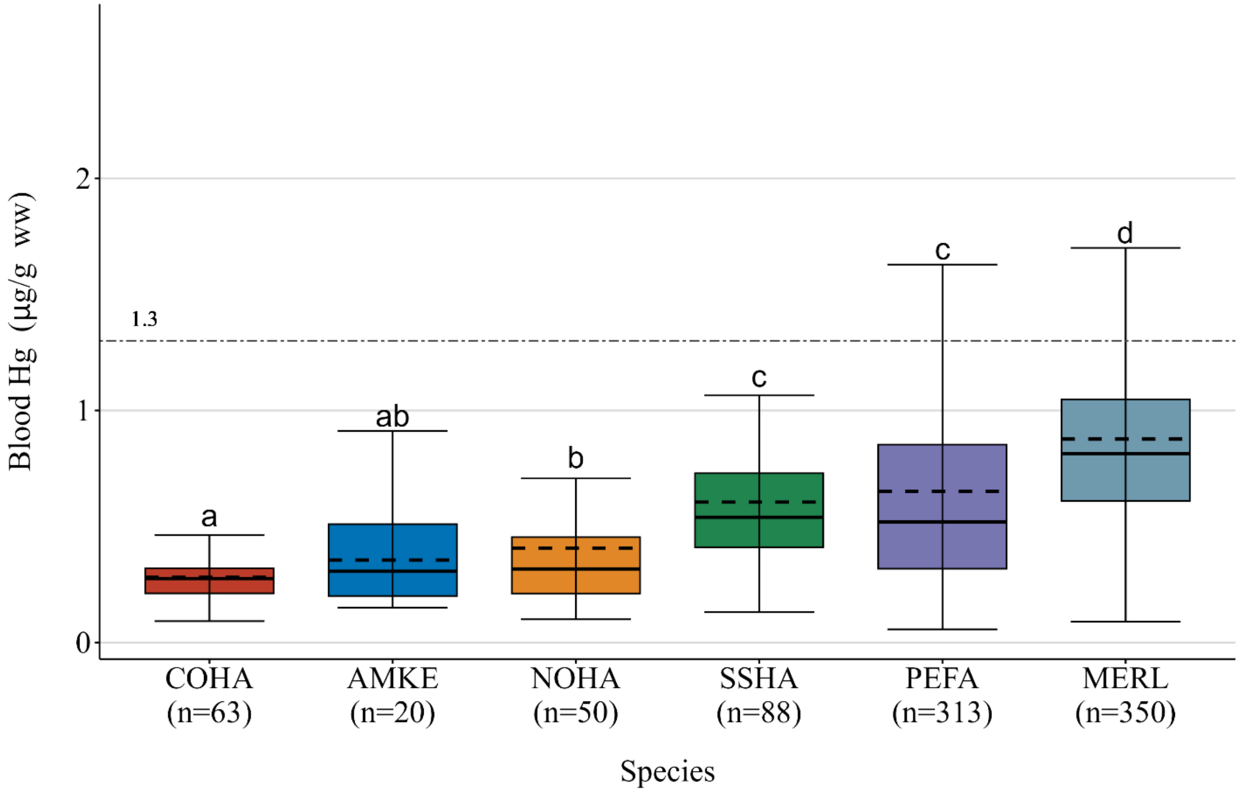


Figure 23. Blood Mercury concentrations (µg/g) in six species of hatching year migrant raptors sampled at three raptor research stations (predominantly BIRRS; see text) along the Atlantic coast, 2009-2022.

* Box shows interquartile range. Whiskers show 95% confidence intervals. Solid line indicates median and dashed line indicates mean. Species are ordered by mean values in ascending order. Pairs of species that share the same letter were not significantly different using a Wilcoxon Multiple Comparison Procedure. Species codes follow American Ornithologist Society convention: Cooper's Hawk (COHA), Northern Harrier (NOHA), American Kestrel (AMKE), Merlin (MERL), Peregrine Falcon (PEFA) and Sharp-shinned Hawk (SSHA). Black dashed line indicates blood Hg equivalent level (1.3 µg/g ww) associated with adverse effects on Merlin reproduction (Ackerman et al. 2016).

Age Class – blood and feather: Since non-hatching year raptors (i.e., birds aged as second year or greater; AHYs hereafter) are encountered at notably lower rates than HY individuals at migrant raptor research stations, low AHY sample sizes typically preclude powerful evaluations of the influence of age class on Hg exposure in migrant raptors. In our dataset, mean feather Hg concentrations were greater in AHY, compared to HY Peregrine Falcons ($p = 0.004$) and Merlins ($p = 0.0006$). Age class did not appear to influence blood Hg concentrations in Merlins ($p = 0.568$); but the mean blood Hg concentration was greater in AHY vs. HY peregrines ($p = 0.0018$).

8.1.3 Interpretations and Conclusions – Mercury

The overall Hg exposure pattern observed in migrant raptors sampled at BIRRS and other sites along the Atlantic coast reflects expected patterns given the known dietary habits of individual raptor species and presumed Hg exposure in their prey. For example, Sharp-shinned Hawks and the three falcon species tend to feed either predominantly or exclusively on birds (which likely have higher Hg burdens), while Red-tailed Hawks, Northern Harriers and Cooper's Hawks have varying degrees of dietary emphasis on of small mammals (which generally have lower Hg burdens). In addition to an emphasis on small mammals, Cooper's Hawks are considered to commonly feed upon birds with a lower Hg exposure (i.e., robins, flickers and jays). The finding in our analyses that Merlins exhibited higher Hg concentrations in blood compared to other species studied – a pattern that was not reflected in breast feathers – suggests that Merlins are exposed to the highest levels of Hg during migration among those studied, while Sharp-shinned Hawks were exposed to the highest levels of Hg in natal areas during development. High Hg concentrations in invertebrate prey such as dragonflies (which accumulate Hg; Eagles-Smith et al. 2020) and a dietary emphasis on aquatic habitats (which often facilitate Hg biomagnification), may contribute to elevated Hg exposure in Merlins both during nestling development and during migration.

The sampling of migrant raptors has enabled the establishment of baseline blood and feather Hg exposure concentrations in eight raptor species using the Atlantic Flyway. The exposure of all species to Hg included in this study, despite their different habitat associations, exemplifies the pervasiveness of Hg in our environment across multiple prey guilds and habitats. To date, few studies have clearly established whether Hg adversely affects endpoints such as behavior, physiological biomarkers or reproductive success in any of the species we studied.

Assessing Risk: While adverse effects of Hg have been well-established in multiple independent studies of several non-raptor species such as the Common Loons (Burgess and Hobson 2006, Evers et al. 2008), effects concentrations have not been well-established in many raptor species, particularly post-fledging HY individuals and developing nestlings. Few have evaluated Hg exposure in migrants in our study species using blood, the preferred tissue in many toxicological analyses. Ackerman et al. (2016) derived a blood Hg equivalent of 1.3 µg/g ww in adult Merlins based upon a previous study reporting adverse impacts of Hg on reproduction (Newton and Haas 1988). This blood Hg equivalent is similar to the adult blood Hg concentration (1.2 µg/g ww) associated with a 20% reduction in nest success in wild Carolina Wrens (*Thryothorus ludovicaianus*) (Jackson et al. 2011). Of the limited number of non-hatching year (i.e., in their second or greater year of life) raptors that were captured and sampled for blood during our study (n = 30; most of which were Merlins and Peregrine Falcons), only Merlins and Peregrine Falcons had blood Hg concentrations exceeding 1.3 µg/g; however sample sizes were insufficient to assess risk in kestrels, Cooper's Hawks, or harriers. Of the 14 Merlins and 9 Peregrine Falcons sampled for blood (all non-HYs), 21% and 44% respectively had blood Hg concentrations exceeding 1.3 µg/g ww. In HY raptors sampled in our study, no American Kestrels or Cooper's Hawks exceeded this 1.3 µg/g threshold, while 2.0% of Northern Harriers, 3.5% of Sharp-shinned Hawks, 11% of Peregrine Falcons, and 15.9% of HY Merlins had blood Hg concentrations exceeding this benchmark. Overall, species Hg exposure patterns and differences in Hg by age class found in our study along the Atlantic flyway followed similar species and age class patterns as those reported in other migration flyways (Bourbour et al. 2019, Keyel et al. 2020); however Hg risks are consistently highest along the Atlantic U.S. coast (Evers et al. 1998, Bourbour et al. 2019).

Efforts to assess Hg effects in many of the species we studied in their breeding areas face notable logistical challenges therefore, researchers often attempt to gain insights from laboratory-based studies, or field studies emphasizing other species. One factor that particularly complicates interpretations is that species differ markedly in their level of sensitivity to Hg impacts. Heinz et al. (2009) found that Mallards had a relatively low sensitivity to Hg impacts on reproduction, while American Kestrels were highly sensitive to Hg impacts.

Further study to investigate potential impacts of Hg, other contaminants, or disease prevalence is particularly warranted in several of the raptors studied at BIRRS given poor understanding of Hg sensitivity and impacts in our study species. This poor understanding stems somewhat from challenges (i.e., sample size limitations, inconspicuous nest sites) studying these species in their breeding grounds and thus studies focusing on migrants are particularly valuable. Evidence of population declines have been observed in some species we studied, including Sharp-shinned Hawks and American Kestrels (Viverette et al. 1996, Farmer et al. 2008, Smallwood et al. 2009). Findings in our study suggesting that meaningful proportions of migrating adult Peregrine Falcons and Merlins – two prominent contaminant bioindicators – are likely exposed to concentrations of Hg associated with adverse impacts, warrants additional investigation. Due to its location along the Atlantic flyway, species composition and other factors, the BIRRS represents a critical location to access and study raptors migrating along the Atlantic coast.

8.2 PFAS Exposure

8.2.1 Background – PFAS

An emerging suite of anthropogenic contaminants (per- and poly-alkyl fluorinated substances; PFAS) are of increasing concern at a global scale because they appear to be relatively ubiquitous in our environment, persistent, and associated with adverse health effects in wildlife and humans. PFAS compounds comprise a diverse and expanding list of compounds associated with both industrial and residential products. In Maine, the use of biosludge fertilizers for crops, and firefighting foams at airfields and military facilities are the most well-known and publicized point sources of PFAS into the environment; however, numerous sources of exposure exist given the commonality of PFAS compounds in consumer and industrial products and multiple pathways of potential exposure (i.e., both direct inputs and atmospheric deposition). Increasingly, efforts are being undertaken to investigate the exposure and impacts of PFAS compounds in wildlife. To date, the majority of efforts to understand the impacts of PFAS exposure in wildlife are predominantly derived from field studies of aerial invertivore songbirds, especially Tree Swallows (i.e., Custer et al. 2014, Custer et al. 2021), and laboratory-based dosing studies focused on quail and mallards (Newsted et al. 2005, 2007). High trophic level species such as raptors, are particularly prone to accumulating bioaccumulative compounds and they are therefore vulnerable to potential adverse effects.

8.2.2 Methods – PFAS

We collected blood plasma from raptors captured at the BIRRS and selected 70 samples collected during fall 2021 and 2023 for analysis. Samples representing 6 species were selected for analysis to represent each species encountered. All but three (2 Northern Harriers and one Peregrine Falcon) were of the HY age class. Samples were analyzed at the U.S. Environmental Protection Agency in Research Triangle Park, North Carolina, under the supervision of Dr. Mark Strynar. We analyzed up to 24 PFAS compounds in samples. For preliminary analyses summarized here, we focus on PFOS, the most commonly reported and most well-studied PFAS compound. One sample, the only Rough-legged Hawk represented in our sample, was removed during the QA/QC process. We pooled age classes for this preliminary analysis.

8.2.3 Preliminary Results and Conclusions – PFAS

PFOS was detected in all but one of the 69 samples analyzed (a HY Cooper's Hawk). PFOS comprised the dominant compound amongst those analyzed (not shown). The overall mean concentration of PFOS across all pooled individuals was 32.7 (± 43.6 SD) ng/g. Preliminary comparisons did not reveal statistically significant differences among species (Table 2); however, sample sizes are limited within some species groups. Comparisons of the two most well-represented species in our sampling– Peregrine Falcons and Merlins – did not suggest statistically significant differences in PFOS concentrations ($p<0.05$); however, PFOS concentrations ranged more widely in Peregrine Falcons (2.9 – 208.6 ng/g, ww) and thus variability measures were greater. The highest measured concentration of PFOS in all sampled individuals was in a HY Sharp-shinned Hawk (250 ng/g ww).

Table 2. Descriptive statistics for concentrations of PFOS (ng/g, ww) in six species of raptors sampled during fall migration at the Block Island Raptor Research Station, RI. Age classes are pooled for data summaries (see text).

Species	n	Mean	SD	Min	Max
AMKE	6	6.9	2.9	3.6	10.1
COHA	5	33.7	35.1	0	79.2
MERL	16	28.1	24.6	5.6	88.8
NOHA	9	30.1	28.9	8.0	99.7
PEFA	27	35.7	46.1	2.9	208.6
SSHA	6	60.8	93.4	8.3	250.4
Total:	**69**	**32.7**	**43.6**	**0**	**250.4**

No studies have documented the level at which PFOS concentrations might affect the species sampled in our study. To date, the majority of insights on impacts are derived from laboratory dosing experiments focused on chicken, mallard or quail eggs (Newsted et al. 2005), while field studies assessing relationships between PFAS concentrations and reproductive endpoints are generally limited to passerines (most notably Tree Swallows) and several are contradictory (Custer et al. 2012, Custer 2021). We will conduct a further exploration of these preliminary data after further data analyses and additional sample collections in 2024.

8.3 Avian Influenza

8.3.1 Background – Avian Influenza

Since approximately the fall of 2021, an outbreak of avian influenza, or "bird flu," caused by influenza Type A viruses, has increased dramatically in numerous organisms and across broad geographic regions. Organisms infected with the virus include domestic livestock, marine mammals, domestic birds and a growing list of wild birds. The severity of disease varies in accordance with the species infected, and the virus strain. Infection with Low Pathogenicity Avian Influenza (LPAI) strains typically do not elicit symptoms, while the Highly Pathogenic

Avian Influenza (HPAI) has a high mortality rate in some bird species, particularly in domestic poultry, waterfowl and some raptors. Wild birds infected with HPAI can show no symptoms while spreading the disease to new areas and individuals, including domestic poultry flocks. Raptors can be highly susceptible to HPAI infection given high asymptomatic infection in their prey. State and federal wildlife agencies and numerous others have initiated efforts to collect biological samples from an assortment of organisms, particularly birds, to better understand the prevalence and geographic patterns of HPAI infection. Sampling of individuals in the wild consists of oral and cloacal swabs to detect a current and active viral infection, and/or collection of blood plasma, which can be analyzed to determine if individuals contain antibodies to the virus, indicating a prior infection.

8.3.2 Methods – Avian Influenza Monitoring

During the fall seasons of 2022 and 2023, we collected biological samples from migrant raptors captured at BIRRS in order to evaluate the prevalence of avian influenza infection in raptor migrants using the Atlantic flyway. Individuals were sampled by collecting a single oral and cloacal swab from individuals and placing them in a buffer solution (DNA Shield in 2022, RNA Later in 2023) before freezing and sending to Cummings School of Veterinary Medicine at Tufts University under the supervision of Dr. Wendy Puryear. Analysis methods reported by Tufts are as follows: Viral RNA is extracted from raw sample using a Mag-bind RNA bead purification system. Influenza A Virus is detected with a 1-step RRTPCR assay using primers and probe directed against a conserved region of Influenza A matrix gene. Any positive samples undergo follow up screening with H5 specific primers and probe. Samples with a Ct value <40 are reported as positive, >40 is reported as “not-detected”.

8.3.3 Preliminary Results and Conclusions – HPAI

None of the 162 fall migrant raptors sampled at BIRRS during 2022 or 2023 fall migration seasons produced a positive result for avian influenza (Table 3). These findings indicate that at the time of sampling, there was no indication of infection from either HPAI or LPAI. Our sampling provides a better representation of exposure in Peregrine Falcons, Merlins and Northern Harriers than other species encountered at BIRRS in lower numbers, such as Cooper’s Hawks, Sharp-shinned Hawks and American Kestrels. Migrating Peregrine Falcons sampled for influenza A antibodies at Assateague Island, MD and Padre Island, TX detected an increase in the detection of individuals with influenza A antibodies compared to pre-outbreak sampling in 2021 (Doney et al. 2023, Yates et al. 2023). Those studies also revealed a relatively low number and proportion of migrants with influenza A antibodies (6 of 442 individuals), but sampling suggested that exposure was not necessarily fatal to peregrines.

Table 3. Number of individuals of six different species of raptors screened for influenza A virus ("bird flu") during two fall migration seasons. All individuals screened tested negative and thus exhibited no evidence of either low or high pathogenicity at the time of sampling.

Species	**No. Screened**	
	2022	**2023**
AMKE	2	2
COHA	2	2
NOHA	1	21
MERL	15	39
PEFA	24	39
SSHA	5	10
Total:	**49**	**113**

Further monitoring is particularly important in both migratory and non-migratory raptors given their high susceptibility to infection, limited overall monitoring in "healthy" wild populations, and the role they play in the geographic patterns of disease transmission. Monitoring is particularly important in migrating Peregrine Falcons given recent indications of declines becoming evident at multiple concurrent long-term monitoring sites throughout North America and elsewhere. Sampling and monitoring can play an important role in wildlife disease monitoring in other species regularly encountered at BIRRS such as Merlins and Northern Harriers, which are minimally studied throughout the (western) Atlantic Flyway. We will continue HPAI sampling in subsequent seasons, including analysis of archived blood plasma to assess whether sampled individuals contain antibodies to influenza A.

8.4 Evaluating Blood-borne Parasites in Peregrine Falcons

8.4.1 Background – Avian Malaria and Blood Parasites

The global distribution of avian haemosporidians is poorly understood, and even less is known about the species inhabiting the Arctic Circle. Avian haemosprodians have the potential to cause physiological consequences on their hosts such as anemia, emaciation, or death. These parasites can affect birds both at the individual level and at the population level. These blood parasites can be difficult to study due to their elusiveness and the remoteness of many arctic regions. Documenting the presence of blood borne parasites in birds is considered a front-line of defense in understanding the risk they might pose on wildlife populations and the dynamics of their spread, particularly given the multitude of changes initiated by climate change (particularly in the arctic).

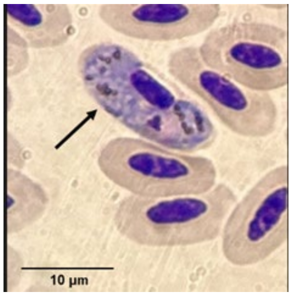
8.4.2 Methods – Blood-borne Parasites

We collected blood smear and filter paper blood spot samples from 51 Hatching year Peregrine Falcons during the fall 2023 season at BIRRS to be analyzed for blood-borne parasites. Samples were analyzed by Ericka Griggs at the Wildlife Pathogens Lab at the University of Vermont under the supervision of Dr. Ellen Martinsen. DNA was extracted from each sample, and a nested endpoint PCR was employed to target a 479 bp region of the cytB gene of haemosporidians. The PCR products were then sequenced using Sanger sequencing to identify the parasite lineage.

8.4.3 Interpretations and Conclusions –Blood-borne Parasites

The PCR results indicated that 2 out of 52 samples were positive for Plasmodium, 11 out of 52 for *Haemoproteus*, and 5 out of 52 for *Leucocytozoon*, translating to respective infection rates of approximately 3.8%, 21.2%, and 9.6%. Sanger sequencing revealed that the two Plasmodium species identified were MELMEL01 and CATCUS05, generalist lineages known to infect a wide range of avian hosts. The *Haemoproteus* species detected was FALAMU02 (Figure 24), which has been reported in falcons in Asia, and the *Leucocytozoon* species identified was FALAMU04, also known to infect Asian species of Falcons.

Figure 24. Light microscopy image of Haemoproteus linage FALAMU02 infected erythrocyte from a hatch year Peregrine Falcon. Note the gametocyte (black arrow). 1000x magnification. Photo credit: Ericka Griggs.



The presence of generalist Plasmodium lineages MELMEL01 and CATCUS05 suggests that mosquitoes feeding on the falcons may also be feeding on other songbird species. The detection of Haemoproteus and Leucocytozoon species, typically associated with falcons in Asia, raises interesting questions about the migration patterns and intercontinental movements of these birds. This study underscores the importance of continued surveillance of avian haemosporidians to better understand their distribution and the ecological interactions between hosts and parasites. Such monitoring will become increasingly important in the future as habitats shift in the arctic and elsewhere in response to climate change.

9.0 Education and Outreach

General information about this project, and downloadable maps, scientific communications and reports can be found on the BRI website at: www.briloon.org/raptors/blockisland.

BRI and TNC have partnered on Block Island to host formalized environmental education and outreach programs on Block Island to promote habitat and wildlife conservation and informed decision-making through field research. We have hosted or provided programs for dozens of school groups, conservation professionals, fellow researchers, and law-makers (including Rhode Island's former Governor, Lincoln Chaffee) and eco-tourism groups. BRI staff also conduct raptor ecology presentations at the James Stover Series Nature Walk and other events sponsored by TNC as much as possible. We did not conduct outreach presentations during fall 2021 or 2022 due to precautions related to covid-19. We continued providing educational outreach programs to local school groups in 2023.

10.0 Scientific Collaborations, Contributions, and Publications

Offshore Wind Energy: Data from the Block Island Raptor Research Station has contributed key information on raptor movements to risk assessments of multiple offshore wind energy facilities along the Atlantic coast. In 2015, BRI completed the Mid-Atlantic Baseline Study, an evaluation of wildlife distribution and movement patterns relative to Mid-Atlantic offshore wind energy areas. Information on the overall study can be found at: www.briloon.org/mabs. Summaries and report chapters can be found at: http://www.briloon.org/mabs/reports. Our report chapter evaluating Peregrine Falcon movements relative to offshore wind energy areas can also be found at: http://www.briloon.org/raptors/blockisland, along with a science communication about BIRRS, this report, downloadable maps, and other information.
An update on our 2015 summary findings evaluating movement patterns of Peregrine Falcons relative to proposed offshore wind energy areas in the Mid-Atlantic was presented at the *50th annual conference of the Raptor Research Foundation (RRF) in Cape May, NJ, 16–20 October 2016*. The abstract for this presentation can be found in the program materials listed on the RRF website (p.32):
http://www.raptorresearchfoundation.org/files/2016/11/2016_conference_program.pdf.

The use of raptor tracking data enabled by the BIRRS to inform offshore wind energy risk assessments are ongoing. Further analyses of raptor movement data relative to offshore wind energy facilities along the Atlantic coast using comprehensive datasets are currently underway.

Evaluating Resource Availability Influences - Tucker et al. 2019: Data collected during this study contributed to a global-scale animal movement study published in the journal *Global Ecology and Biogeography* that evaluated how bird movements may be influenced by resource availability and habitat characteristics (Tucker et al. 2019). The abstract of this study, titled *Large birds travel farther in homogeneous environments* can be found at:
https://onlinelibrary.wiley.com/doi/abs/10.1111/geb.12875

Climate Change – Davidson et al. 2020: Data collected during this work contributed a landmark study published in the journal *Science* that uses three decades of animal tracking data to gather insights about animal responses to changing environmental conditions in the Arctic (Davidson et al. 2020). The study, titled *Ecological insights from three decades of animal movement tracking across a changing Arctic*, utilizes and broadly introduces the Arctic Animal Movement Archive (AAMA). The AAMA is an active collection of tracking datasets from researchers across the globe for marine and terrestrial animals in the arctic. The AAMA is hosted on the online global movebank database (www.movebank.org). The study can be found here:
https://science.sciencemag.org/content/370/6517/712

Evaluating Movement Timing – Mallon et al. 2020: Data collected during this study contributed to study published in the *Journal of Avian Biology* titled *Diurnal timing of nonmigratory movement in birds: the importance of foraging spatial scales* (Mallon et al. 2020). The study used animal tracking data to better understand the factors affecting the timing of

movement activity in birds. The study can be found here:
https://onlinelibrary.wiley.com/doi/abs/10.1111/jav.02612

Mercury Investigations: BRI is collaborating with more than a dozen researchers, organizations and individuals to investigate patterns of Hg exposure in North American raptors, and to evaluate Hg risks to populations.

Oxidative Stress Investigation: BRI is collaborating with Scott McWilliams and Clara Cooper-Mullins of URI, and Matt Etterson (Hawk Ridge Bird Observatory, USEPA) on a study evaluating cellular damage and oxidative stress in migrant raptors, and its potential relationship with Hg exposure.

Ongoing Collaborations: Researchers and conservation groups are encouraged to contact us with collaboration ideas.

Figure 25. Sunset at BIRRS.

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Appendix A. Merlin nanotag study

Digitally Encoded VHF Radio Tags (‘NanoTags’)

In 2014, BRI began collaborating with researchers at the University of Rhode Island to study the migratory habits of Merlins using the Atlantic Flyway using automated VHF telemetry. During 2014–2016, we fitted 80 Merlins (20 females, 19 males in 2014; 17 females, 13 males in 2015; 5 females, 6 males in 2016) with digitally encoded VHF radio tags to gain perspectives on the Merlin migration and stopover areas along the Atlantic coast. Commonly referred to as ‘NanoTags,’ digitally encoded transmitters emit an individual-specific VHF radio burst that can be detected at automated tower arrays erected by a network of research partners. Due in large part to its open source and collaborative nature, and low cost compared to some wildlife tracking options, the MOTUS wildlife tracking system network is growing rapidly in North America, particularly along the Atlantic coast including the Eastern Seaboard (Figure A-1), Canadian Maritimes, and the Great Lakes (www.motus-wts.org). This tracking network enables researchers to economically gather information on wildlife movement patterns and stopover timeframes on both a large and/or small geographic scale, providing that individuals fly within the detection range of arrays.

A subset of captured Merlins were fitted with ‘NanoTags’ (Lotek Wireless, Newmarket, Ontario, Canada). Individuals that were visibly healthy and heavier were selected for instrumentation, such that the female and male backpacks remained ≤3.0% of bird body mass and tail mount units remained ≤1% of bird body mass (Figure A-2). Females were fitted with backpacks (NTQB-6-2; 2.6 g prior to customization and fitting) to achieve a greater unit lifespan in hopes of registering at automated telemetry arrays during first spring and/or second fall migrations. Tail mount tags (NTQB-3-2; 0.67g prior to customization and fitting) were attached to a central retrix (tail feather) of both males and females using a light cured resin (Clear Cure Goo, Southlake TX). Merlins were harnessed with backpacks using 0.18 in. (4.76 mm) Teflon® ribbon (Bally Ribbon Mills, Bally, PA) sewn with Spiderwire® Dyneema® thread. Harnesses were centered over the mid-keel of individuals similar to designs described elsewhere (Kenward 2001, Steenhof et al. 2006, Walls and Kenward 2007, Fair et al. 2010). After manufacturer customization and harnessing, male backpacks weighed approximately 2.5 g, and female backpacks weighed approximately 4.5 g. Tail mount units fitted to both males and females weighed approximately 1.6 g at deployment. Transmitter lifespan is estimated by the manufacturer to be approximately 84 days and 459 days for smaller and larger transmitters, respectively.

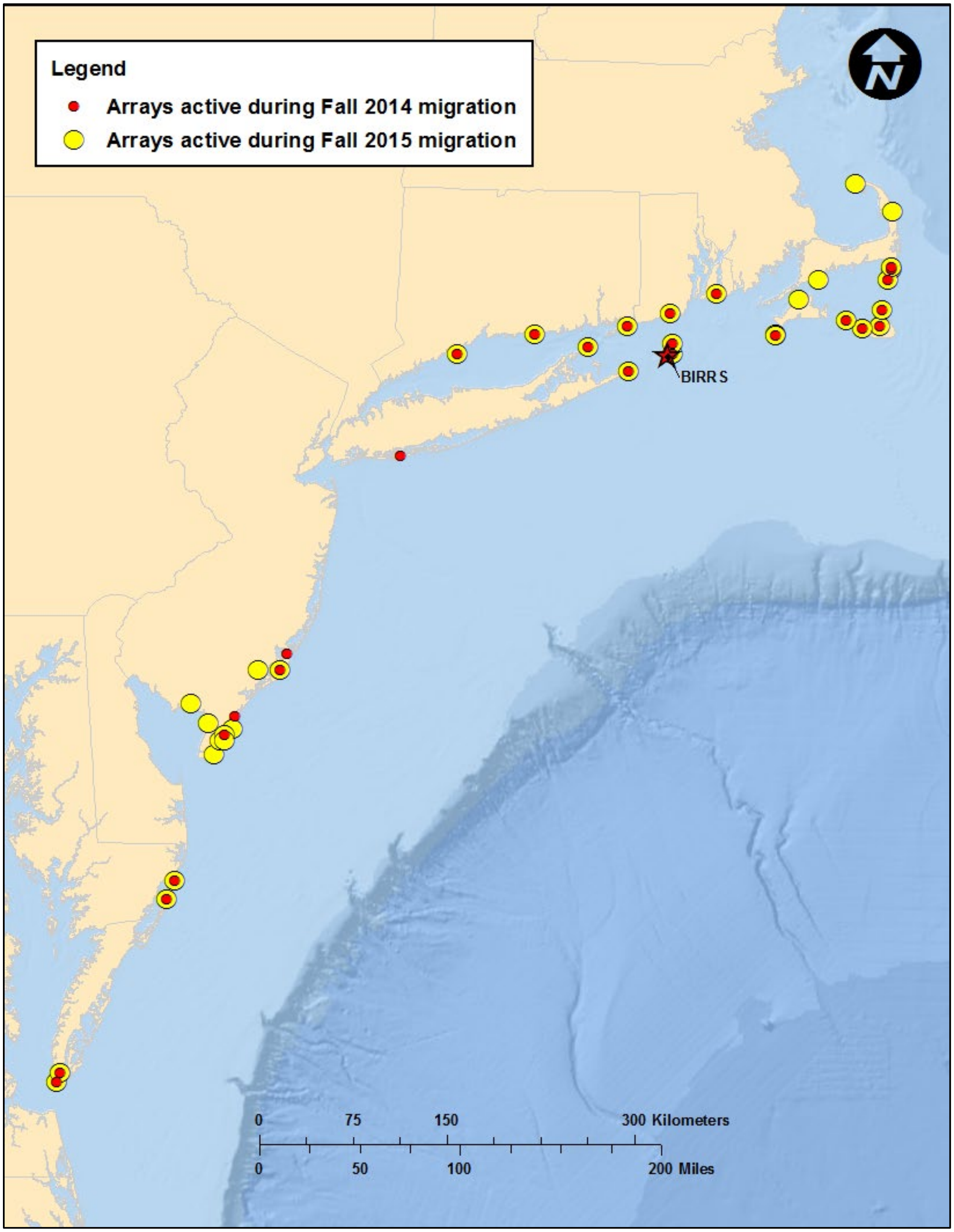

Figure A-1. Location of automated telemetry arrays along the Atlantic coast relative to the Block Island Raptor Research Station (BIRRS) during 2014 and 2015.

* Automated Telemetry Arrays are not permanent structures, some are moved to suit the associated project needs and some are taken down in the fall to be reinstalled in the spring or summer of the following year due to permitting restrictions. The network of arrays is generally growing each year. Arrays shown on this map were active during the timeframe of the Merlin migration (mid-September through the end of November). As indicated (above) three 2014 arrays were removed or moved; overall 9 additional arrays were installed in 2015. Detection range up to 15 km, but varies widely according to many factors including receiver antenna type and size, transmitter size, topography, weather conditions, etc.

Figure A-2. Female hatching year Merlin fitted with backpack-style digitally encoded VHF radio tag.

Migration Patterns along the Atlantic Seaboard Using Automated Radio-Telemetry Receivers

A total of 80 digitally encoded VHF radio transmitters (‘NanoTags’) were deployed on Merlins captured at BIRRS between the years 2014–2016 (39 in 2014; 30 in 2015, 11 in 2016). These tags provided first-time perspectives about the migratory ecology of this poorly studied species. Overall, 94% of Merlins fitted with NanoTags were detected by ≥1 automated telemetry array (92% in 2014 [n = 36]; 97% in 2015 [n = 29]; 91% in 2016 [n = 10]), and 60% (48 of 80) were detected by ≥3 telemetry arrays. No females were detected during their first spring or second fall migration (only the ~ 4 g tags put on females had a predicted lifespan capable of spring/second fall detections; see methods).

Our study characterizes previously undocumented movements of Merlins during migration. Of 69 individuals tagged in 2014–2015 analyzed, 39% were detected by a telemetry arrays along the Eastern Seaboard, confirming southerly movements for this portion of individuals (Figure A-3). The southernmost detections were in New Jersey (n = 6) and Virginia (n = 20), reflecting limitations of the tower network. Interestingly, 14% of the remaining individuals were documented to travel in an easterly direction from BIRRS (n = 9) (Figure A-4), while another 16% were documented to travel in a westerly direction relative to their Block Island deployment site (n = 10) (Figure A-5). None of these individuals were detected at any other telemetry arrays south of New York. Less than 1% (n = 4) of tags were not detected at any array; the remaining 30% (n = 20) of the tags were detected only at Block Island and/or Montauk, Long Island.

The overall detection pattern of Merlins tagged at BIRRS suggests that a portion of Merlins either use inland migration routes, or that they overwinter inland along the Atlantic coast in areas where automated telemetry arrays were not present. Information on bird sightings in eBird supports this explanation; a filtered search on Merlin sightings during the last four years during winter months shows that Merlins commonly overwinter in southern New England and New York with coastal concentrations.

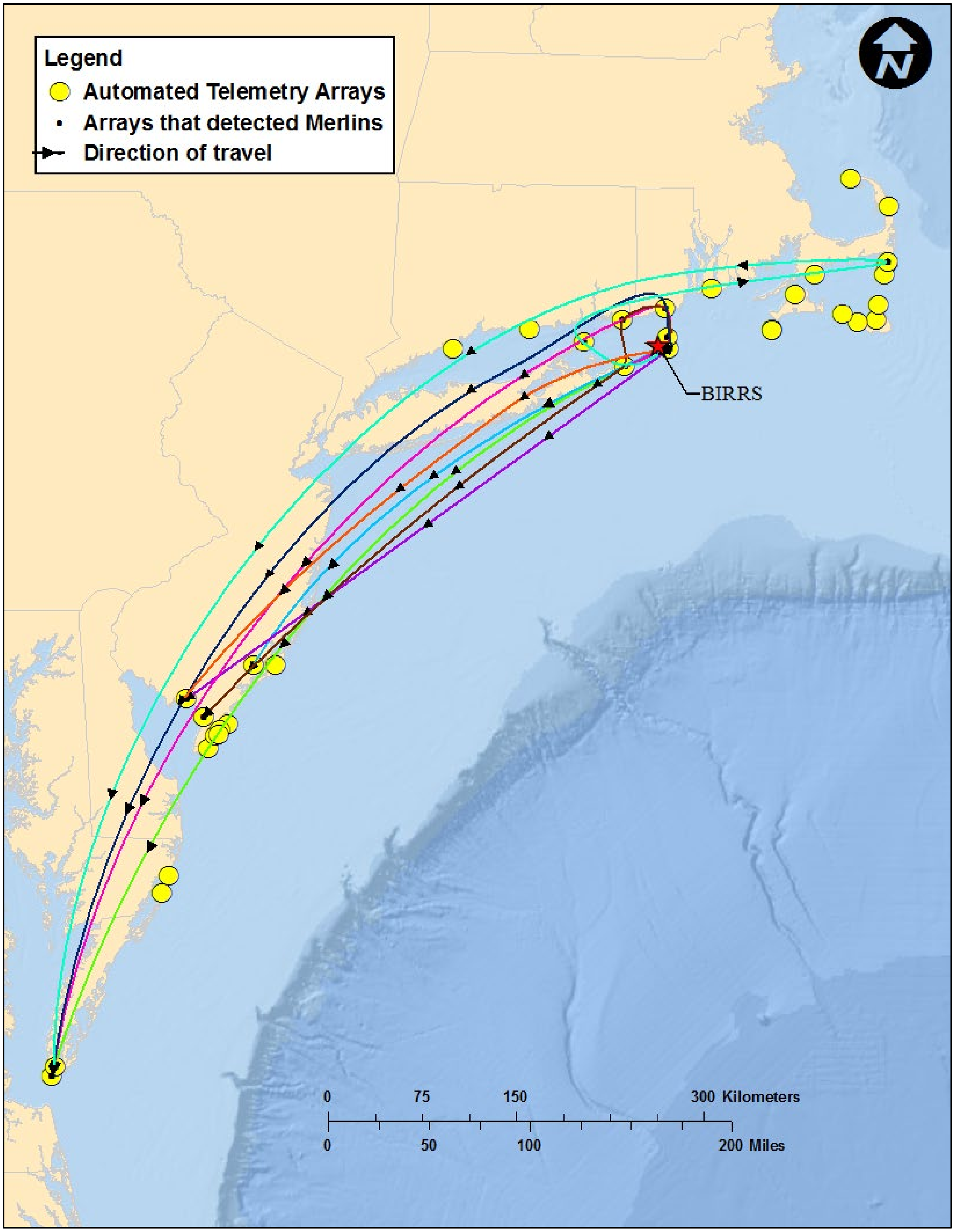

Figure A-3. Southward Movements of eight (of 30) Merlins fitted with digitally encoded VHF tags at BIRRS in 2015, as indicated by detections at automated telemetry arrays along the Atlantic coast.

Merlins fitted with NanoTags in this study provided rare perspectives on Merlin travel rates and information on the direction of departure of Merlins from Block Island. Average travel times between Block Island and detections at telemetry arrays in New Jersey and Virginia were 5.6 and 7.6 days or 64.2 km/day and 76.3 km/day, respectively. Detection patterns suggested that the majority of Merlins leave Block Island to the south or southwest (Figure A-3); however, north and northeast departures were also evident. Gaps in automated telemetry array coverage in the northwestern quadrant of the island may have resulted in northwestern departures that were undetected. Further analyses is required to understand stopover patterns of migrant Merlins on Block Island and elsewhere.

Overall, broad-scale migration patterns of Merlins are poorly studied to date. Merlins commonly follow the Atlantic coastline, but lacking detections of individuals at some key telemetry arrays is suggestive of variable use of coastal and offshore habitats during migration. These findings are consistent with those indicated by satellite telemetry, which verify use of offshore habitats by migrant Merlins. The relatively large sample size of Merlins studied with NanoTags in this study allowed characterization of different migratory strategies that are otherwise poorly documented by other approaches such as banding, and costly to document using satellite telemetry.

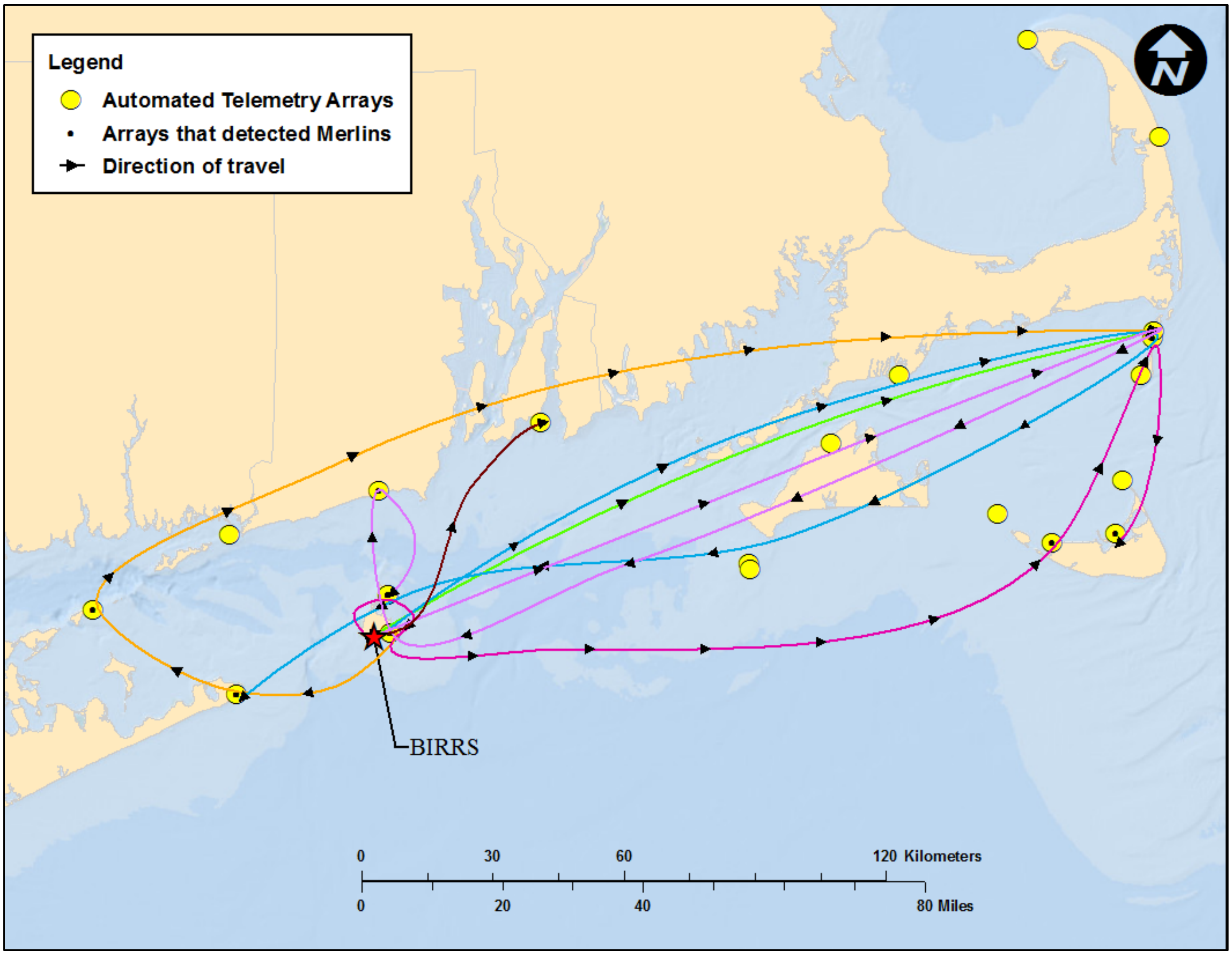

Figure A-4. Easterly Merlin movements detected by automated telemetry arrays during fall 2015. These six Merlins were not detected by arrays other than those displayed above.

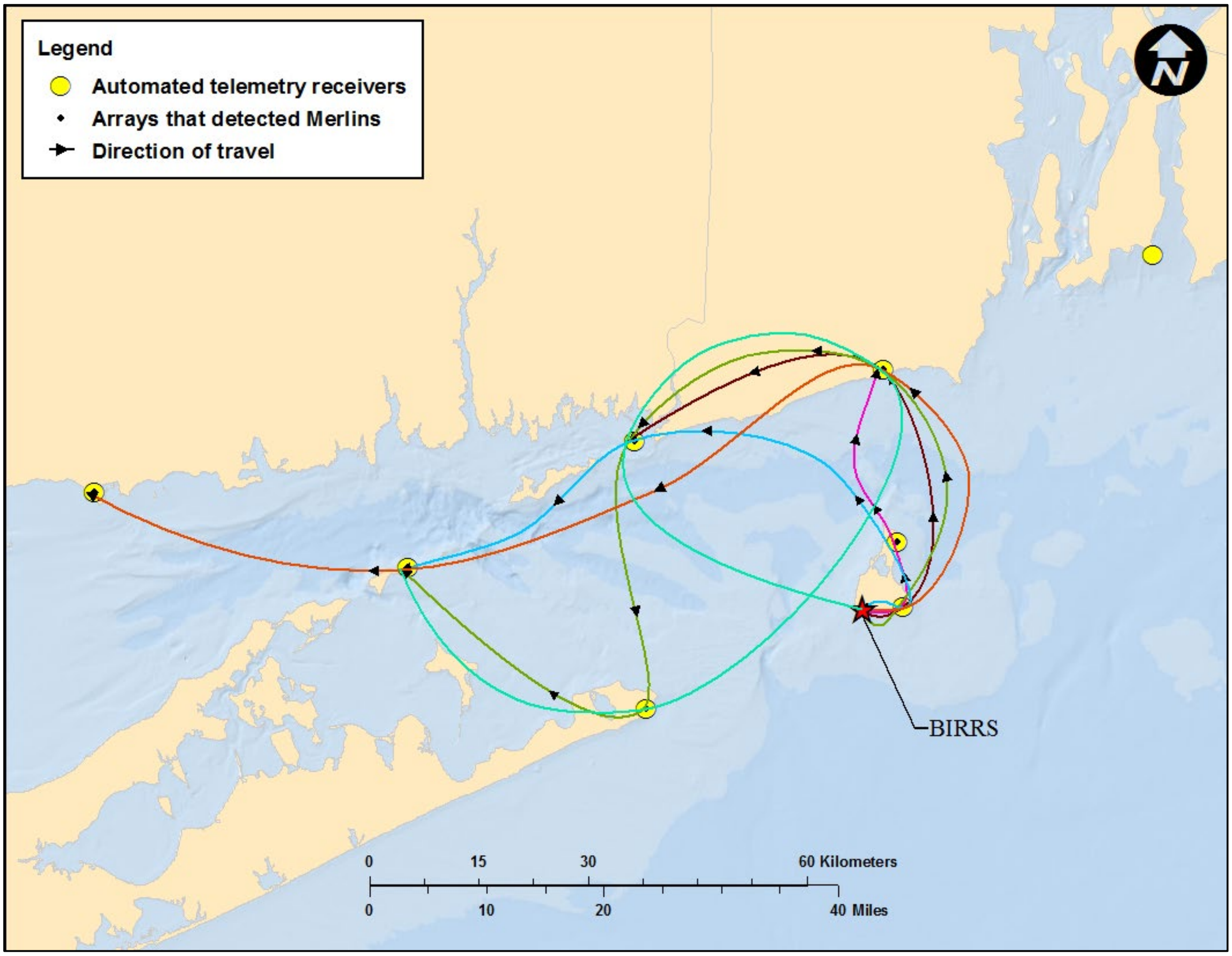

Figure A-5. Westerly movements of Merlins detected by automated telemetry arrays during fall 2015. These six Merlins were not detected at arrays other than those displayed above.

Appendix B. Wintering Areas and Last Transmission Areas for Peregrine Falcons and Merlins.

Table B-1. Wintering areas for 33 fall migrant Peregrine Falcons tracked from Block Island, RI (n = 25; 2012–2019), Monhegan Island (n = 2; 2010), and Cutler, Maine (n = 4, 2020) using tracking devices.

	Number of Individuals				
Wintering Area[a]	**Male**	**Female**	**Both**	**% (Both)**	**Note**
Bahamas / Turks and Caicos Is.	0	3	3	9.1	b
Cuba / Jamaica	0	5	5	15.2	c
D.R. / P.R. / Haiti / British Virgin Islands	2	2	4	12.1	d
Central America	4	3	7	21.2	e
South America - N. of Equator	4	3	7	21.2	f
South America - S. of Equator	3	1	4	12.1	g
Florida	0	2	2	6.1	h
Rhode Island	0	1	1	3.0	i
Total	**13**	**20**	**33**	**100.0**	

Notes:

a. Wintering area described as the furthest south location where the bird spent multiple days in one area

b. HYF01 (Turks and Caicos), HYF02 (Crooked Island, Bahamas), HYF11 (Spanish Wells, Bahamas), HYM08 (Moss Town, Bahamas)

c. ADF01 (Jamaica), HYF04 (Cuba), HYF07 (Cuba), HYF09 (went to the Dominican Republic, then back to Cuba), HYF14 (Cuba)

d. HYF06 (Dominican Republic), HYF08 (Dominican Republic), HYM07 (Spanish Town, British Virgin Islands), HYM10 (Haiti)

e. HYF03 (Honduras), HYF18 (Panama), HYF23 (Nicaragua), HYM03 (Nicaragua), HYM04 (Isla de San Andres), HYM17 (Panama), HYM23 (Mexico)

f. HYF05 (Columbia), HYF19 (Columbia), HYF24 (Columbia), HYM01 (Columbia), HYM06 (Venezuela), HYM14 (Guyana), HYM21 (Venezuela)

g. ADF03 (Brazil), HYM12 (Argentina), HYM13 (Bolivia), HYM26 (Brazil)

h. HYF15 (South East FL), HYF22 (Central FL)

i. ADF02 (Wintered on Block Island)

Table B-2. Last known locations of Peregrine Falcons fitted with tracking devices with presumed incomplete fall migration paths (2012–2020).

	Number of Individuals				
Last Transmition Area[a]	**Male**	**Female**	**Both**	**% (Both)**	**Note**
Rhode Island	0	1	1	5.0	b
Massachusetts	1	0	1	5.0	c
New York	1	1	2	10.0	d
New Jersey	1	0	1	5.0	e
Maryland	0	1	1	5.0	f
Virginia	1	0	1	5.0	g
North Carolina	2	0	2	10.0	h
South Carolina	2	1	3	15.0	i
Georgia	2	0	2	10.0	j
Florida	0	2	2	10.0	k
Bermuda	0	1	1	5.0	l
Bahamas	1	0	1	5.0	m
Cayman Islands	1	0	1	5.0	n
S America	1	0	1	5.0	o
Total	**13**	**7**	**20**	**100**	

Notes:

a. Areas in which transmitters fitted to Peregrine Falcons last transmitted during migration.
b. HYF16 (South Kingstown)
c. HYM22 (Southern Cape Cod)
d. HYM11 (Eastern Long Island), HYF21 (Long Island)
e. HYM19 (Recovered in NJ and sent to rehab)
f. HYF20 (Delmarva Peninsula)
g. HYM05 (Presumed mortality, transmitter recovered under eagle nest)
h. HYM02 (Ship Rider, offshore from NC), HYM16 (Offshore from Wilmington)
i. HYF13 (Parris Island), HYM09 (Charleston), HYM18 (Charleston)
j. HYM15 (Blackbeard Island), HYM25 (St. Catherine's Island)
k. HYF10 (Cocoa), HYF12 (found emaciated in Titusville); both stopped transmitting in Cape Canaveral
l. HYF17 (east of Bermuda)
m. HYM08 (Exuma Island)
n. HYM24 (SW of Cayman Islands over water)
o. HYM20 (Bolivia)

Table B-3. Wintering and last transmission areas for female Merlins tracked from Block Island, RI and Cutler, ME 2014–2019.

Complete Migration[a]	Number of Individuals				
Wintering Area[b]	Adult	HY	Both	% (Both)	Note
Puerto Rico	1	0	1	8	d
Cuba	2	3	5	42	e
Virginia	0	1	1	8	f
North Carolina	0	1	1	8	g
New England	0	2	2	17	h
Delmarva Peninsula	0	2	2	17	i
Total Complete Migration	3	9	12	100	

Incomplete Migration[c]	Adult	HY	Both	% (Both)	Note
Last Transmission Area					
Rhode Island	0	2	2	40	j
Long Island	0	1	1	20	k
Florida	0	2	2	40	l
Total Incomplete Migration	0	5	5	100	

Notes:

a. Complete migration defined as bird reaching wintering area.
b. Wintering area described as the furthest south location where the bird spent multiple days in one area.
c. Incomplete migration described as bird not reaching wintering area.
d. ADF01
e. ADF02, ADF03, HYF07, HYF09, HYF14
f. HYF04 (Great Dismal Swamp)
g. HYF08 (South Pamlico Sound)
h. HYF06 (Stonington, CT), HYF11 (Conanicut Island, RI)
i. HYF12 (Salisbury, MD), HYF13 (New Castle, DE)
j. HYF02, HYF10 (Block Island, RI)
k. HYF05 (South of Long Island, NY)
l. HYF01 (Biscayne Bay, FL), HYF03 (Miami, FL)

Appendix C. Dates Used in Winter Home Range Estimates

Table C-1. Dates used to delineate wintering range for 12 Peregrine Falcons and three Merlins fitted with satellite transmitters 2012 - 2018.

Animal ID	1st Winter Start	1st Winter Stop	2nd Winter Start	2nd Winter Stop	3rd Winter Start	3rd Winter Stop
ML_ADF02	11/1/2018	4/22/2019				
ML_HYF08	10/19/2017	5/2/2018				
ML_HYF12	10/23/2018	4/7/2019				
PF_ADF01	11/2/2012	4/14/2013				
PF_ADF02	10/9/2013	5/12/2014				
PF_ADF03	12/30/2018	4/10/2019				
PF_HYF02	11/23/2012	4/23/2013				
PF_HYF07	11/6/2013	5/12/2014	10/23/2014	4/30/2015		
PF_HYF08	10/19/2013	5/4/2014				
PF_HYF14	10/24/2016	4/8/2017				
PF_HYF15	11/10/2016	4/29/2017	9/15/2017	4/12/2018	10/17/2018	4/16/2019
PF_HYM01	11/27/2012	4/28/2013				
PF_HYM10	11/6/2016	4/28/2017				
PF_HYM12	12/2/2016	4/4/2017	11/5/2017	4/25/2018		
PF_HYM14	11/22/2016	4/5/2017				