Offshore wind turbines; Dennis Schroeder, National Renewable Energy Lab (CC)

Using shorebird tracking data to support a risk assessment related to offshore wind development in Atlantic Canada

Conservation Contribution #10

Conservation Action: Land/Water Protection

Smithsonian Migratory Bird Center

Environment and Climate Change Canada

Prepared by the Shorebird Science & Conservation Collective:
Candace Stenzel, Allie Anderson, Autumn-Lynn Harrison

March 2024

Table of Contents

Project Background

Conservation Request

The Canadian Wildlife Service (CWS) requested shorebird tracking data from the Shorebird Science and Conservation Collective (hereafter, "Shorebird Collective") to support a risk mapping exercise related to offshore wind development in parts of Atlantic Canada near Nova Scotia, Newfoundland, and Labrador. (**Figure 1**). Specifically, CWS requested relevant data to understand the temporal and spatial distribution of shorebirds moving through the offshore environment within the regional assessment area of interest (AOI). The Shorebird Collective provide CWS with maps and analyses of shorebird tracking data to support this request (link to page with more information on tracking data).

About the Shorebird Science and Conservation Collective

The Shorebird Collective is a partnership of scientists and practitioners working to translate the collective findings of shorebird tracking and community science data into effective on-the-ground actions to advance shorebird conservation in the Western Hemisphere. Learn more on our webpage: link to the Shorebird Collective webpage.

About the Canadian Wildlife Service

CWS is a branch of Environment and Climate Change Canada (ECCC) and serves as Canada's national wildlife agency. CWS is responsible for the conservation of migratory birds, species at risk, and biodiversity. Learn more on ECCC's website: link to the CWS webpage.

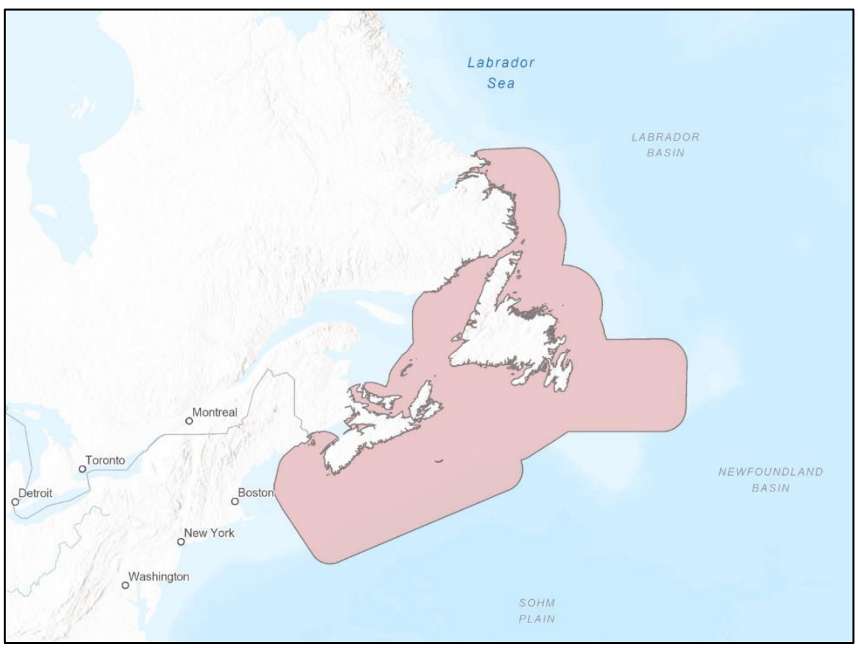
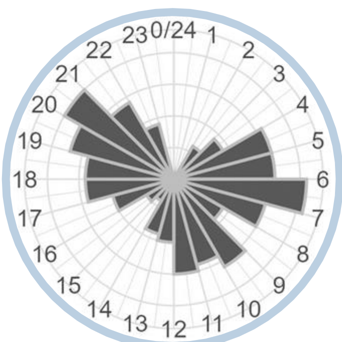


Figure 1. CWS's Atlantic Canada area of interest, which includes areas around the island of Newfoundland, Gulf of Saint Lawrence, New Brunswick, Prince Edward Island, Nova Scotia, and Gulf of Maine.

Key Findings & Outputs

Below we summarize key outputs, findings, and recommendations provided to CWS to support their offshore wind risk mapping exercise:

1. The Shorebird Collective provided CWS with maps and analyses of shorebird tracking data to support a risk mapping exercise related to offshore wind development in parts of Atlantic Canada. In a full report to CWS and with permission of data owners, we provided maps of electronically tracked shorebirds with tag transmissions in their AOI with additional information noting areas where multiple individuals and species congregated. **102 individuals** of **eight species** were estimated to have moved through the offshore AOI. **41** individuals of **eight** species had tag transmissions in the AOI, while **61** additional individuals from **seven** of the eight species had estimated tracklines in the AOI.



2. In addition to the tracking maps, the Shorebird Collective produced a series of tables and graphs detailing 1) sample sizes and proportions of individuals tracked in the AOI based on the total number of higher resolution satellite tracks contributed to the Collective, 2) breeding and wintering locations for each bird, 3) seasonal migration timing, and 4) timing of tag transmissions.

3. Additional information may become available as data contributors continue to share new tracking data with the Shorebird Collective. We invited CWS to periodically check in with the Shorebird Collective on the availability of new data to support any future risk mapping exercises related to offshore wind development.

Images: 1. Estimated movement paths for tracked shorebirds in CWS' area of interest. **2.** Histogram of time of day of tag transmissions from shorebirds that occurred over CWS' AOI; **3.** Red Knot (*Calidris canutus*) with 3.4-gram GPS tag, Tim Romano, Smithsonian

Methods

The Shorebird Collective filtered contributed GPS and Argos satellite tracking data to remove false detections and determined the most likely movement path of each bird using mathematical models that account for spatial uncertainty of locations recorded by tracking devices. We then overlayed the cleaned shorebird tracks on a map of CWS' area of interest (AOI). When a tracked shorebird was either 1) tracked within the AOI, or 2) had tag transmissions outside of the AOI but with tracklines estimated through the AOI (i.e., "interpolated tracklines"), we contacted the data owner to receive permission to share maps and details about the bird with CWS. In a full report to CWS, we provided maps of tracked shorebird movements () and summary analyses for species and individuals tracked in CWS' AOI (**Figure 3**).

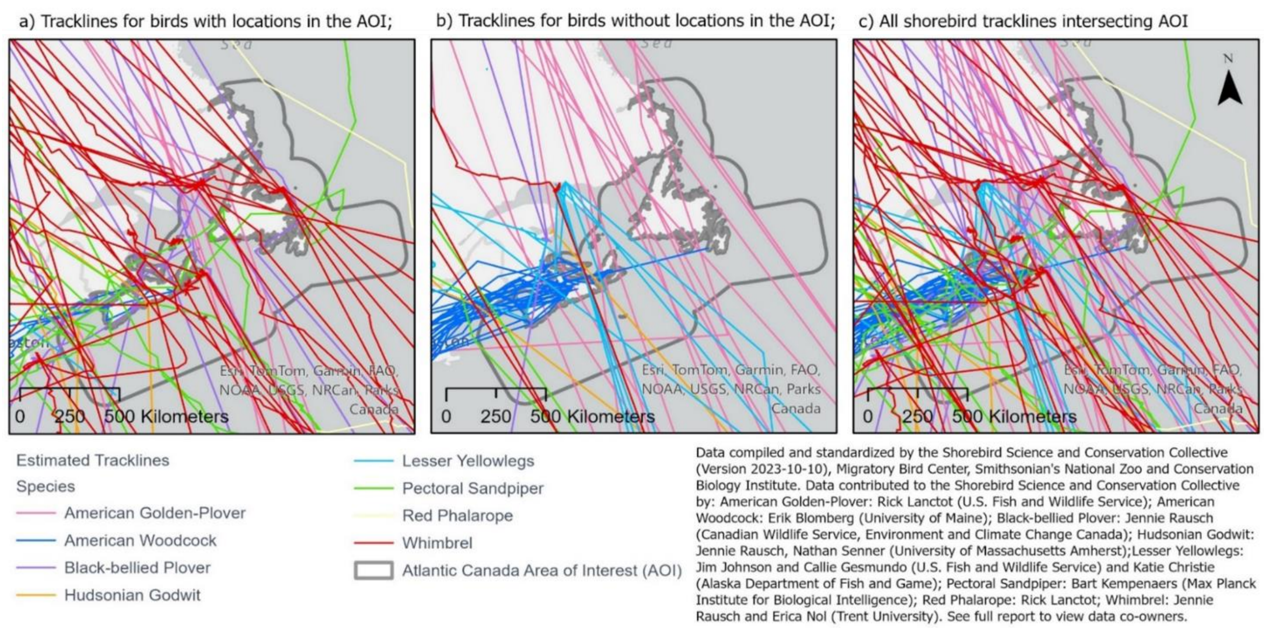


Figure 2. Estimated movement paths (tracklines) for tracked shorebirds in CWS' AOI. Panels include **a)** tracklines of individual birds with tag transmissions in the AOI (*n* = 41), **b)** additional tracklines estimated through the AOI where all tag transmissions were outside the AOI (*n* = 61), and **c)** all tracklines combined (n = 102).

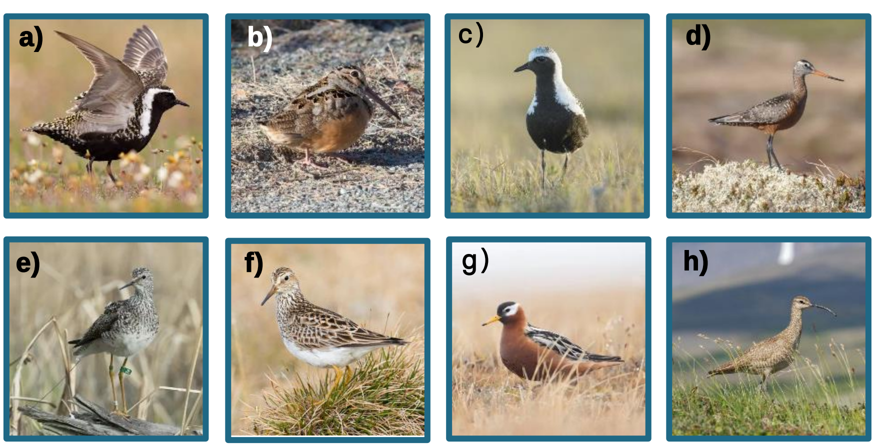


Figure 3. Species detected in CWS's AOI: **a)** American Golden-Plover, USFWS (CC); **b)** American Woodcock, Keith Ramos, USFWS (CC); **c)** Black-bellied Plover, Ryan Askren, USGS/ Smithsonian; **d)** Hudsonian Godwit, Kristine Sowl, USFWS (CC); **e)** Lesser Yellowlegs, Zak Pohlen, USFWS (CC); **f)** Pectoral Sandpiper, Lisa Hupp, USFWS (CC); **g)** Red Phalarope, Peter Pearsall, USFWS (CC), **h)** Whimbrel, Rachel Richardson, USGS Alaska Science Center (CC)

Shorebirds Tracked in Area of Interest

Of the shorebirds tracked by GPS and Argos satellite technologies and contributed to the Shorebird Collective[1] (**Box 1**), **102** individuals of **eight** species migrated through the offshore waters of CWS' Atlantic Canada AOI between 2010 and 2022 (after accounting for spatial error associated with the tracking technologies, **Table 1**).

Shorebird migration through the AOI was estimated in two ways: 1) tags transmitted a location from within the AOI (**41** individuals of **eight** species, shared in Phase I), or 2) a movement path (i.e., trackline) was estimated to have crossed through the AOI by connecting estimated positions of a tag (i.e., locations) outside the AOI with a pathway (**61** additional individuals from **seven** of the eight species). This includes, for example, tracklines that connected a tag transmission north of the AOI with a tag transmission south of the AOI.

Box 1. Summary of shorebird tracks in Atlantic Canada AOI

1,678 individuals of **21** species contributed to the Shorebird Collective

102 individuals of **8 species** estimated to have moved through the AOI:

- **41** individuals of **8** species with tag transmissions in the AOI
- **61** additional individuals from 7 of the 8 species with **estimated tracklines** in the AOI

Tag transmissions in the AOI ranged from a single observation during a flyover to multiple locations along the coastline during stopovers in the fall and spring on migration (**, Figure 4**-**Figure 19**). In a report to CWS, we provided maps of all tracklines estimated to have crossed the AOI (**, Figure 4**-**Figure 8**), in addition to maps for each species tracked across seasons (**Figure 9**-**Figure 19**).

Data from geolocators (tracking devices with lower spatial accuracy) and Motus data were not included in this report and will be incorporated into the Shorebird Collective Dataset at a later date. See **page 27** for more information on different data types available for tracking shorebirds. Additional information may become available as data contributors continue to share new tracking data with the Shorebird Collective. We invited CWS to periodically check in with the Shorebird Collective on the availability of new data to support any future risk mapping exercises related to offshore wind development.

Table 1. Number of individual tracked shorebirds contributed to the Shorebird Collective with estimated movements in CWS' AOI.

Common & Scientific Name	Individuals w/ Tag Transmissions in AOI	Additional Birds w/ Tracklines Intersecting AOI	Total w/ Tracklines Intersecting AOI
American Golden-Plover (*Pluvialis dominica*)	6	17	23
American Woodcock (*Scolopax minor*)	3	25	28
Black-bellied Plover (*Pluvialis squatarola*)	9	1	10
Hudsonian Godwit (*Limosa haemastica*)	2	2	4
Lesser Yellowlegs (*Tringa flavipes*)	1	11	12
Pectoral Sandpiper (*Calidris melanotos*)	7	2	9
Red Phalarope (*Phalaropus fulicarius*)	1	0	1
Whimbrel (*Numenius phaeopus*)	12	3	15
TOTAL	41	61	102

[1] These data come from 74 organizations, collected from 2006 to 2023 (Shorebird Collective Data Version 2023-10-10).

Notable Areas in Area of Interest

Here we summarized the number of shorebird species (**Figure 4a**) and individuals (**Figure 4b**) with tracked locations within 200 km of CWS' AOI to show areas used by multiple tracked birds. Coastlines along the Gulf of Maine, Cape Cod, Massachusetts, and Mingan Archipelago, Quebec showed higher numbers of tracked individuals and species. We also used trackline maps to highlight locations in the AOI where actual tag transmissions for multiple individuals (*n* = 41) and species (*n* = 8) congregated (**Figure 5**). CWS could consider these areas for further investigation as these data may represent the flight paths of and/or locations used by additional shorebirds not tracked with tracking devices.

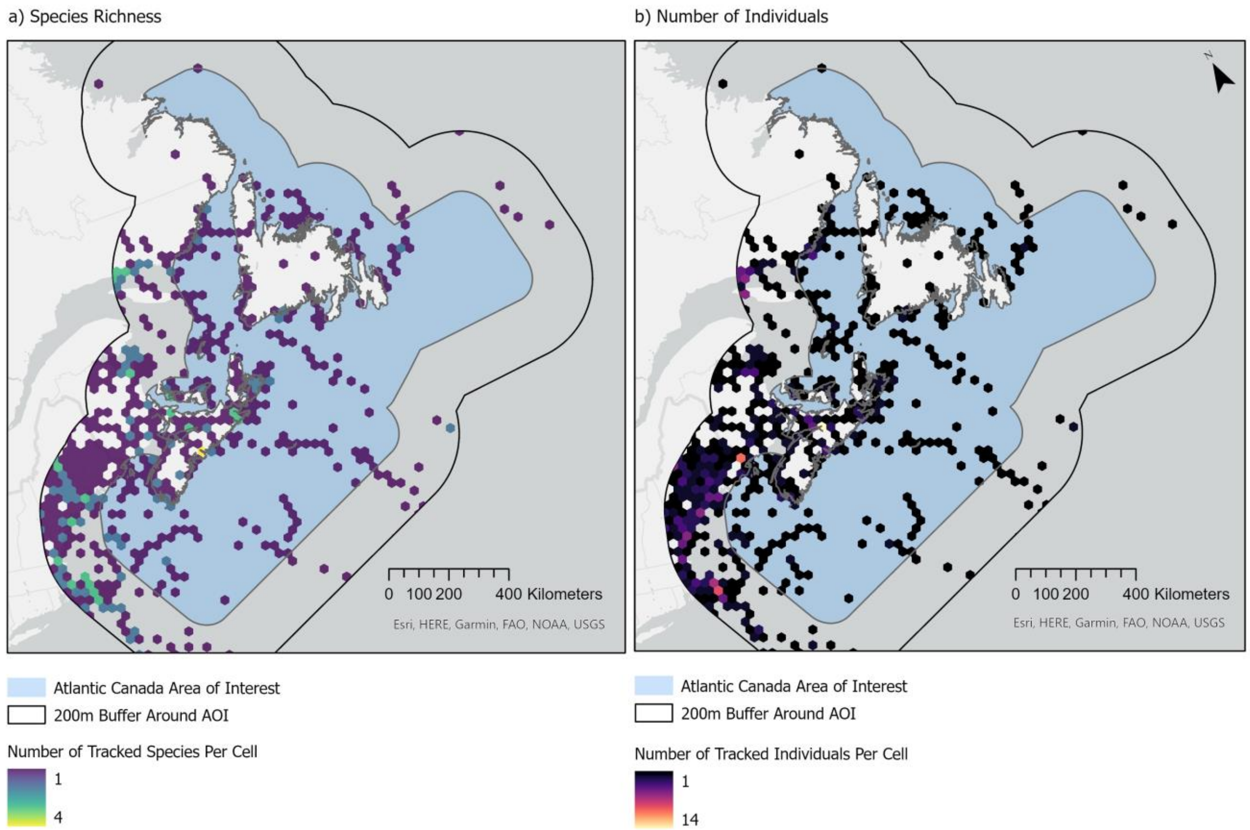


Figure 4. Density of tracked **a)** species and **b)** individual shorebirds contributed to the Shorebird Collective within 200 km of CWS' AOI. Each cell is a 30km hexagon and counts per cell are summed from the number of species or individuals with an estimated location in the cell at the original sampling interval of the tag.

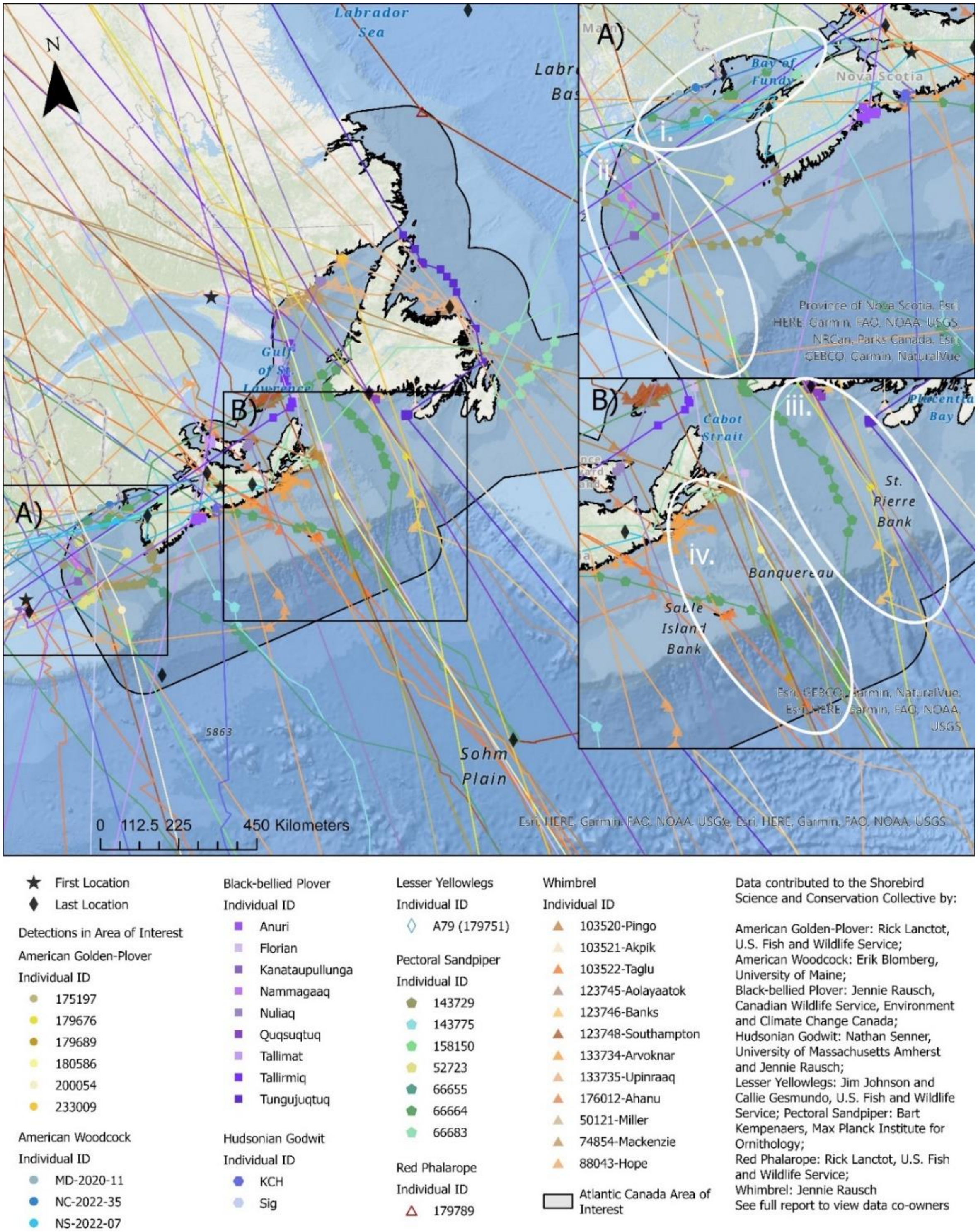
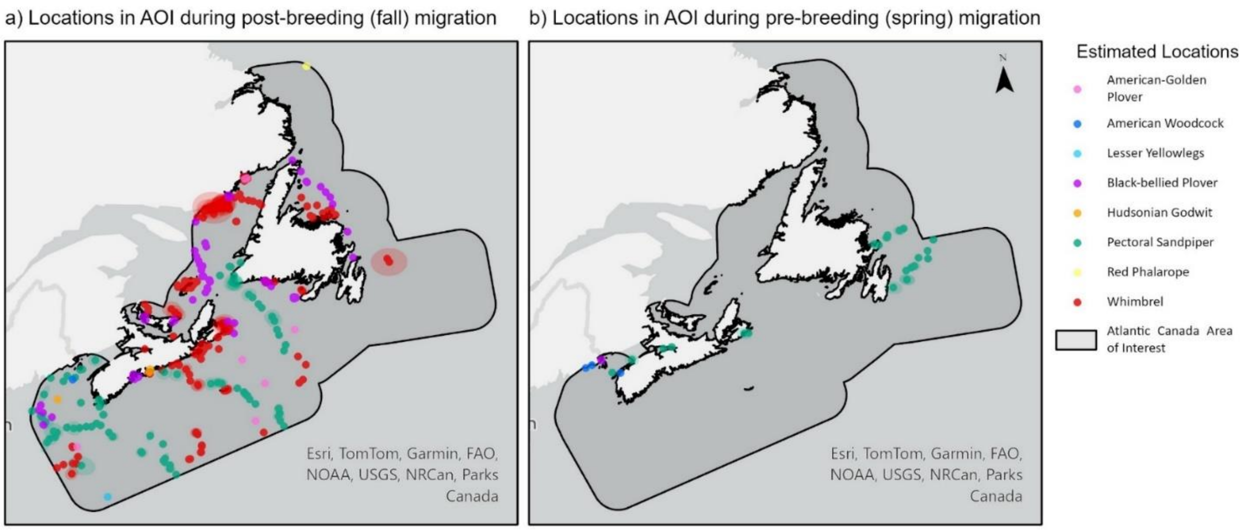


Figure 5. An example of tracked shorebirds with tag transmissions in CWS's AOI (n = 41). Highlighted are two broad areas where tracklines converged for multiple species and individuals: **A)** the southwestern portion of the AOI and **B)** the central portion of the AOI. Within area A, tracklines converge in the **i)** Bay of Fundy region and **ii)** Gulf of Maine. In area B, tracklines converge in the **iii)** Laurentian Channel to St. Pierre Bank and **iv)** between Sable Island Bank and Banquereau. Note that this is a summary of shorebird detections across multiple years and does not necessarily reflect the birds co-occurring in the area at the same time.

Tracked Locations with Spatial Error in AOI

When considering space use of shorebirds in the AOI, estimated locations are more valuable than movement paths that are interpolated between transmissions. Here we show tracked locations with estimates of spatial error to show confidence in the position of locations in the AOI (**Figure 6**). Spatial error depends on the type of tracking technology used: GPS data have high accuracy (typically within 10-15 m [Noonan et al. 2019] but sometimes up to 100 m [CLS 2016]), whereas Argos data have moderate accuracy (typically within 250-1500 m [CLS 2016] but sometimes individual locations can have error larger than 25 km [Jonsen et al. 2020]). We used statistical models to estimate spatial error around locations (Jonsen et al. 2023). **Figure 6** shows all locations in the AOI and 95% percent confidence ellipses for birds tracked with Argos or tags that collect both Argos and GPS data. Note that error ellipses are not visible for GPS locations and high-accuracy Argos locations because of their low spatial error.



Data compiled and standardized by the Shorebird Science and Conservation Collective (Version 2023-10-10), Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute. Data contributed to the Shorebird Science and Conservation Collective by: American Golden-Plover: Rick Lanctot, U.S. Fish and Wildlife Service; American Woodcock: Erik Blomberg, University of Maine; Black-bellied Plover: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada; Hudsonian Godwit: Nathan Senner, University of Massachusetts Amherst and Jennie Rausch; Lesser Yellowlegs: Jim Johnson and Callie Gesmundo, U.S. Fish and Wildlife Service; Pectoral Sandpiper: Bart Kempenaers, Department of Ornithology, Max Planck Institute for Biological Intelligence; Red Phalarope: Rick Lanctot, U.S. Fish and Wildlife Service; Whimbrel: Jennie Rausch. See full report for list of data co-owners.

Figure 6. Locations of tracked Shorebirds in CWS' AOI during **a)** post-breeding (fall) and **b)** pre-breeding (spring) migration. Transparent polygons surrounding point locations indicate 95% confidence ellipses.

Temporal Distribution

To inform CWS about the temporal distribution of tracked shorebirds within their AOI, we created seasonal migration maps for tracked individuals with actual tag transmissions (n = 41) in the AOI during fall and spring migration (**Figure 7**-**Figure 8**).

Post-breeding (Fall, Southward) Migration

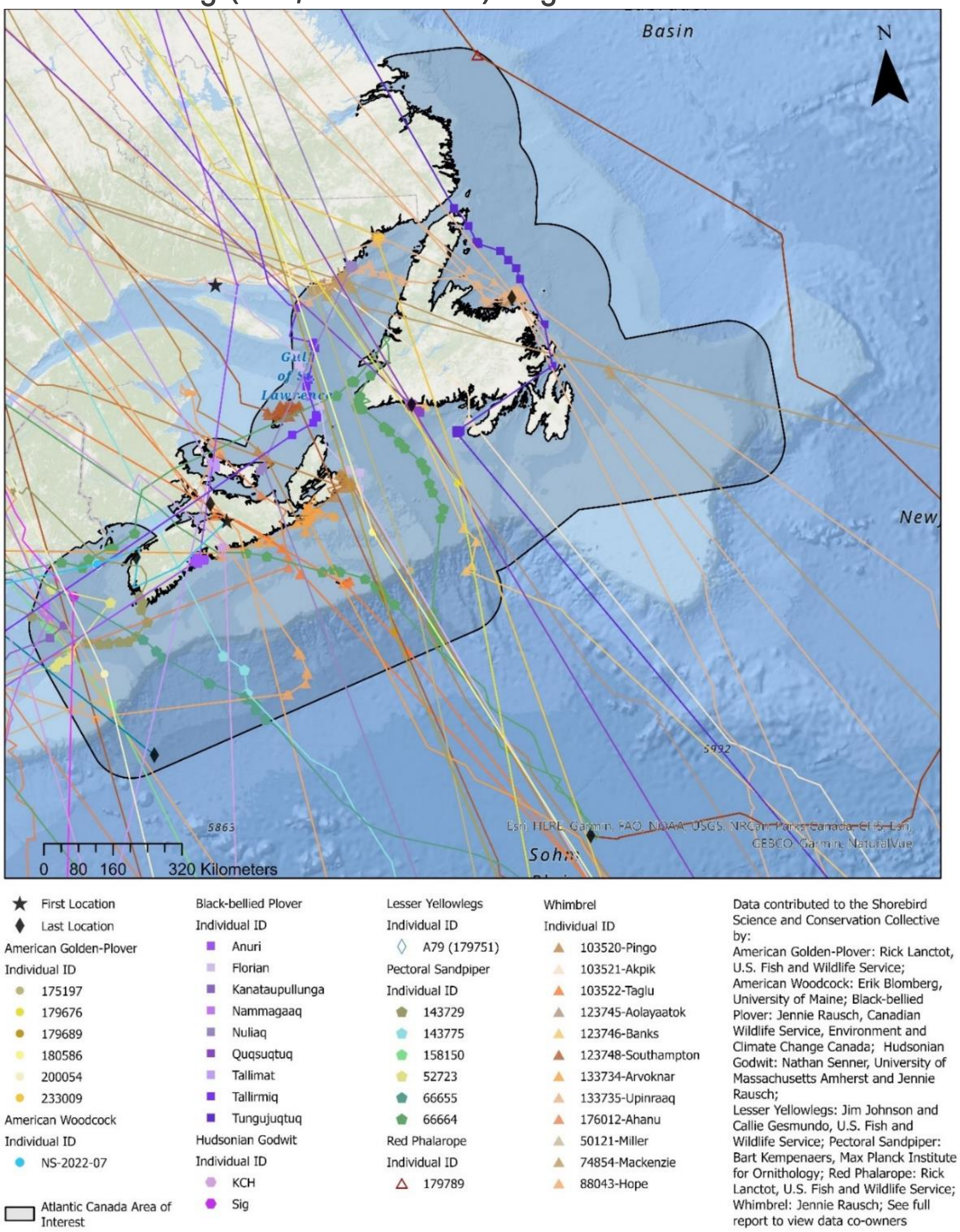
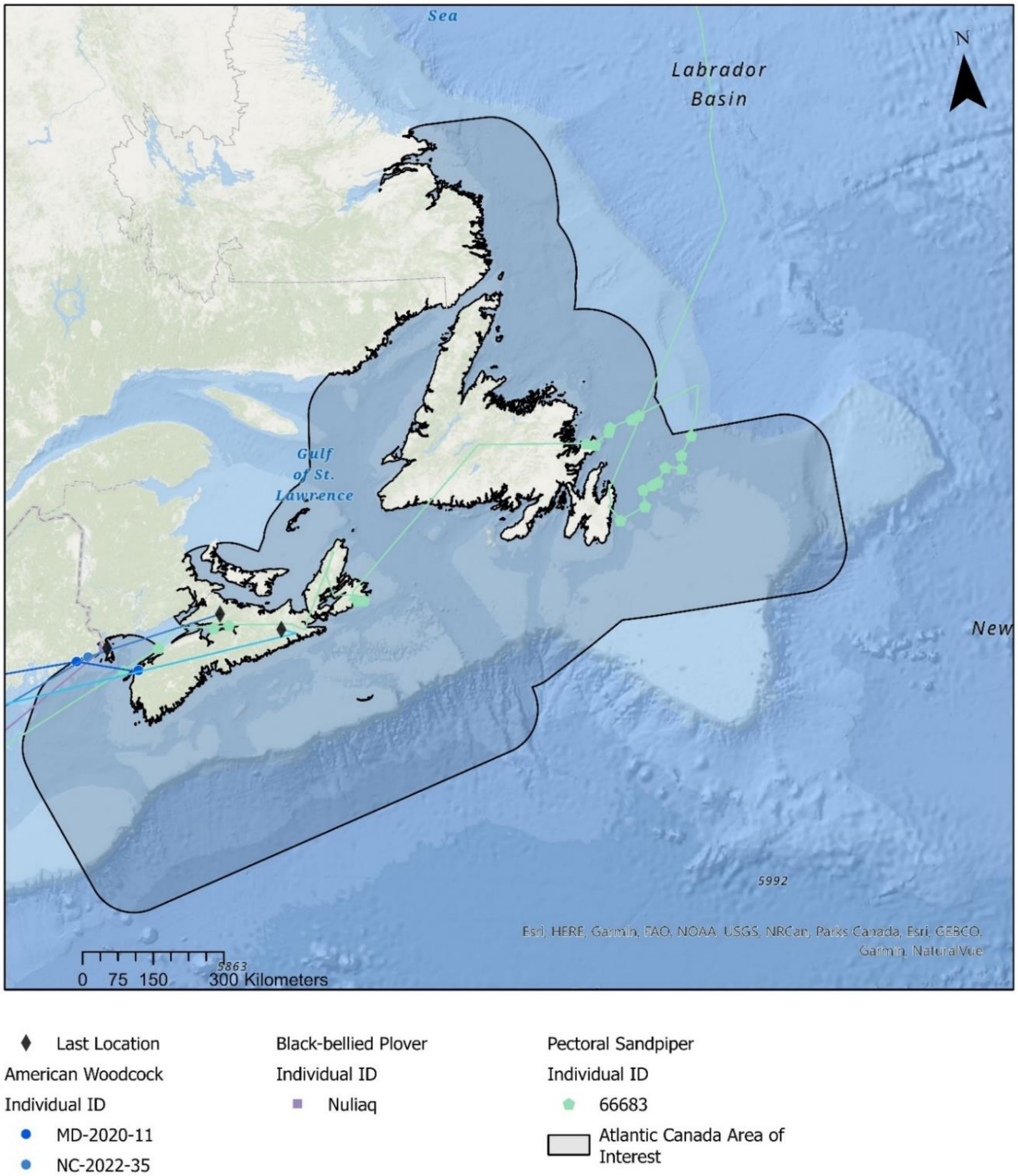


Figure 7. Tracked shorebirds with tag transmissions in CWS's AOI during post-breeding migration in the fall. This includes 38 individuals of eight species.

Pre-breeding (Spring, Northward) Migration



Data contributed to the Shorebird Science and Conservation Collective by:
American Woodcock: Erik Blomberg, University of Maine. Data co-owners include: Liam Berigan, Alexander Fish, and Amber Roth of the University of Maine.

Black-bellied Plover: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada. Data co-owned by: Paul Woodard (Canadian Wildlife Service, Environment and Climate Change Canada).

Pectoral Sandpiper: Bart Kempenaers, Max Planck Institute for Ornithology. Data co-owned by: Mihai Valcu (Max Planck Institute for Ornithology).

Figure 8. Tracked shorebirds with tag transmissions in CWS's AOI during pre-breeding migration in the spring. This includes four individuals of three species.

Species-specific Maps & Summary Information

For the individual shorebirds tracked through the AOI, we also generated species-specific maps tracked across seasons with associated summary information. **Figure 9-Figure 19** provide example species maps provided to CWS.

American Golden-Plover

Post-breeding (Fall) Migration

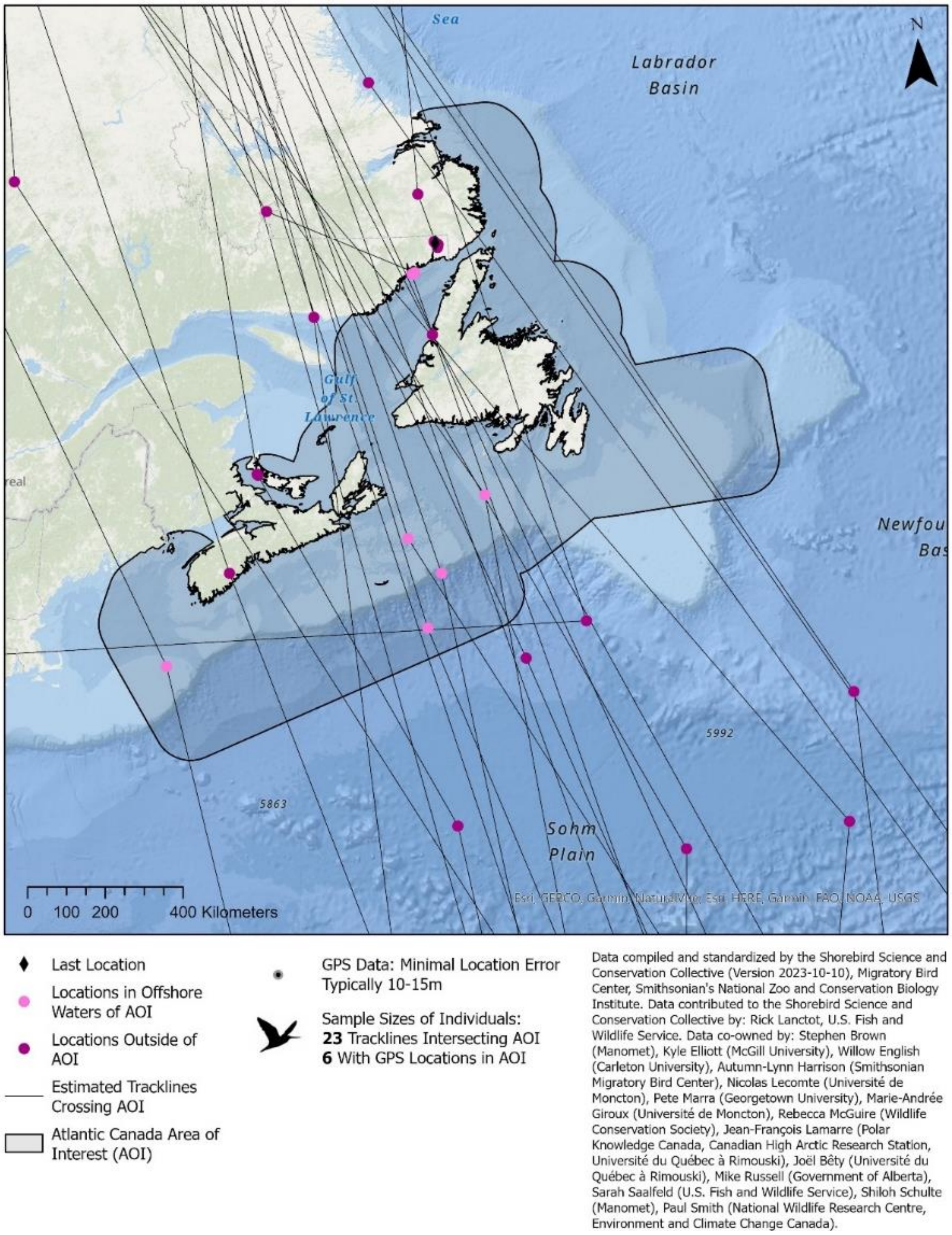
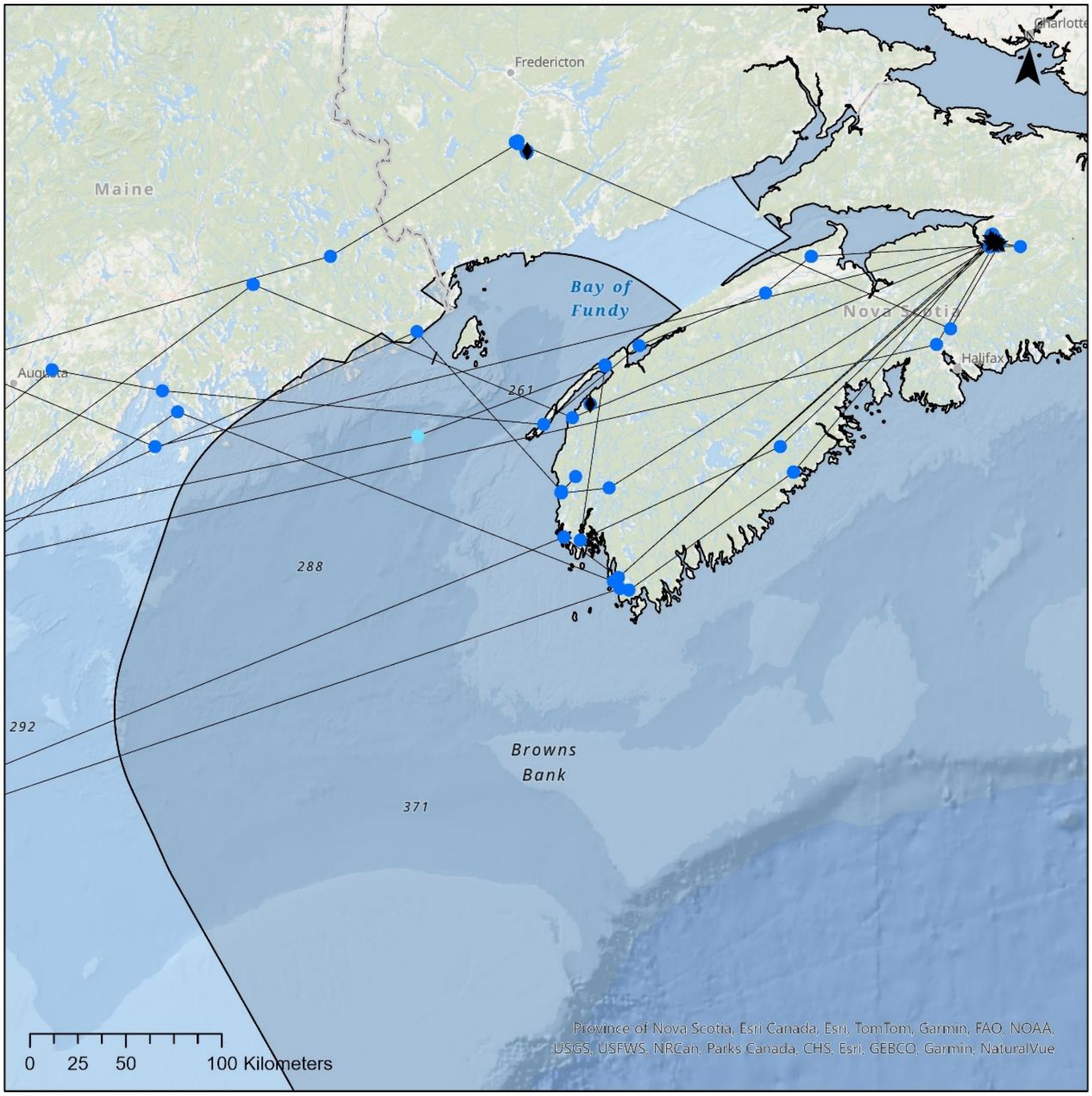


Figure 9. Tracked American Golden-Plovers ($n = 23$) with estimated movements in CWS' AOI during post-breeding (fall) migration. Six individuals had tag transmissions within the AOI, 17 additional birds had tracklines intersecting the AOI.

American Woodcock

Post-breeding (Fall) Migration



Last Location
First Location
Locations in Offshore Waters of AOI
Locations Outside of AOI
Estimated Tracklines Crossing AOI
Atlantic Canada Area of Interest

GPS Data: Minimal Location Error Typically 10-15m

Sample Sizes of Individuals:
10 Tracklines Intersecting AOI
1 With GPS Locations in AOI

Data compiled and standardized by the Shorebird Science and Conservation Collective (Version 2023-10-10), Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute. Data contributed to the Shorebird Science and Conservation Collective by: Erik Blomberg, University of Maine. Data co-owned by: Liam Berigan, Alexander Fish, and Amber Roth (University of Maine).

Figure 10. Tracked American Woodcock (*n* = 10) with estimated movements in CWS' AOI during post-breeding (fall) migration. One individual had tag transmissions within the AOI, 9 additional birds had a trackline intersecting the AOI.

Pre-breeding (Spring) Migration

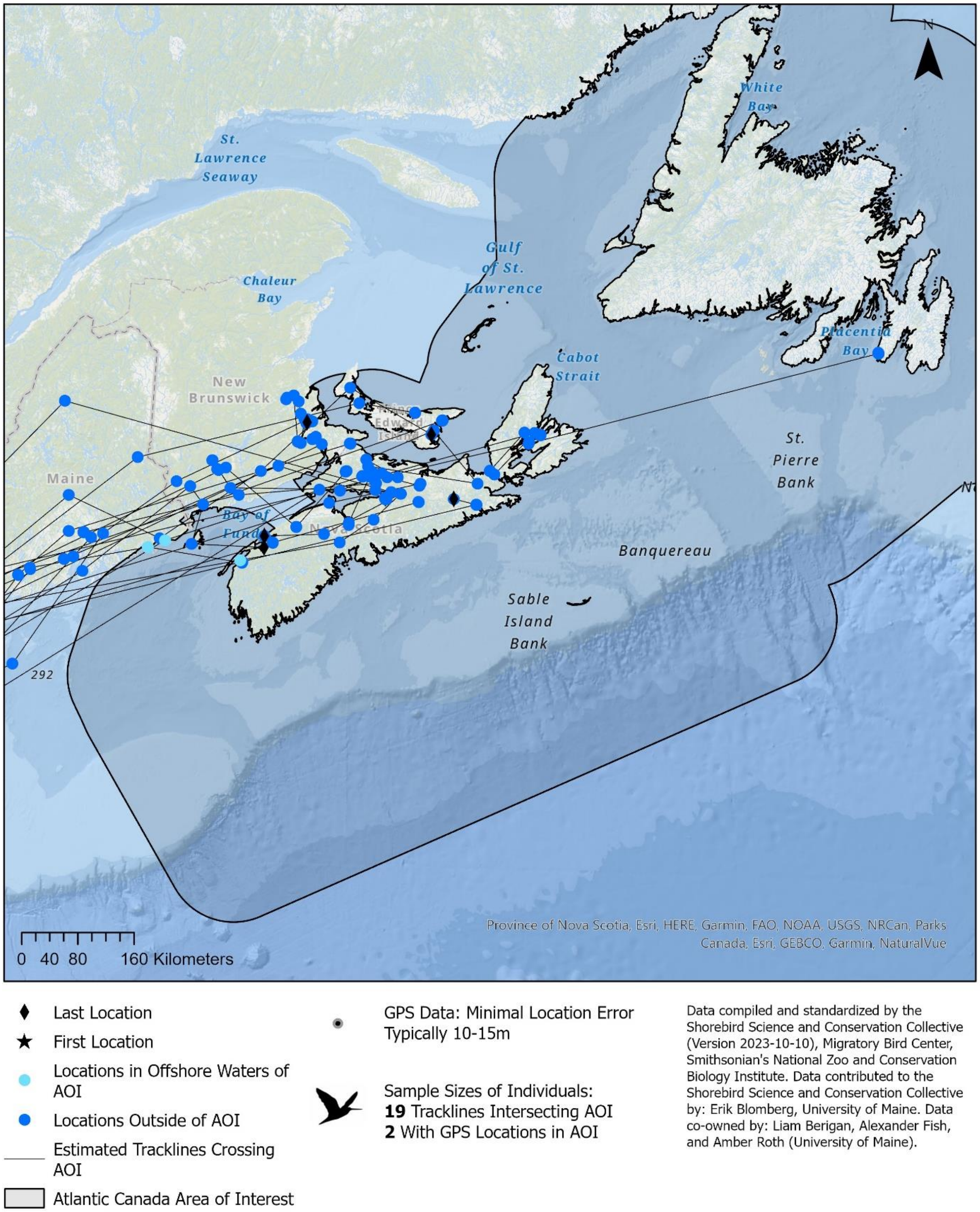


Figure 11. Tracked American Woodcock (*n* = 19) with estimated movements in CWS' AOI during pre-breeding (spring) migration. Two individuals had tag transmissions within the AOI, 17 additional birds had a trackline intersecting the AOI.

Black-bellied Plover

Post-breeding (Fall) Migration

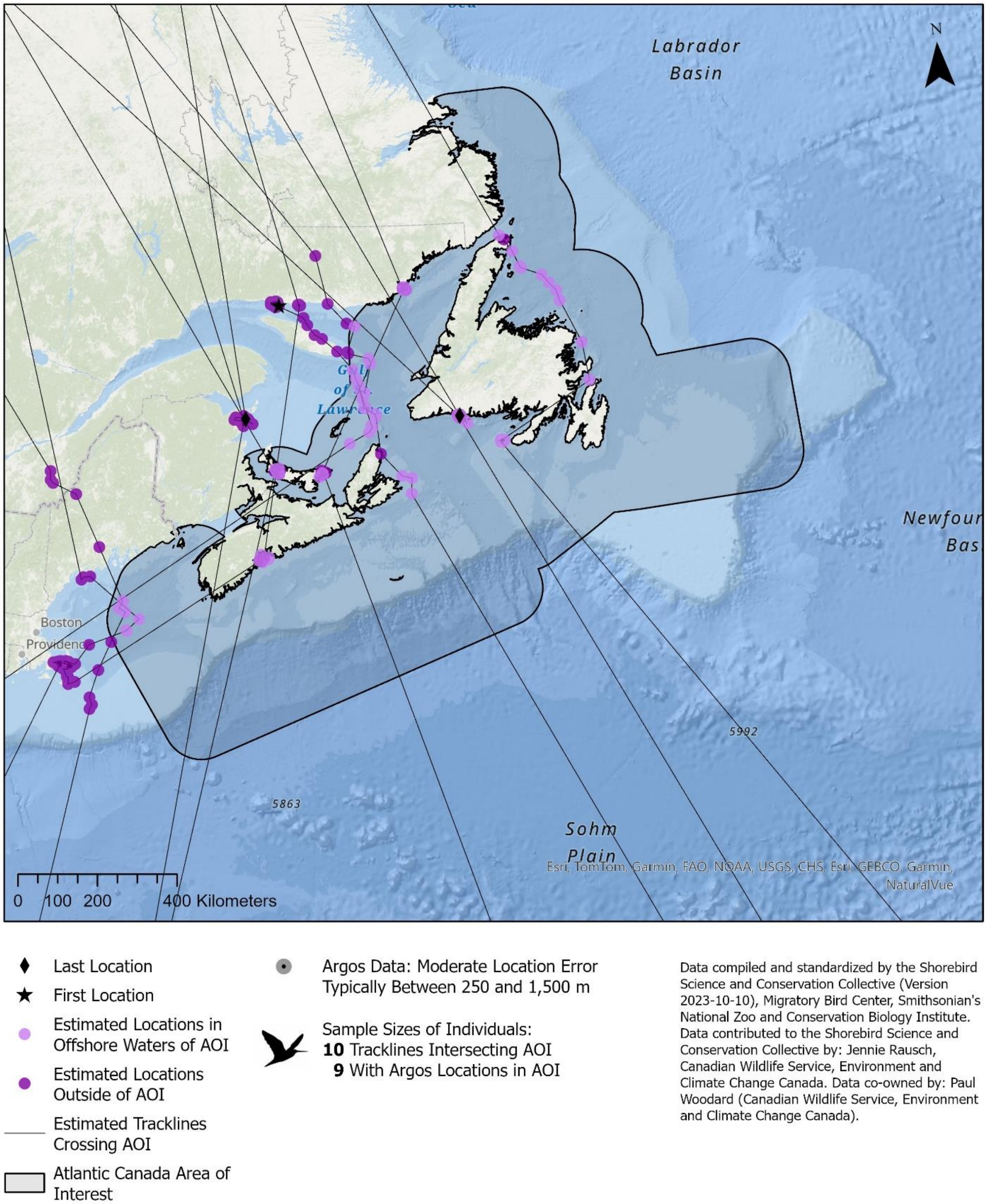


Figure 12. Tracked Black-bellied Plovers (*n* = 10) with estimated movements in CWS' AOI during post-breeding (fall) migration. Nine individuals had tag transmissions within the AOI, one additional bird had a trackline intersecting the AOI.

Pre-breeding (Spring) Migration

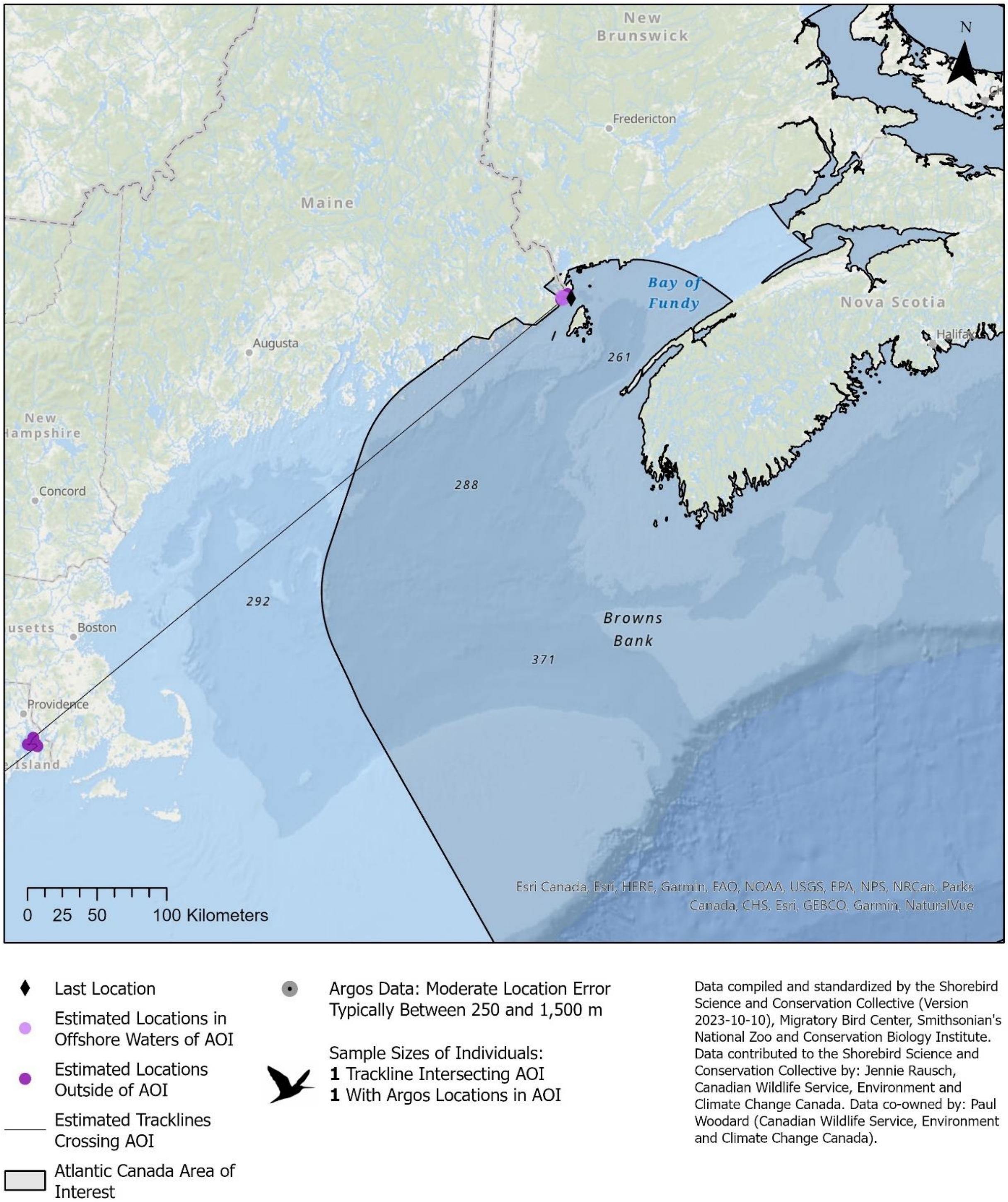
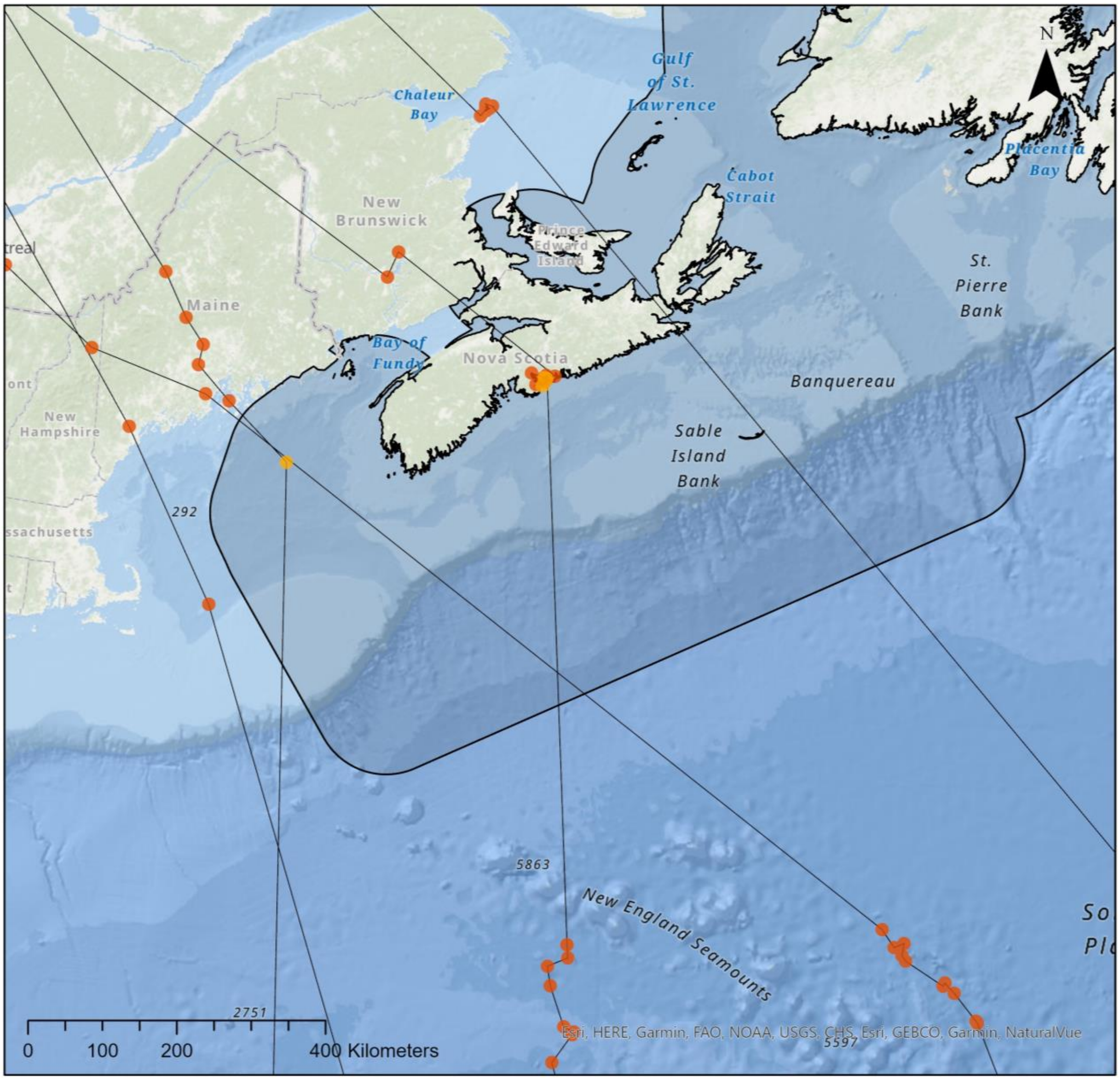


Figure 13. Tracked Black-bellied Plover ($n = 1$) with tag transmissions in CWS' AOI during pre-breeding (spring) migration.

Hudsonian Godwit

Federally Threatened Species in Canada

Post-breeding (Fall) Migration



Estimated Locations in Offshore Waters of AOI

Estimated Locations Outside of AOI

Estimated Tracklines Crossing AOI

Atlantic Canada Area of Interest

Argos Data: Moderate Location Error Typically Between 250 and 1,500 m

Sample Sizes of Individuals:
4 Tracklines Intersecting AOI
2 With Argos Locations in AOI

Data compiled and standardized by the Shorebird Science and Conservation Collective (Version 2023-10-10), Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute. Data contributed to the Shorebird Science and Conservation Collective by: Nathan Senner, University of Massachusetts Amherst and Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada. Data co-owned by: Jennifer Linscott (University of South Carolina), Jorge Ruiz (Universidad Austral de Chile), Mitch Weegman (University of Missouri, University of Saskatchewan), Bart Ballard (Texas A&M University, Kingsville), Juan Navedo (Universidad Austral de Chile); Fletcher Smith (College of William and Mary, Georgia Department of Natural Resources), Bryan Watts (College of William and Mary).

Figure 14. Tracked Hudsonian Godwits (*n* = 4) with estimated movements in CWS' AOI during post-breeding (fall) migration. Two individuals had tag transmissions within the AOI, two additional birds had a trackline intersecting the AOI.

Lesser Yellowlegs

Federally Threatened Species in Canada

Post-breeding (Fall) Migration

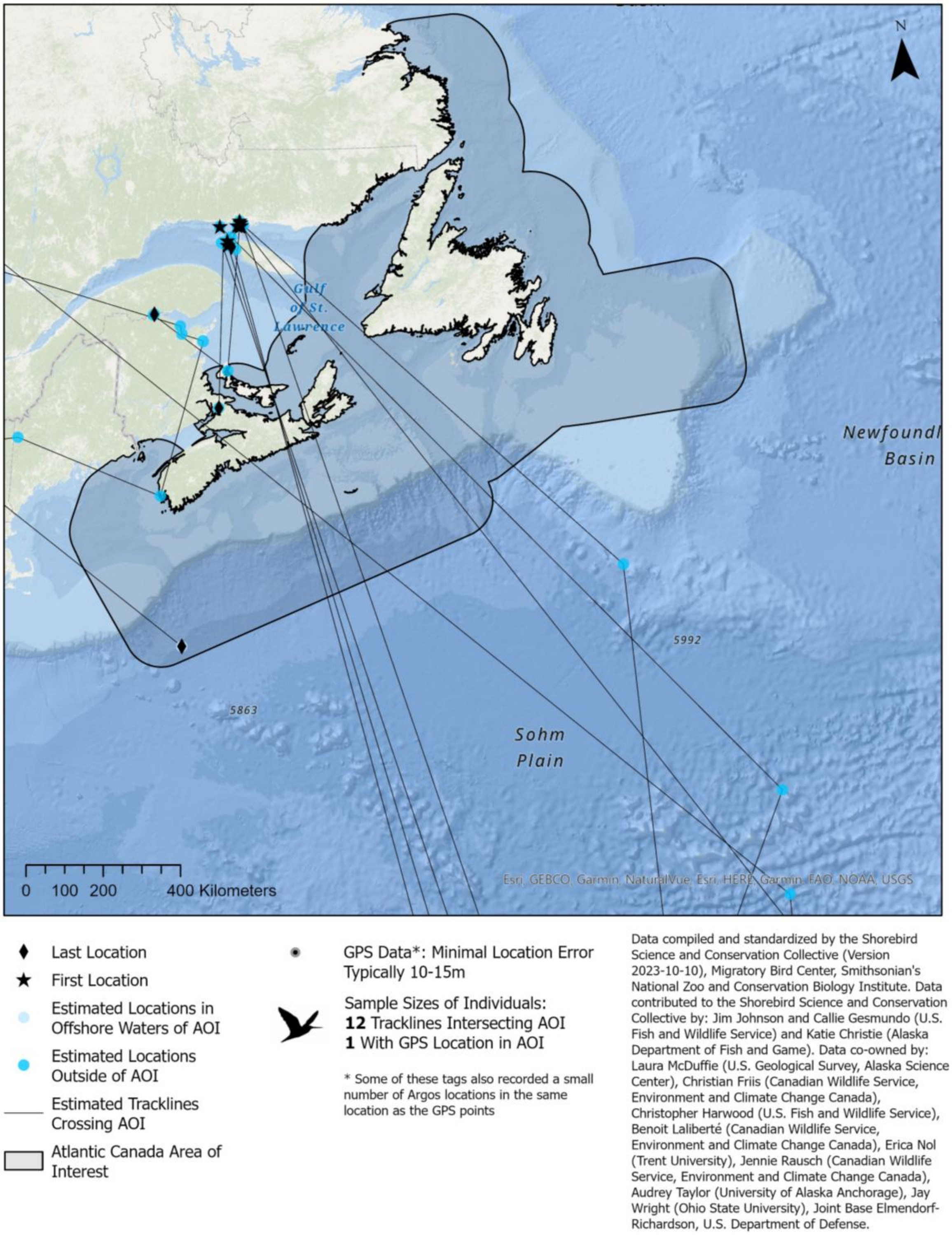


Figure 15. Tracked Lesser Yellowlegs (*n* = 12) with estimated movements in CWS' AOI during post-breeding (fall) migration. One individual had tag transmissions within the AOI, 11 additional birds had a trackline intersecting the AOI.

Pectoral Sandpiper

Post-breeding (Fall) Migration

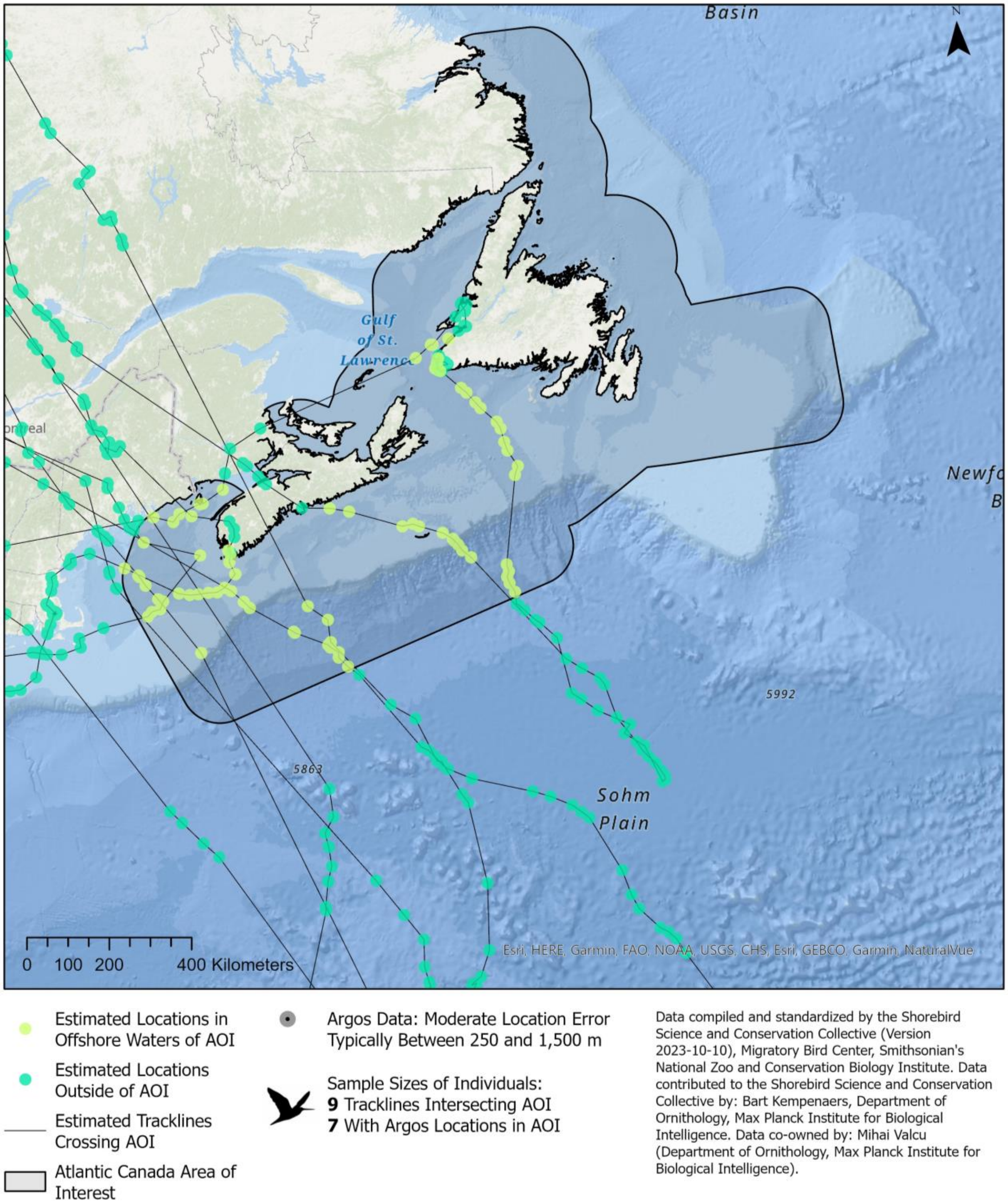


Figure 16. Tracked Pectoral Sandpipers (*n* = 9) with estimated movements in CWS' AOI during post-breeding (fall) migration. Seven individuals had tag transmissions within the AOI, two additional birds had a trackline intersecting the AOI.

Pre-breeding (Spring) Migration

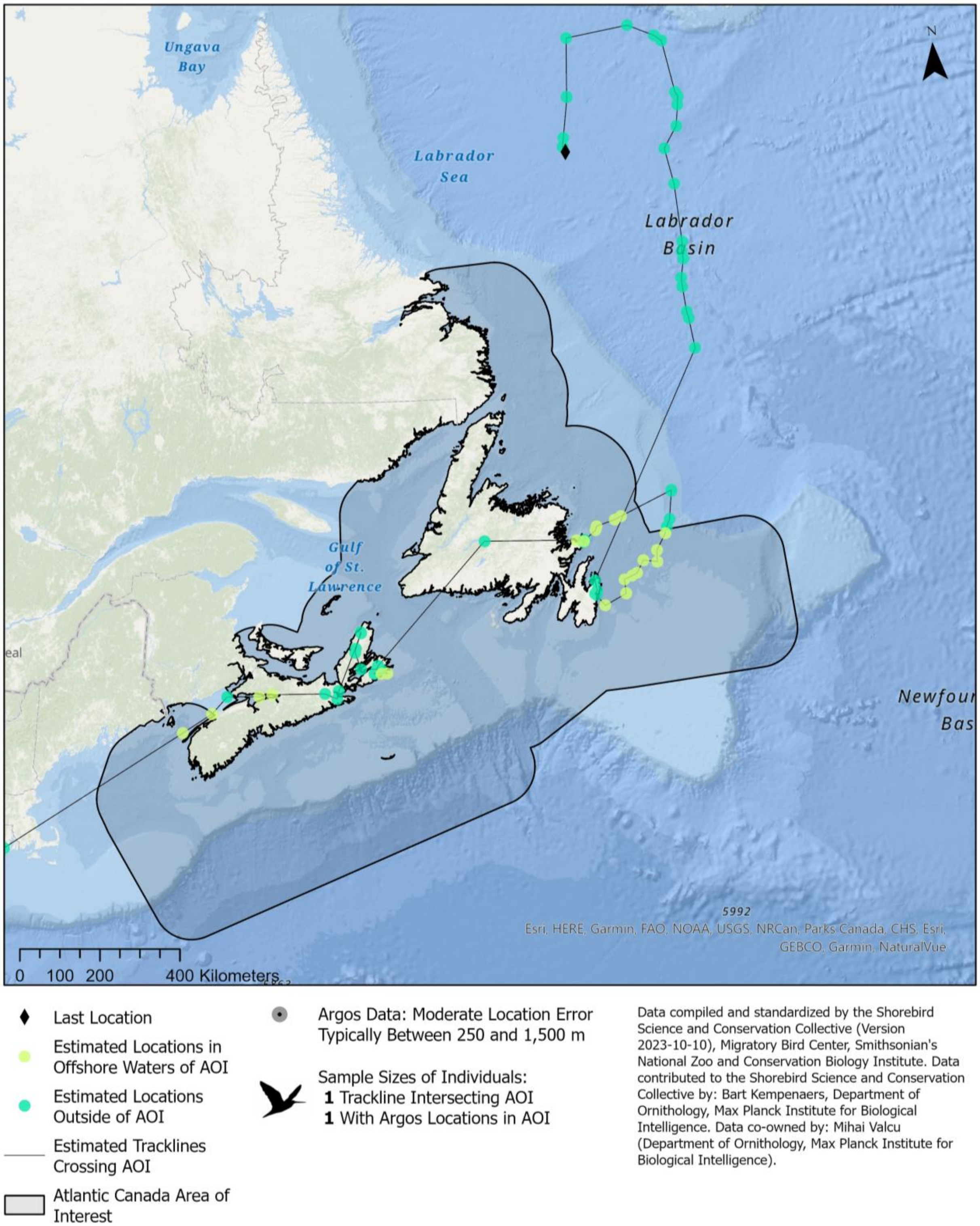


Figure 17. Tracked Pectoral Sandpiper (*n* = 1) with tag transmissions in CWS' AOI during pre-breeding (spring) migration.

Red Phalarope

Post-breeding (Fall) Migration

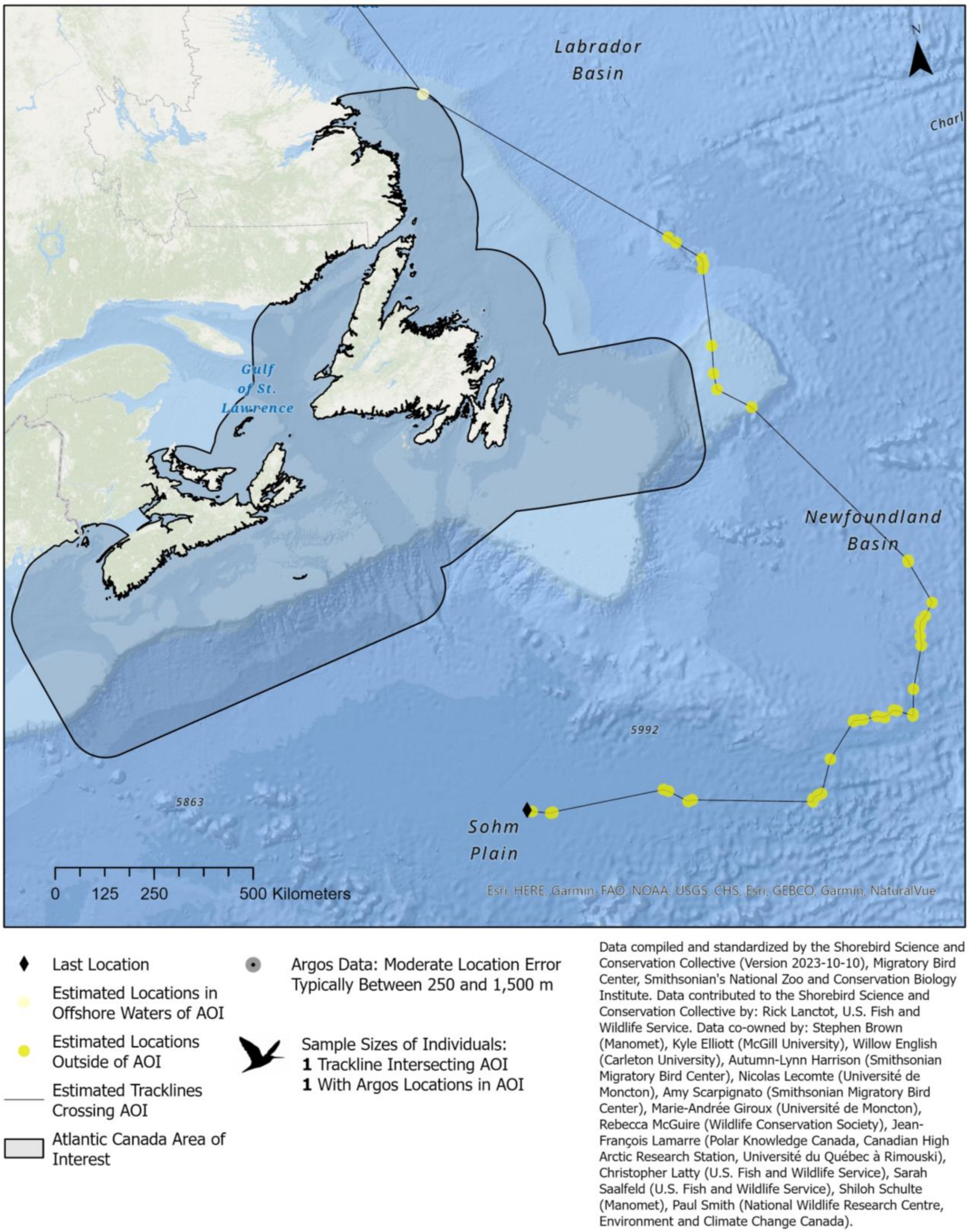


Figure 18. Tracked Red Phalarope (n = 1) with tag transmissions in CWS' AOI during post-breeding (fall) migration.

Whimbrel

Post-breeding (Fall) Migration

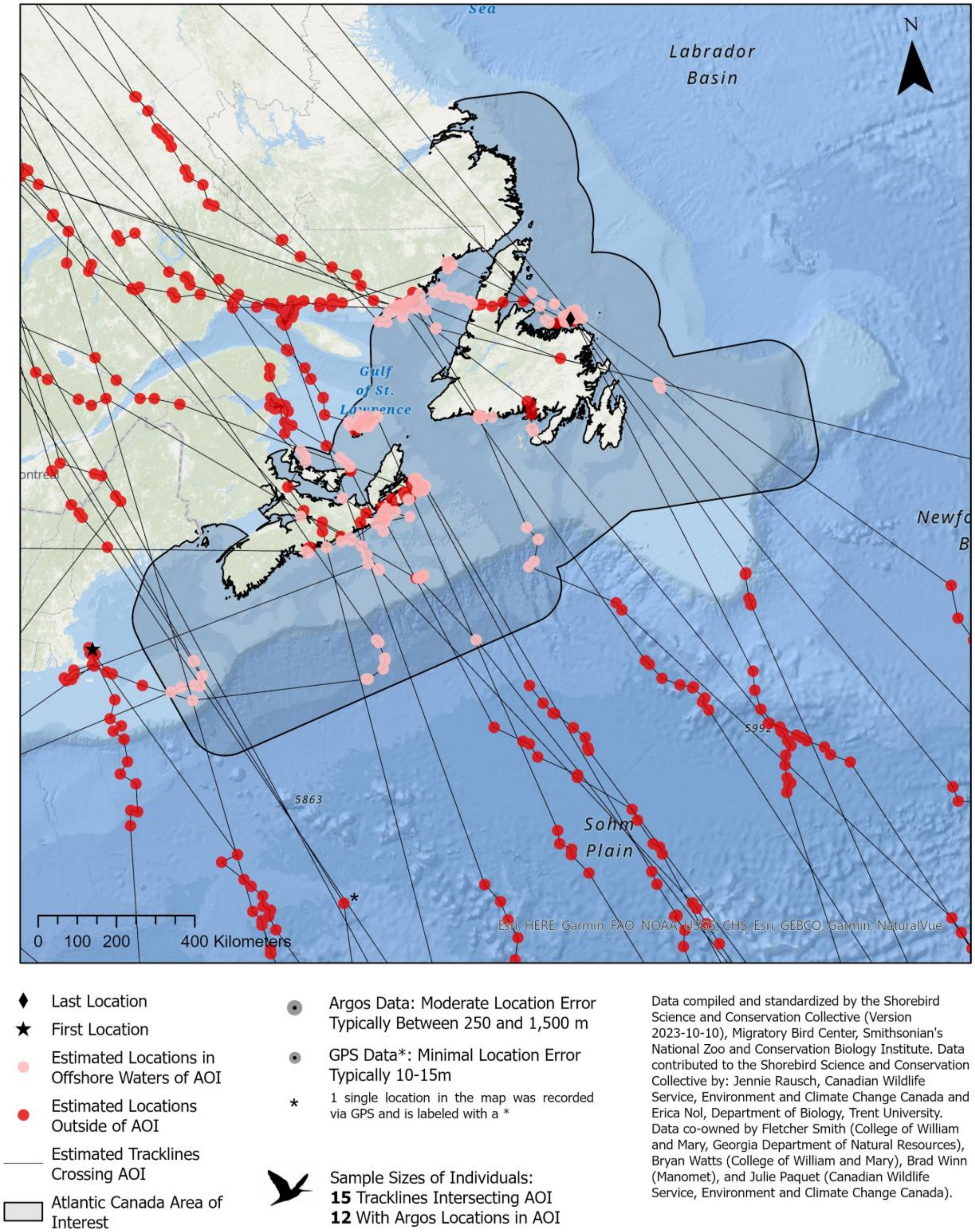


Figure 19. Tracked Whimbrels (*n* = 15) with estimated movements in CWS' AOI during post-breeding (fall) migration. 12 individuals had tag transmissions within the AOI, three additional birds had a trackline intersecting the AOI.

Seasonal Timing of Movements Through Atlantic Canada

We examined the seasonal timing of movements of tracked shorebirds through CWS' AOI and surrounding 200 km buffer to highlight broad times where a subset of species may be exposed to wind turbines developed in the region. Species have different migration phenologies, especially American Woodcock, which breed and have been tagged in Atlantic Canada. Generally, tag transmissions in the AOI during **post-breeding (fall) migration** occurred **mid-July through October** with the number of tracked individuals **peaking in mid-August to mid-September** (**Figure 20**). Tracking data are limited for pre-breeding (spring) migration, so additional data (such as eBird data) is needed to clarify pre-breeding migration timing patterns.

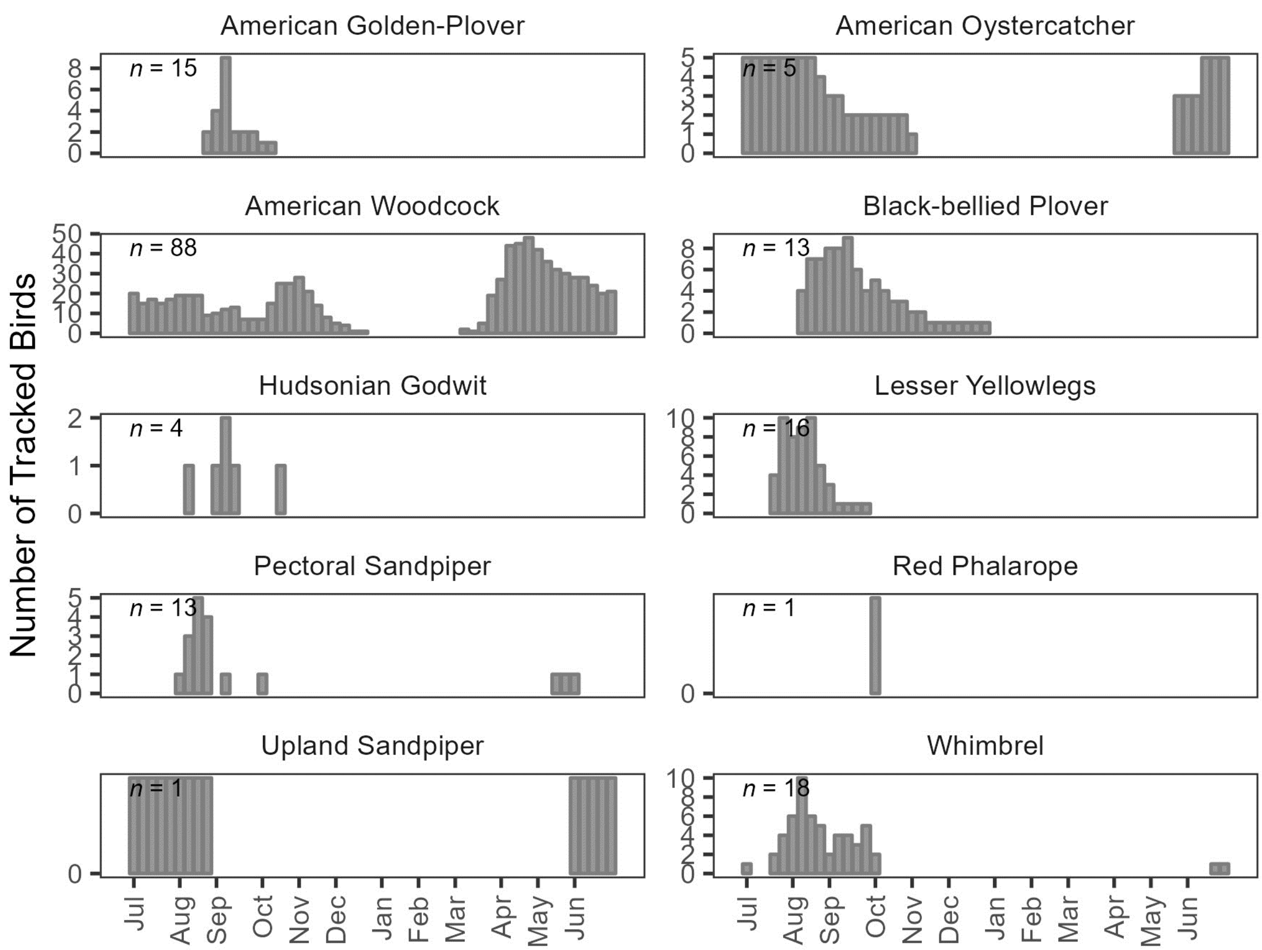


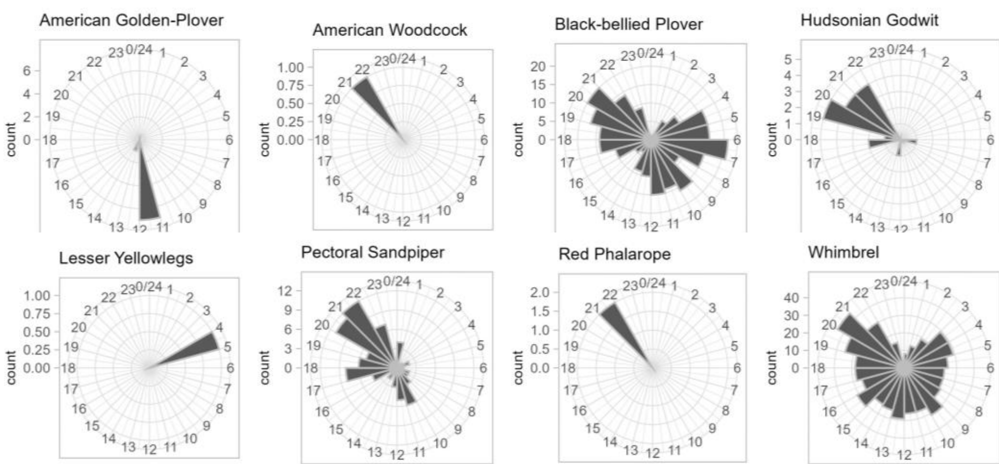
Figure 20. The number of shorebirds contributed to the Shorebird Collective, grouped by species, and tracked within 200 km of CWS' AOI throughout the year.

Timing of Transmissions in Offshore AOI

In addition to seasonal timing analyses, we also examined the timing of the tag transmissions over CWS' AOI (**Figure 21**). The timing of transmissions depends on the programming of the tag; for example, American Golden-Plover GPS tags were programmed to record a location every other day at 07:00 Alaska Time (Lanctot unpublished data), which resulted in most over-water transmissions in the AOI between 11:00 and 12:00, ADT (**Figure 21a**). Interestingly, transmissions from American Golden-Plover tags overwater midday differed from many other species during pre-breeding (spring) migration (American Woodcock, Black-bellied Plover, Hudsonian Godwit, Pectoral Sandpiper, Red Phalarope, and Whimbrel) for which transmissions tended to peak in the **evenings between 19:00 and 22:00 ADT**. Importantly, although most species cross the AOI at dusk or early evening, some may cross during the day; therefore, smart curtailment strategies (such as shutting turbines off at night during peak migration as is sometimes done for bats) may not be an effective approach for all shorebird species.

Black-bellied Plover and Whimbrel tag transmission also occurred in the AOI during the day, and some of these individuals stopped in the region. Daytime transmissions in the AOI for these species could be from spatial error of Argos tags for birds onshore, for birds using intertidal areas in the AOI, or from short distance flights over water during stopovers. Additional analyses to partition stopovers from flights and map spatial error would help clarify this. Note that count data presented in **Figure 21** include multiple tag transmissions from the same individual during a flight. In the future, we could statistically account for the non-independence from repeated measures from tagged individuals during flights.

a) Post-breeding (Fall) Migration



b) Pre-breeding (Spring) Migration

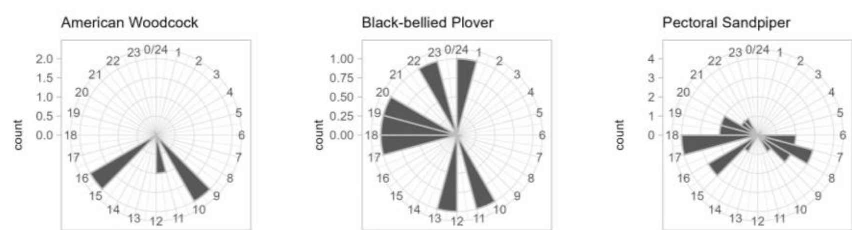
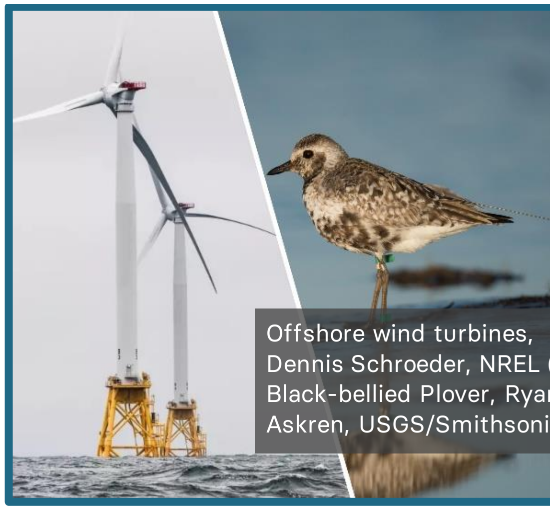


Figure 21. Counts of the number of transmissions that occurred in CWS' AOI with associated timestamps. Timestamps were rounded to the nearest hour in ADT (America/Halifax time) prior to calculating counts. Note the limited sample sizes for some species (especially Lesser Yellowlegs and Red Phalarope) and during pre-breeding (spring) migration.

Flight Altitude Information

Data on the flight heights of shorebirds are currently limited, and only three American Woodcock with transmissions in the AOI were tracked with devices that also recorded altitude. These individuals were tracked with PinPoint GPS Argos Tags (Lotek Wireless Inc.), and the tag manufacturer indicated that altitude data are accurate to within 50 meters (M. Vandentillaart, personal communication). However, researchers also suggest that raw data require careful calibration adjustment prior to interpretation. Dr. Erik Blomberg, Principal Investigator of the American Woodcock study, relayed to us that a student will be evaluating the woodcock flight altitude accuracy more carefully this spring and is happy to keep CWS updated about this work and to be contacted directly.



Offshore wind turbines, Dennis Schroeder, NREL (CC); Black-bellied Plover, Ryan Askren, USGS/Smithsonian

Tracking data from shorebirds in other regions show that some shorebirds fly at the heights of offshore wind turbine blades (Schwemmer et al. 2023, Galtbalt et al. 2021), which tend to spin between 25-30 m above the water to 204 m on average (Musial et al. 2023). For example, a study on Eurasian Curlews (*Numenius arquata*) tracked with GPS-GSM data loggers in the Baltic Sea (*n* = 51) found curlews flew at median heights of 60 m over sea (compared to 335 m over the mainland) during post-breeding (fall) migration (Schwemmer et al. 2023). During pre-breeding (spring) migration, median flight heights were 150 m over sea (576 m above land), thus indicating a risk of collision with offshore turbine blades during both seasons. A separate study on Far Eastern Curlews (*N. madagascariensis*, *n* = 17) and Whimbrel (*N. phaeopus*, *n* = 9) tracked with GPS-GSM data loggers along the East Asia - Australasia Flyway reported similar patterns, with Curlews and Whimbrels flying lower over sea (median heights of 156 m and 133 m, respectively) compared to over the mainland (Galtbalt et al. 2021).

Inconsistent with the previous two studies, Loring et al.'s (2020) Motus tracking study on the migratory movements and flight heights of 12 Western Hemisphere shorebird species[2] (*n* = 594) in the U.S. Atlantic Outer Continental Shelf Region found modeled-estimated flight heights to vary between 28 m - 2,940 m above sea level but generally occurred above the Rotor Swept Zone (RSZ, 250 m above sea level) with spring and fall flight heights averaging 914 m and 545 m, respectively. However, risk exposure to the RSZ was higher during the fall with approximately 36% of the offshore flights occurring in the RSZ, compared to 24% in the spring (Loring et al. 2020).

[2] Loring et al.'s 2021 study includes tracking data from the following 12 species: Black-bellied Plover (*Pluvialis squatarola*), Dunlin (*Calidris alpina*), Least Sandpiper (*Calidris minutilla*), Lesser Yellowlegs (*Tringa flavipes*), Pectoral Sandpiper (*Calidris melanotos*), Red Knot (*Calidris canutus*), Ruddy Turnstone (*Arenaria interpres*), Sanderling (*Calidris alba*), Semipalmated Plover (*Charadrius semipalmatus*), Semipalmated Sandpiper (*Calidris pusilla*), Whimbrel (*Numenius phaeopus*), and White-rumped Sandpiper (*Calidris fuscicollis*).

Shorebird Background

Shorebirds are a diverse group of birds in the order Charadriiformes, including sandpipers, plovers, avocets, oystercatchers, and phalaropes. There are approximately 217 shorebird species in the world (O'Brien at al. 2006), 81 of which occur in the Americas. 52 species breed in North America (Morrison et al. 2000) and 35 species breed in Latin America and the Caribbean (Lesterhuis and Clay 2019). They are among the planet's most migratory groups of animals. Many species in the Western Hemisphere, for example, travel thousands of miles every year between their breeding grounds in the Arctic and wintering grounds in the Caribbean and Central and South America, stopping at key sites along the way to rest and refuel. Across their vast range, shorebirds depend on a variety of habitats, including coastlines, shallow wetlands, mudflats, lake and pond edges, grasslands, and fields.

Long-billed Curlew;
Tim Romano, Smithsonian

While shorebirds are champion migrants, their populations are rapidly declining. Many populations have lost over 70% of their numbers in the past 50 years (NABCI 2022, Rosenberg et al. 2019, Smith et al. 2023), making them one of the most vulnerable bird groups in North America. Habitat loss and alteration, human disturbance, and climate change are just some of the major threats facing shorebirds today. Effective shorebird management is even more of a challenge due to many species depending on habitats across multiple countries under different political jurisdictions. Despite these trends and logistical challenges, many public and private groups are working to protect shorebirds and the habitats they depend on.

Offshore Wind & Shorebirds

Offshore wind turbines, though important for reducing carbon emissions, may have cumulative negative effects on birds through collisions or displacement (Goodale & Milman 2016, Fox & Petersen 2019), and vulnerability of shorebirds to these effects is not well understood. Shorebirds are difficult to identify and quantify at sea and are not well-represented in offshore species occurrence datasets (Hartman et al. 2022). Tracking data can thus provide valuable insight about movement routes and timing of passage in both proposed and active areas to inform turbine operations (Loring et al. 2021, Schwemmer et al. 2023). For example, by documenting timing of shorebird movements, tracking data could inform siting decisions or "smart curtailment" strategies during high-risk migratory periods.

Offshore wind farm;
USWFS (CC)

About Shorebird Tracking Data

Tracking data provide valuable insight into where shorebirds move and are located throughout the year. These data can ultimately help biologists and practitioners make more informed conservation and land management decisions to protect shorebirds and their habitats. Tracking data are collected via tiny electronic tags (i.e., tracking device) which are attached directly to individual birds and may be carried by the birds year-round. Tag types of the tracked birds contributed to this request included GPS and Argos satellite tags.

Satellite tags work by sending signals to orbiting satellites that re-transmit location data back to a receiving station which researchers can access through their computer. The two types of satellite tags commonly used to study birds include Global Positioning System (GPS) and Argos tags. GPS tags typically have high spatial accuracy (i.e., minimal location error, generally <10 meters), while Argos tags can have location error of 500-2,500 meters. Link for more information on satellite tags.

Geolocator tags use ambient light levels to estimate location. This tag type is equipped with a light sensor, internal clock, and computer that records light levels that the sensor is exposed to throughout the day; light levels must then be processed to obtain location estimates. These tags have a lower spatial accuracy compared to location data retrieved from satellite tags, generally 50 - 200 km with much greater error in latitude during spring and fall equinox. A drawback to using this tag type is scientists must recapture the bird to obtain the location data. However, geolocator tags are significantly cheaper compared to satellite tags and are incredibly lightweight, allowing them to be used on smaller birds. Link for more information on geolocator tags.

Motus tags are small radio tags that work by sending signals to Motus Wildlife Tracking System receivers (i.e., Motus towers) that record the tag ID, signal strength, and time of detection. Tags may be detected if an animal moves within the detection range of a receiver, often 15-20 km but sometimes up to 180 km. Like geolocators, these tags are lightweight and suitable for tracking smaller-bodied birds. A downside to Motus data is locations are limited to the latitude and longitude of Motus Wildlife Tracking System receiving stations which are primarily distributed in North America and rarely in remote/offshore locations. Link for more information on Motus tags.

Images: 1. Black-bellied Plover with leg flag and <5g solar satellite tag, Ryan Askren, USGS/Smithsonian; **2.** Light-level geolocator tag, Smithsonian; **3.** Example of a Motus tower station, Smithsonian

Data Contributors

Tracking data for this project were contributed to the Shorebird Collective by the following people and organizations. Individuals with an asterisk (*) indicates the technical point of contact for the dataset. A full list of data contributors to the Shorebird Collective can be found on our webpage: link to Shorebird Collective webpage.

The following contributors provided detailed tracks and maps of shorebird movements:

American Golden-plover Tracks:

Rick Lanctot*[1], Stephen Brown[2], Kyle Elliott[3], Willow English[4], Autumn-Lynn Harrison[5], Nicolas Lecomte[6], Pete Marra[7], Marie-Andrée Giroux[6], Rebecca McGuire[8], Jean-François Lamarre[9,10], Joël Bêty[10], Mike Russell[11], Sarah Saalfeld[1], Shiloh Schulte[2], Paul Smith[12]

Unpublished Data, U.S. Fish and Wildlife Service, Manomet, McGill University, Carleton University, Smithsonian Migratory Bird Center, Université de Moncton, Georgetown University, Wildlife Conservation Society, Polar Knowledge Canada, Canadian High Arctic Research Station, Université du Québec à Rimouski, Government of Alberta, National Wildlife Research Centre, Environment and Climate Change Canada

American Woodcock Tracks:

Erik Blomberg*[13], Liam Berigan[13], Alexander Fish[13], Amber Roth[13]

Associated Citation: Blomberg, E. J, A. C. Fish, L. A. Bergian, and A. M. Roth. 2022. Eastern Woodcock Migration Research Cooperative. University of Maine

Black-bellied Plover Tracks:

Jennie Rausch*[14], Paul Woodard[14]

Unpublished data, Canadian Wildlife Service, Environment and Climate Change Canada, Northern Region, Yellowknife, NT, Canada

Hudsonian Godwit Tracks:

Nathan Senner*[15,16], Jennifer Linscott[15], Jorge Ruiz[17], Mitch Weegman*[18,19], Bart Ballard*[20], Juan Navedo[17]

Associated Citation: Linscott, J. A., Navedo, J. G., Clements, S. J., Loghry, J. P., Ruiz, J., Ballard, B. M., Weegman, M. D., and Senner, N. R. 2022. Compensation for wind drift prevails for a shorebird on a long-distance, transoceanic flight. *Movement Ecology*, 10(1), 1-16.

Jennie Rausch*[14], Fletcher Smith[21,22], Bryan Watts[21]

Associated Citation: Smith, F. M., Watts, B. D., and Rausch, J. 2021. Tracking hudsonian godwit in Canada. The Center for Conservation Biology, College of William and Mary and the Virginia Commonwealth University, Williamsburg, VA U.S.A.

Lesser Yellowlegs Track:

Callie Gesmundo*[1], Jim A. Johnson*[1], Katie Christie[23], Laura McDuffie[24], Christian Friis[14], Christopher Harwood[1], Benoit Laliberté[14], Erica Nol[25], Jennie Rausch[14], Audrey Taylor[26], Jay Wright[27], Joint Base Elmendorf-Richardson[28]

Associated Citation: McDuffie, L. A., Christie, K. S., Taylor, A. R., Nol, E., Friis, C., Harwood, C. M., Rausch, J., Laliberté, B., Gesmundo, C., and Johnson, J. A. 2022. Flyway-scale GPS tracking reveals migratory routes and key stopover and non-breeding locations of lesser yellowlegs. *Ecology and Evolution*, 12(11), e9495.

Pectoral Sandpiper Tracks:

Bart Kempenaers*[29], Mihai Valcu[29]

Associated Citation: Kempenaers, B., and M., Valcu. 2017. Breeding site sampling across the Arctic by individual males of a polygynous shorebird. *Nature*, 541(7638), 528-531.

Red Phalarope Track:

Rick Lanctot*[1], Stephen Brown[2], Kyle Elliott[3], Willow English[4], Autumn-Lynn Harrison[5], Nicolas Lecomte[6], Amy Scarpignato[5], Marie-Andrée Giroux[6], Rebecca McGuire[8], Jean-François Lamarre[9,10], Christopher Latty[1], Sarah Saalfeld[1], Shiloh Schulte[2], Paul Smith[12]

Unpublished data, U.S. Fish and Wildlife Service, Manomet, McGill University, Carleton University, Smithsonian Migratory Bird Center, Université de Moncton, Wildlife Conservation Society, Polar Knowledge Canada, Canadian High Arctic Research Station, Université du Québec à Rimouski, National Wildlife Research Centre, Environment and Climate Change Canada

Whimbrel Tracks:

Jennie Rausch*[14], Fletcher Smith[21,22], Bryan Watts[21], Brad Winn[2], Julie Paquet[14]

Associated Citation: Watts, B. D., Smith, F. M., Hamilton, D. J., Keyes, T., Paquet, J., Pirie-Dominix, L., Truitt, B., and Woodard, P. 2019. Seasonal variation in mortality rates for Whimbrels (*Numenius phaeopus*) using the Western Atlantic Flyway. *The Condor: Ornithological Applications*, 121(1), duy001.

Contributor Organizations:

[1] U.S. Fish and Wildlife Service, [2] Manomet, [3] McGill University, [4] Carleton University, [5] Smithsonian Migratory Bird Center, [6] Université de Moncton, [7] Georgetown University, [8] Wildlife Conservation Society, [9] Polar Knowledge Canada, Canadian High Arctic Research Station, [10] Université du Québec à Rimouski, [11] Government of Alberta, [12] National Wildlife Research Centre, Environment and Climate Change Canada, [13] University of Maine, [14] Canadian Wildlife Service, Environment and Climate Change Canada,[15] University of South Carolina, [16] University of Massachusetts Amherst, [17] Universidad Austral de Chile, [18] University of Missouri, [19] University of Saskatchewan, [20] Texas A&M University, Kingsville, [21] College of William and Mary, [22] Georgia Department of Natural Resources, [23] Alaska Department of Fish and Game, [24] U.S. Geological Survey, Alaska Science Center, [25] Trent University, [26] University of Alaska Anchorage, [27] Ohio State University, [28] U.S. Department of Defense, [29] Max Planck Institute for Biological Intelligence

References

[CLS] Collecte Localisation Satellites. 2016. Argos user's manual: Worldwide tracking and environmental monitoring by satellite. CLS, Ramonville Saint-Agne, France.

Fox, A. D., and I. K. Petersen. 2019. Offshore wind farms and their effects on birds. *Dansk Orn Foren Tidsskr*, 113:86-101.

Galtbalt, B., Lilleyman, A., Coleman, J. T., Cheng, C., Ma, Z., Rogers, D. I., Woodworth, B. K., Fuller, R. A., Garnett, S. T., and Klaassen, M. 2021. Far eastern curlew and whimbrel prefer flying low - wind support and good visibility appear only secondary factors in determining migratory flight altitude. *Movement Ecology*, 9:32.

Goodale, M. W., and A. Milman. 2016. Cumulative adverse effects of offshore wind energy development on wildlife. *Journal of Environmental Planning and Management*, 59(1):1-21.

Hartman, S., Hallock, P., and Muller-Karger, F. 2022. Obligation to Enhance OBIS Data for Sea- and Shorebirds of the Americas. *Diversity*, 14(12):1099.

Jonsen, I. D., Patterson, T. A., Costa, D. P., Doherty, P. D., Godley, B. J., Grecian, W. J., Guinet, C., Hoenner, X., Kienle, S. S., Robinson, P. W., Votier, S. C., Whiting, S., Witt, M. J., Hindell, M. A., Harcourt, R. G., and McMahon, C. R. 2020. A continuous-time state-space model for rapid quality control of Argos locations from animal-borne tags. *Movement Ecology*, 8:31.

Lesterhuis, A. J., and R. P. Clay. 2019. Conservation status of shorebird species resident to Latin America and the Caribbean, v1. WHSRN Executive Office and Manomet, Inc., Manomet, MA.

Loring, P. H., Lenske, A. K., McLaren, J. D., Aikens, M., Anderson, A. M., Aubrey, Y., Dalton, E., Dey, A., Friis, C., Hamilton, D., Holberton, B., Kriensky, D., Mizrahi, D., Niles, L., Parkins, K. L., Paquet, J., Sanders, F., Smith, A., Turcotte, Y., Vitz, A., Smith, P. A. 2021. Tracking Movements of Migratory Shorebirds in the US Atlantic Outer Continental Shelf Region. *Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management OCS Study BOEM* 8:104.

Morrison, R. I. G., Gill, R. E., Harrington, B. A., Skagen, S., Page, G. W., Gratto-Trevor, C. L., and Haig, S. M. 2000. Population estimates of Nearctic shorebirds. *Waterbirds*, 23:337-352.

[NABCI] North American Bird Conservation Initiative. 2022. The State of the Birds, USA, 2022.

Noonan, M. J., Fleming, C. H., Akre, T. S., Drescher-Lehman, J., Gurarie, E., Harrison, A-L., Kays, R., and Calabrese, J. M. 2019. Scale-insensitive estimation of speed and distance traveled from animal tracking data. *Movement Ecology*, 7:35.

O'Brien, M., Crossley, R., and Karlson, K. 2006. The shorebird guide. Houghton Mifflin Company, New York, NY.

Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., and Marra, P. 2019. Decline of the North American avifauna. *Science*, 366(6461):120-124.

Schwemmer, P., Pederson, R., Haecker, K., Bocher, P., Fort, J., Mercker, M., Jiguet, F., Elts, J., Marja, R., Piha, M., Rousseau, P., and Garthe, S. 2023. Assessing potential conflicts between offshore wind farms and migration patterns of a threatened shorebird species. *Animal Conservation*, 26(3):303-316.

Smith, P. A., Smith, A. C., Andres, B., Francis, C. M., Harrington, B., Friis, C., Guy Morrison, R. I., Paquet, J., Winn, B., and Brown, S. 2023. Accelerating declines of North America's shorebirds signal the need for urgent conservation action. *Ornithological Applications,* 125:1-14.