Shorebird Science and Conservation Collective

Report to the Canadian Wildlife Service

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

Phase II

Offshore wind turbines; Andy Dingley (CC)

Smithsonian *Migratory Bird Center*

Environment and Climate Change Canada

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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 (**Figure 1**) Specifically, CWS requested relevant shorebird tracking data that might help them understand how and where shorebirds are moving through offshore areas. In October 2023, we provided CWS with a detailed report containing maps and summary information of tracked shorebirds with tag transmissions in CWS' area of interest (AOI). This document is an extension to that report (i.e., Phase II) and provides the following additional items:

- Species maps and summary information of tracked birds with locations outside of the AOI but with tracklines intersecting the AOI.
- Details on sample sizes and proportion of tracked shorebirds in CWS' AOI based on the GPS and Argos satellite tracks contributed to the Shorebird Collective.
- Additional information on seasonal migration timing in Atlantic Canada and timing of tag transmissions over offshore waters of the AOI.
- A summary of the limited state of knowledge about shorebird flight altitudes.

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 at: https://nationalzoo.si.edu/migratory-birds/shorebird-collective.

About the Canadian Wildlife Service

CWS is a branch of Environment and Climate Change Canada and serves as Canada's national wildlife agency. CWS is responsible for the conservation of migratory birds, species at risk, and biodiversity. Learn more at: https://www.canada.ca/en/environment-climate-change.html.

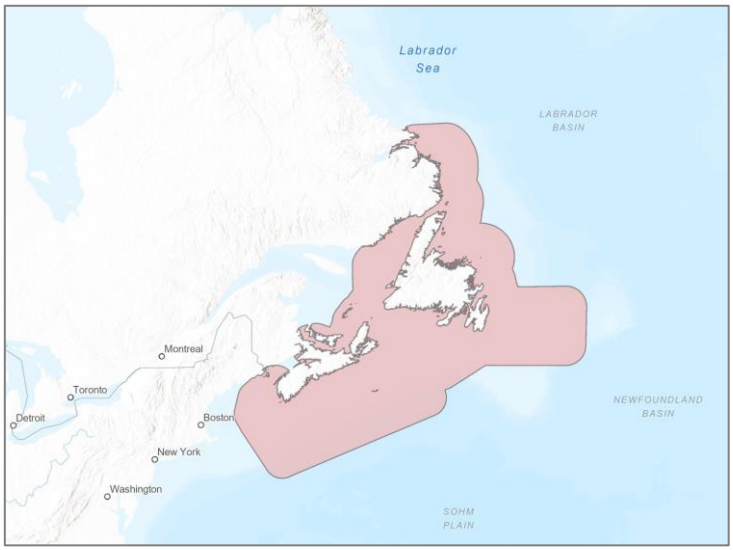


Figure 1. CWS' Atlantic Canada AOI which includes areas around the island of Newfoundland, Gulf of Saint Lawrence, New Brunswick, Prince Edward Island, Nova Scotia, and Gulf of Maine.

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, Appendix I**).

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 modeling the most probable pathway connecting tag transmissions (i.e., locations) outside the AOI (**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 (**Figures 2-15**). Here we provide maps of all tracklines estimated to have crossed the AOI (**Figure 2**), in addition to tracked locations in the AOI by data type (**Figure 3**) and maps for each species tracked across seasons (**Figures 4-14**). We also summarize the proportion of birds tracked from different breeding and wintering locations with estimated movements through the AOI (**Tables 2 and 3**).

Data from geolocators (tracking devices with lower spatial accuracy) and Motus data will be incorporated into the Shorebird Collective Dataset at a later date. See **Appendix I** for more information on different data types available for tracking shorebirds and a summary of methods. Additional information may become available as data contributors continue to share new tracking data with the Shorebird Collective. We invite 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/ Tracks 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).

Sample Sizes & Proportion of Tracked Shorebirds in AOI

Tables 2 and **3** summarize sample sizes of contributed shorebird tracks from breeding and wintering areas with counts and percentages of estimated movements through CWS' AOI during post-breeding (fall) and pre-breeding (spring) migration. See **Appendix I** for an example of how breeding and wintering areas were assigned. Tracked species without estimated movements through the AOI are not reported in the tables. In general, a higher proportion tracklines from individuals breeding in the eastern Canadian Arctic crossed the AOI during post-breeding (fall) migration than individuals from populations further west (e.g., American Golden-Plover, American Woodcock, Black-bellied Plover, Hudsonian Godwit, Lesser Yellowlegs, **Table 2**). Tracking data are limited during pre-breeding (spring) migration because tags were often deployed at Arctic breeding grounds and either collected locations for a short time period or the tags stopped transmitting as a result of the tag falling off, malfunctioning, or from animal death.

Note that some individuals were tracked through Atlantic Canada in more than one year. If a trackline for an individual crossed the AOI in at least one year, we considered the individual to have intersected the AOI even if it did not cross in another year. Additionally, the presence of a location in the AOI depends on the temporal interval that the tracking device records locations. For example, in the Shorebird Collective Dataset, Argos tags often recorded multiple lower accuracy locations every day or every other day, whereas GPS tags often recorded a single high accuracy location over the same time interval. This resulted in fewer birds tracked with GPS with transmissions in the AOI. Therefore, we recommend against comparing counts and proportions of individuals with locations in the AOI if populations were tracked with different data types and data collection intervals. Instead, the proportion of individuals with tracklines intersecting the AOI should provide a better estimate of relative exposure of different populations to the AOI than the proportions of individuals with at least one location in the AOI.

In the future, the Shorebird Collective could examine how often individuals tracked in more than one year crossed the AOI Additionally, we could expand our analyses to examine the probability of occurrence of individuals from different populations in the AOI throughout the season (see McDuffie et al. 2022 as an example of this type of analysis).

Post-breeding (Fall) Migration

Table 2. Summary of sample sizes of individual shorebirds tracked from breeding areas with counts and percentages of estimated movements through the AOI during post-breeding (fall) migration.

Species	Shorebird Collective Dataset Overall (*n* Individuals)	Relevant Sample (*n* Individuals)	Trackline Intersected AOI (*n* Individuals)	≥ 1 Location in AOI (*n* Individuals)	Data Type & Interval Between Transmissions	Relevant Sample Description
American Golden-Plover	**59**	**34**	**23 (68%)**	**6 (18%)**	**GPS, 1 location every 2 days**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI)**
Breeding Areas	Eastern Canadian Arctic	6	6 (100%)	2 (33%)	GPS, 1 location every 2 days	Birds tagged at Bylot Island, Coal Harbor, and Igoolik, NU
	Western Canadian Arctic	6	4 (66%)	0 (0%)	GPS, 1 location every 2 days	Birds tagged at Cambridge Bay and one tagged in Alberta during pre-breeding migration that may have bred at Adelaide Peninsula, NU
	North Slope of Alaska	22	13 (60%)	4 (18%)	GPS, 1 location every 2 days	Birds tagged at multiple locations along the North Slope, AK
American Woodcock	**546**	**210**	**10 (5%)**	**1 (0%)**	**GPS, 1 location every 1 or 2 days**	**Individuals tracked from > 40°N (the southern latitude of the AOI) to south of the AOI**
Management Unit	Eastern Canada	46	10 (22%)	1 (2%)	GPS, 1 location every 1 or 2 days	Birds with furthest north location in the following provinces: NB, NS, QB
	Eastern USA	149	0 (0%)	0 (0%)	GPS, 1 location every 1 or 2 days	Birds with furthest north location in the following states: CT, MA, ME, NH, NY, PA, RI, VT

	Central Canada	8	0 (0%)	0 (0%)	GPS, 1 location every 1 or 2 days	Birds with furthest north location in the following provinces: MB, ON
	Central USA	7	0 (0%)	0 (0%)	GPS, 1 location every 1 or 2 days	Birds with furthest north location in the following states: MI, MN
Black-bellied Plover	**55**	**41**	**10 (24%)**	**9 (22%)**	**Argos, multiple locations every 2 days; GPS, 1 location every 6 days**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI)**
Breeding Areas	Eastern Canadian Arctic	22	10 (45%)	9 (41%)	Argos, multiple locations every 2 days	Birds tagged at Bylot Island, Coal Harbor, and Igoolik, NU. One individual tracked south of 55°N was excluded because tracking stopped at James Bay, ON, and other individuals moved from James Bay to the AOI. 2 birds tagged during migration at Mingan Archipelago, QC were included in this group
	Western Canadian Arctic and North Slope of Alaska	10	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	Birds tagged at single location along the North Slope, AK or migrated to the area from southern tagging locations
	Western Alaska	9	0 (0%)	0 (0%)	Argos (4), multiple locations every 2 days; GPS (5), 1 location every 6 days	Birds tagged in Seward Peninsula, AK or surrounding areas
Hudsonian Godwit	**42**	**12**	**4 (33%)**	**2 (17%)**	**Argos, multiple daily locations; GPS & Argos, 1-2 locations every 2 hrs**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI)**
Breeding Areas	Near Churchill, Manitoba	1	1 (100%)	1 (100%)	Argos, multiple daily locations	Bird originally tagged in Chile
	Western Canadian Arctic	3	3 (100%)	1 (33%)	Argos, multiple daily locations	Birds tagged near Mackenzie Bay, NWT
	Alaska	8	0 (0%)	0 (0%)	Argos (4), multiple daily locations; GPS & Argos (4), 1-2 locations every 2 hrs	Birds tagged in Chile
Lesser Yellowlegs	**107**	**97**	**12 (13%)**	**1 (1%)**	**GPS, 1 location every 2-4 days; GPS & Argos, 1-2 locations every 2 days**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI)**
Breeding Areas	Eastern Canada	9	9 (100%)	0 (0%)	GPS (6), 1 location every 2-4 days; GPS & Argos (3), 1-2 locations every 2 days	Birds tagged in Mingan Archipelago, QC. 4 tags that dropped or stopped recording between Mingan and Anticosti Island were removed from assessment
	Hudson Bay Lowlands	6	2 (33%)	0 (0%)	GPS (5), 1 location every 2-4 days; GPS & Argos (1), 1-2 locations every 2 days	Birds tagged near James Bay Coast
	South-central Canadian Arctic	20	1 (5%)	1 (5%)	GPS & Argos, 1-2 locations every 2 days	Birds tagged near Churchill, MB
	Western Canadian Subarctic	11	0 (0%)	0 (0%)	GPS (1), 1 location every 2 days; GPS & Argos (10), 1-2 locations every 2 days	Birds tagged near Yellowknife, NWT
	Central Alaska	12	0 (0%)	0 (0%)	GPS (4), 1 location every 2 days; GPS & Argos (8), 1-2 locations every 2 days	Birds tagged in single location
	Southern Alaska	39	0 (0%)	0 (0%)	GPS (33), 1 location every 2 days; GPS & Argos (6), 1-2 locations every 2 days	Birds tagged in single location
Pectoral Sandpiper	**226**	**103**	**9 (9%)**	**7 (7%)**	**GPS, 1 location daily; Argos, multiple locations every 14 hrs-2 days**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI).**
Breeding Areas	North Slope of Alaska	103	9 (9%)	7 (7%)	GPS (27), 1 location daily; Argos (73), multiple locations every 14 hrs-2 days	One individual tracked south of 55°N was excluded because tracking stopped at James Bay, ON, and other individuals moved from James Bay to the AOI.
Red Phalarope	**29**	**1**	**1 (100%)**	**1 (100%)**	**Argos, multiple locations every 16 hrs**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI).**
Breeding Areas	Eastern Canadian Arctic	1	1 (100%)	1 (100%)	Argos, multiple locations every 16 hrs	Bird tagged in Igoolik, NU
Whimbrel	**66**	**56**	**15 (27%)**	**12 (21%)**	**Argos, multiple locations every 1-2 days; GPS, 1 location every 2 days**	**Individuals tracked from the Arctic breeding area to 55°N (the northern latitude of the AOI).**
Breeding Areas	Hudson Bay Coast	11	4 (36%)	2 (18%)	Argos (2), multiple locations every 1-2 days; GPS, 1 location every 2 days	Birds tagged near Churchill (1), MB and or tagged along Atlantic coast during migration and tracked to Hudson Bay Coast
	Western Canadian Arctic	11	11 (100%)	10 (91%)	Argos, multiple daily locations	Birds tagged near Mackenzie Bay, NWT or tagged along Atlantic coast during migration and tracked to northern NWT
	Alaska	29	0 (0%)	0 (0%)	Argos, multiple locations every 1-2 days	Birds tagged at multiple locations
Additional Tagging Locations	Cape Cod, Massachusetts	5	0 (0%)	0 (0%)	Argos, multiple locations every 1-2 days	Birds tagged during post-breeding migration with unknown breeding area but had the potential to fly through the AOI

Pre-breeding (Spring) Migration

Table 3. Summary of sample sizes of individual shorebirds tracked from wintering areas with counts and percentages of estimated movements through the AOI during pre-breeding (spring) migration.

Species	Shorebird Collective Dataset Overall (*n* Individuals)	Relevant Sample (*n* Individuals)	Trackline Intersected AOI (*n* Individuals)	≥ 1 Location in AOI (*n* Individuals)	Data Type & Interval Between Detections	Relevant Sample Description
American Golden-Plover*	**59**	**1**	**0 (0%)**	**0 (0%)**	**GPS, 1 location every 2 days**	**Individuals tracked from their wintering location to 40°N (the southern latitude of the AOI)**
Wintering Areas	Buenos Aires Province, Argentina	1	0 (0%)	0 (0%)	GPS, 1 location every 2 days	NA
American Woodcock	**546**	**243**	**19 (8%)**	**2 (1%)**	**GPS, 1 location every 1 or 2 days**	**Individuals tracked from south of the AOI to > 40°N (the southern latitude of the AOI)**
Management Unit	Eastern USA	206	19 (9%)	2 (1%)	GPS, 1 location every 1 or 2 days	Birds with furthest south location in the following states: FL, GA, MD, NC, NJ, VA, SC, WV
	Central USA	37	0 (0%)	0 (0%)	GPS, 1 location every 1 or 2 days	Birds with furthest south location in the following states: AL, LA, MS, TN
Black-bellied Plover	**55**	**18**	**1 (6%)**	**1 (6%)**	**Argos, multiple locations every 2 days; GPS, 1 location every 6 days**	**Individuals tracked from their wintering location to 40°N (the southern latitude of the AOI)**
Wintering Areas	Louisiana	1	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
	Texas and North Mexico	3	0 (0%)	0 (0%)	Argos (2), multiple locations every 2 days; GPS (1), 1 location every 6 days	NA
	Sea of Cortez	3	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
	California and Baja	3	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
	Caribbean	3	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
	Brazil and French Guiana	2	1 (50%)	1 (50%)	Argos, multiple locations every 2 days	NA
	Venezuela and Colombia	2	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
	Peru	1	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
Hudsonian Godwit*	**42**	**15**	**0 (0%)**	**0 (0%)**	**Argos, multiple daily locations; GPS & Argos, 1-2 locations every 2 hrs**	**Individuals tracked from their wintering location to 40°N (the southern latitude of the AOI)**
Wintering Areas	Chile	15	0 (0%)	0 (0%)	Argos (8), multiple daily locations; GPS & Argos (7), 1-2 locations every 2 hrs	Most individuals were tagged in coastal Chile
Lesser Yellowlegs	**107**	**36**	**0 (0%)**	**0 (0%)**	**GPS, 1 location every 2-4 days; GPS & Argos, 1-2 locations every 2 days**	**Individuals tracked from their wintering location to 40°N (the southern latitude of the AOI)**
Wintering Areas	Haiti	2	0 (0%)	0 (0%)	GPS, 1 location every 2-3 days	NA
	Nicaragua and Honduras	2	0 (0%)	0 (0%)	GPS, 1 location every 4 days	NA
	Sea of Cortez	2	0 (0%)	0 (0%)	GPS & Argos, 1-2 locations every 2-3 days	NA
	Suriname, Brazil, French Guiana	5	0 (0%)	0 (0%)	GPS (5), 1 location every 2-4 days	NA
	Colombia and Venezuela	5	0 (0%)	0 (0%)	GPS (4), 1 location every 2-4 days; GPS & Argos (1), 1-2 locations every 2 days	NA
	Ecuador and Peru	3	0 (0%)	0 (0%)	GPS (2), 1 location every 2 days; GPS & Argos (1), 1-2 locations every 2 days	NA
	Bolivia	1	0 (0%)	0 (0%)	GPS & Argos, 1-2 locations every 2 days	NA
	Pampas, Argentina	16	0 (0%)	0 (0%)	GPS (5), 1 location every 2-4 days; GPS & Argos (11), 1-2 locations every 2 days	NA
Pectoral Sandpiper*	**226**	**13**	**1 (8 %)**	**1 (8%)**	**Argos, multiple locations every 14 hrs-2 days**	**Individuals tracked from their wintering location to 40°N (the southern latitude of the AOI)**
Wintering Areas	Pampas, Argentina	13	1 (8 %)	1 (8%)	Argos, multiple locations every 14 hrs-2 days	NA

Whimbrel*	**66**	**24**	**0 (0%)**	**0 (0%)**	**Argos, multiple locations every 1-2 days; GPS, 1 location every 2 days**	**Individuals tracked from their wintering location to 40°N (the southern latitude of the AOI)**
Wintering Area	Western Central America	7	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	Birds wintering in Ecuador, Panama, Honduras, El Salvador
	Brazil, French Guiana, Suriname	15	0 (0%)	0 (0%)	Argos (14), multiple locations every 1-2 days; GPS (1), 1 location every 2 days	NA
	Chile	1	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	NA
Additional Tagging Locations	Coastal Georgia	1	0 (0%)	0 (0%)	Argos, multiple locations every 2 days	Bird tagged in coastal Georgia during pre-breeding migration but was not tracked to wintering location

*Pre-breeding migration through Atlantic Canada would be uncommon or rare for this species.

Tracklines for Shorebirds in Area of Interest

In our first report to CWS (i.e., Phase I), we provided maps of individuals with tag transmissions in CWS' AOI ($n = 41$, **Figure 2a**). In Phase II, we identified an additional **61** individuals with tag transmissions outside of the AOI but with tracklines estimated through the AOI (**Figure 2b**). These additional tracklines tended to be from species tracked with GPS tags that record fewer locations than Argos tags (e.g., Lesser Yellowlegs, American Woodcock, and American Golden Plover; see **Tables 2** and **3** tag sampling intervals). **Figure 2c** shows all estimated shorebird movements through the AOI ($n = 102$). Note that these tracklines are drawn between locations from tag transmissions and actual flight paths of the birds vary from those shown. Thus, tracklines can provide valuable information about the proportion of tracked individuals that cross an area but less accurate information about the position of the animals in the area (see page 11 for maps showing positions of shorebirds in the AOI).

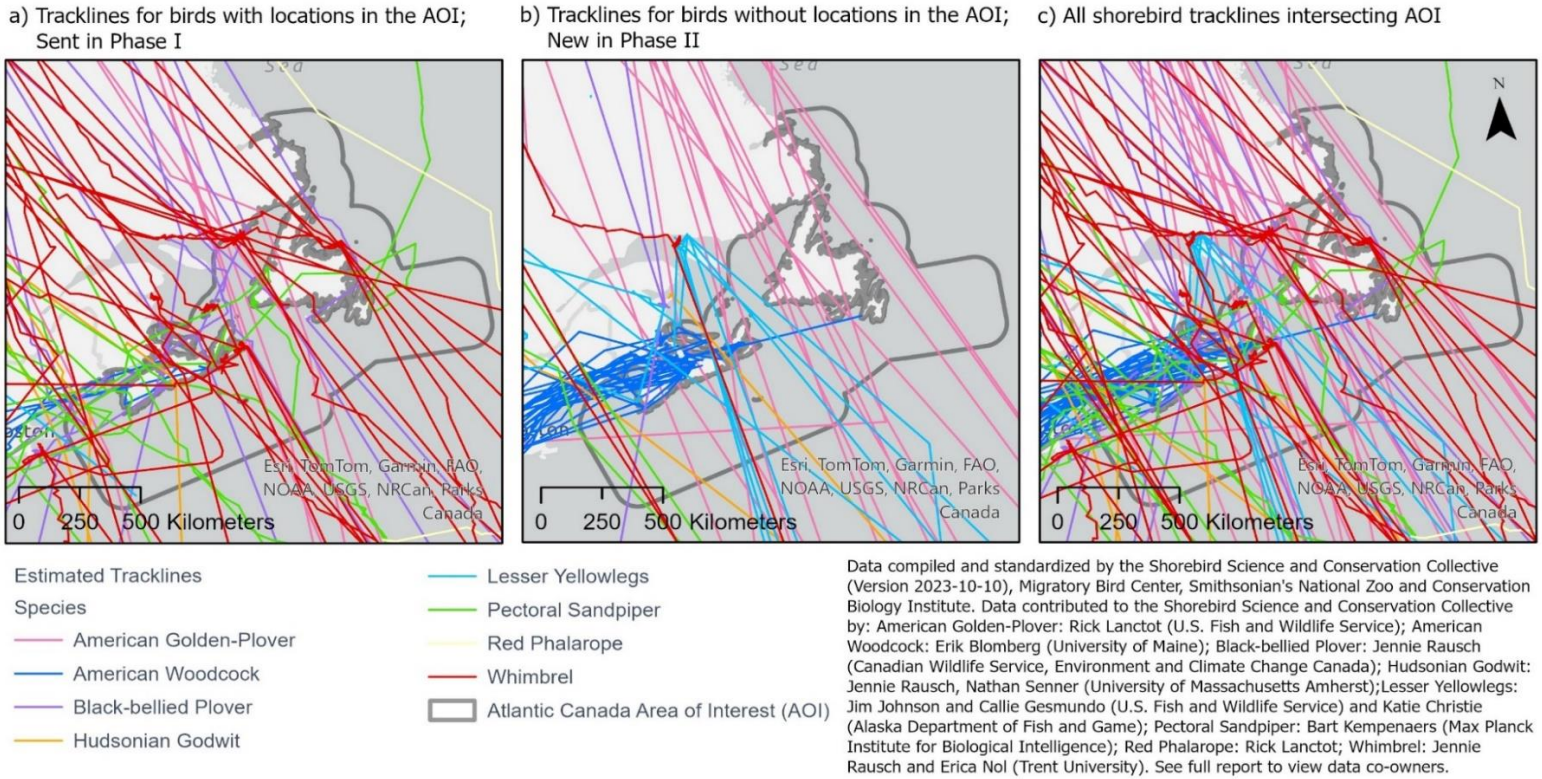
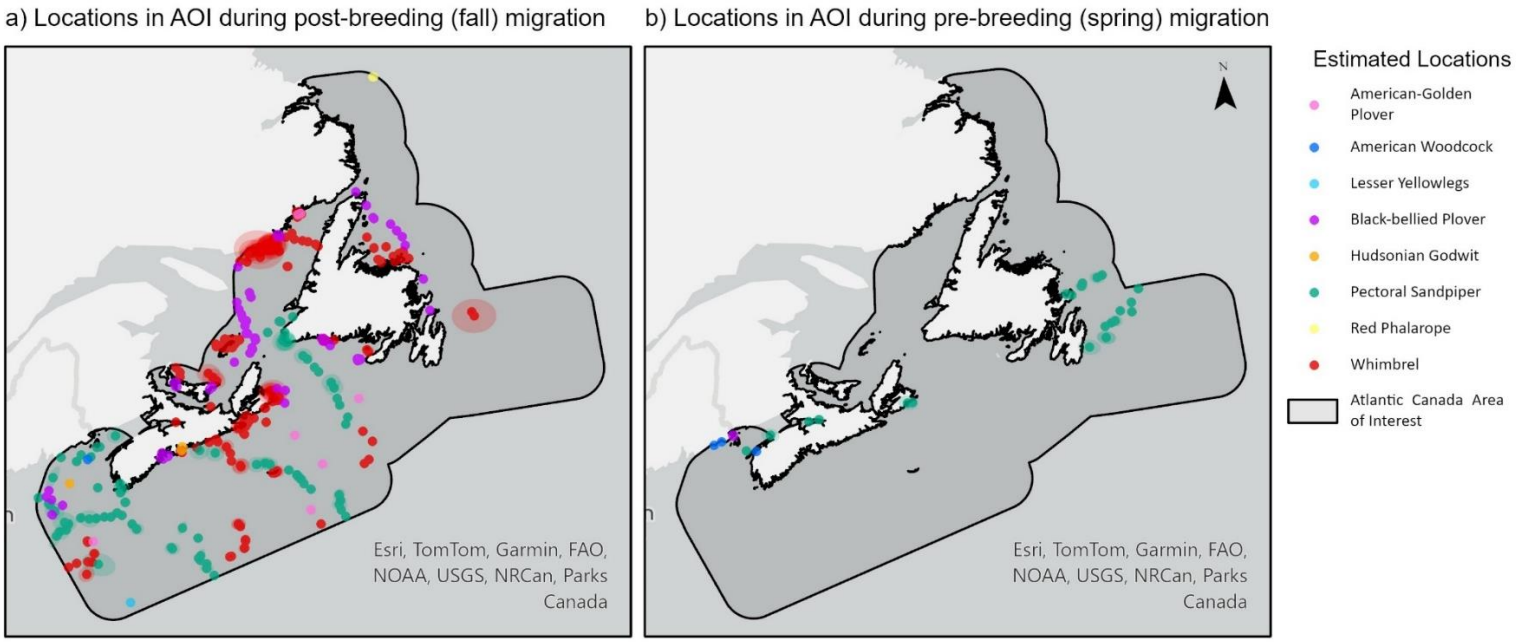


Figure 2. Estimated movement paths (tracklines) for tracked shorebirds in CWS' AOI. Panels include **a)** tracklines of individual birds with tag transmissions in the AOI ($n = 41$), **b)** additional tracklines estimated through the AOI where all tag transmissions were outside the AOI ($n = 61$), and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

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. In Phase I, we provided maps of tracked shorebird locations in CWS' AOI; here we expand to show these locations with estimates of spatial error to show confidence in the position of locations in the AOI (**Figure 3**). 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, see **Appendix I**). In **Figure 3** we show 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.

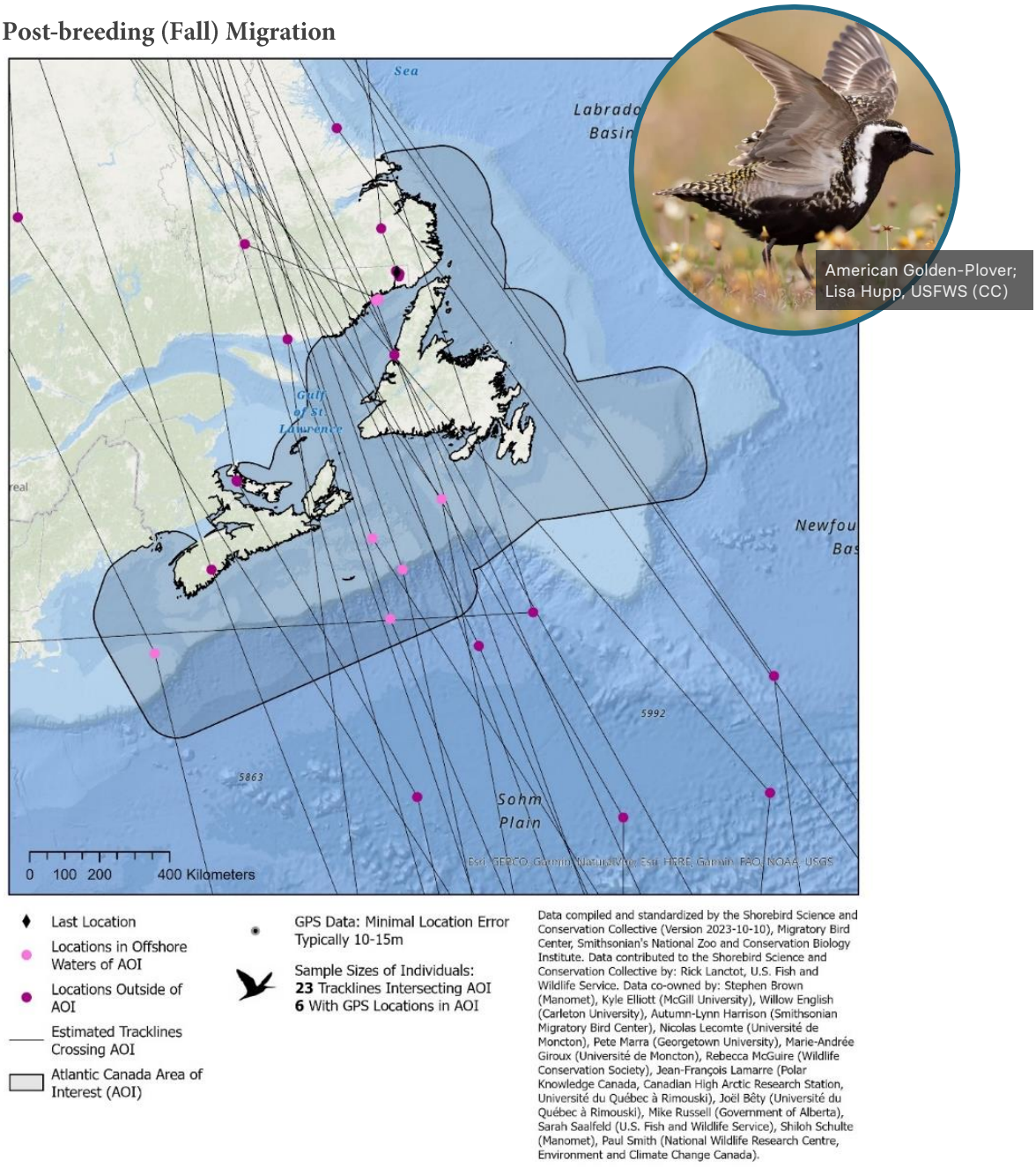
Figure 3. Locations of tracked Shorebirds in CWS' AOI during **a)** post-breeding (fall) and **b)** pre-breeding (spring) migration. Transparent polygons surrounding point locations indicate 95% confidence ellipses.

Species-specific Maps & Summary Information

In Phase I, we provided species maps and summary tables of tracked shorebirds with tag transmissions in CWS' AOI (n = 41); here we expand to also include the tracked birds (n = 61) with locations outside of the AOI but with tracklines estimated through the AOI (**Figure 4-14, Tables 4-11**)

American Golden-Plover

Post-breeding (Fall) Migration



American Golden-Plover; Lisa Hupp, USFWS (CC)

Figure 4. 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 a trackline intersecting the AOI. See Table 4 for additional tagging information.

Table 4. Tagging information for the tracked American Golden-Plovers with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
175197	Alaska, USA	Cayenne, French Guiana	2018
179676	Alaska, USA	Rio Grande do Sul, Brazil	2019
179689	Nunavut, Canada	Rio Grande do Sul, Brazil	2019
180586	Nunavut, Canada	Buenos Aires, Argentina	2019
200054	Nunavut, Canada	Pará, Brazil	2021
233009	Alaska, USA	Buenos Aires, Argentina	2022
Additional Birds w/ Tracks Intersecting AOI			
175190	Alaska, USA	Pará, Brazil	2018
175193	Alaska, USA	Buenos Aires, Argentina	2018
175196	Alaska, USA	Saint-Laurent-du-Maroni, French Guiana	2018
179668	Nunavut, Canada	Santa Fe, Argentina	2019
179674	Alaska, USA	Buenos Aires, Argentina	2021
179678	Alaska, USA	Treinta y Tres, Uruguay	2019
179681	Nunavut, Canada	Québec, Canada	2019
179686	Nunavut, Canada	Buenos Aires, Argentina	2019
179687	Alaska, USA	Rocha, Uruguay	2019
180583	Nunavut, Canada	Rocha, Uruguay	2019
180584	Nunavut, Canada	Rivera, Uruguay	2019
180585	Alaska, USA	Buenos Aires, Argentina	2019
180588	Nunavut, Canada	Buenos Aires, Argentina	2019
200057_2022	Alberta, Canada	Grand-Bourg, Guadeloupe	2022
200059	Alaska, USA	Buenos Aires, Argentina	2021
200060	Alaska, USA	Rocha, Uruguay	2021
233007	Alaska, USA	Brokopondo, Suriname	2022

American Golden-Plover tracks contributed by: Rick Lanctot, U.S. Fish and Wildlife Service.
Data Type: GPS Data
Duty Cycle: One location every two days

American Woodcock

Post-breeding (Fall) Migration

American Woodcock; Kieth Ramos, USFWS (CC)

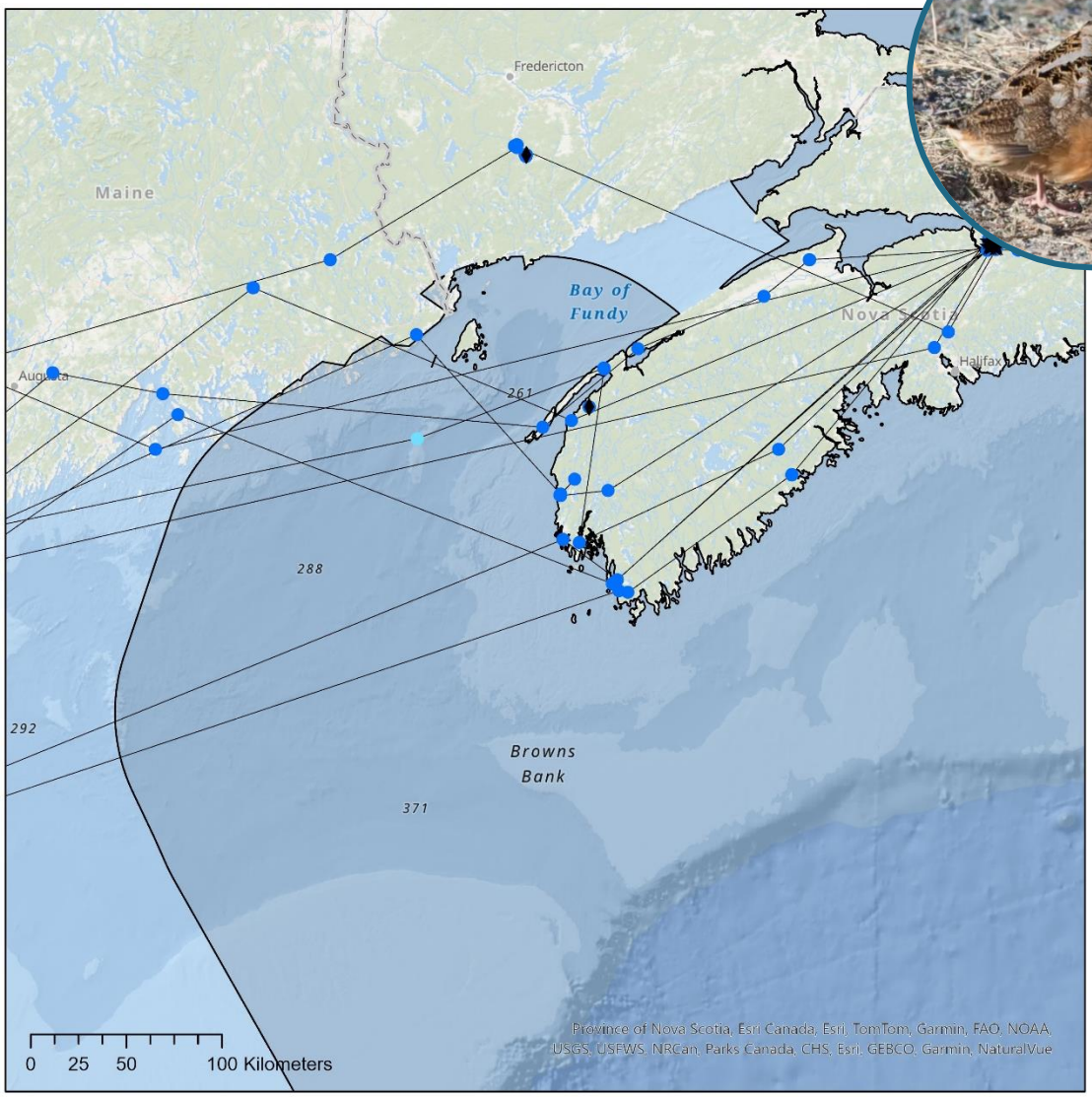


Figure 5. Tracked American Woodcock ($n = 10$) with estimated movements in CWS' AOI during post-breeding (fall) migration. One individual had tag transmissions within the AOI, 9 additional birds had a trackline intersecting the AOI. See Table 5 for additional tagging information.

Pre-breeding (Spring) Migration

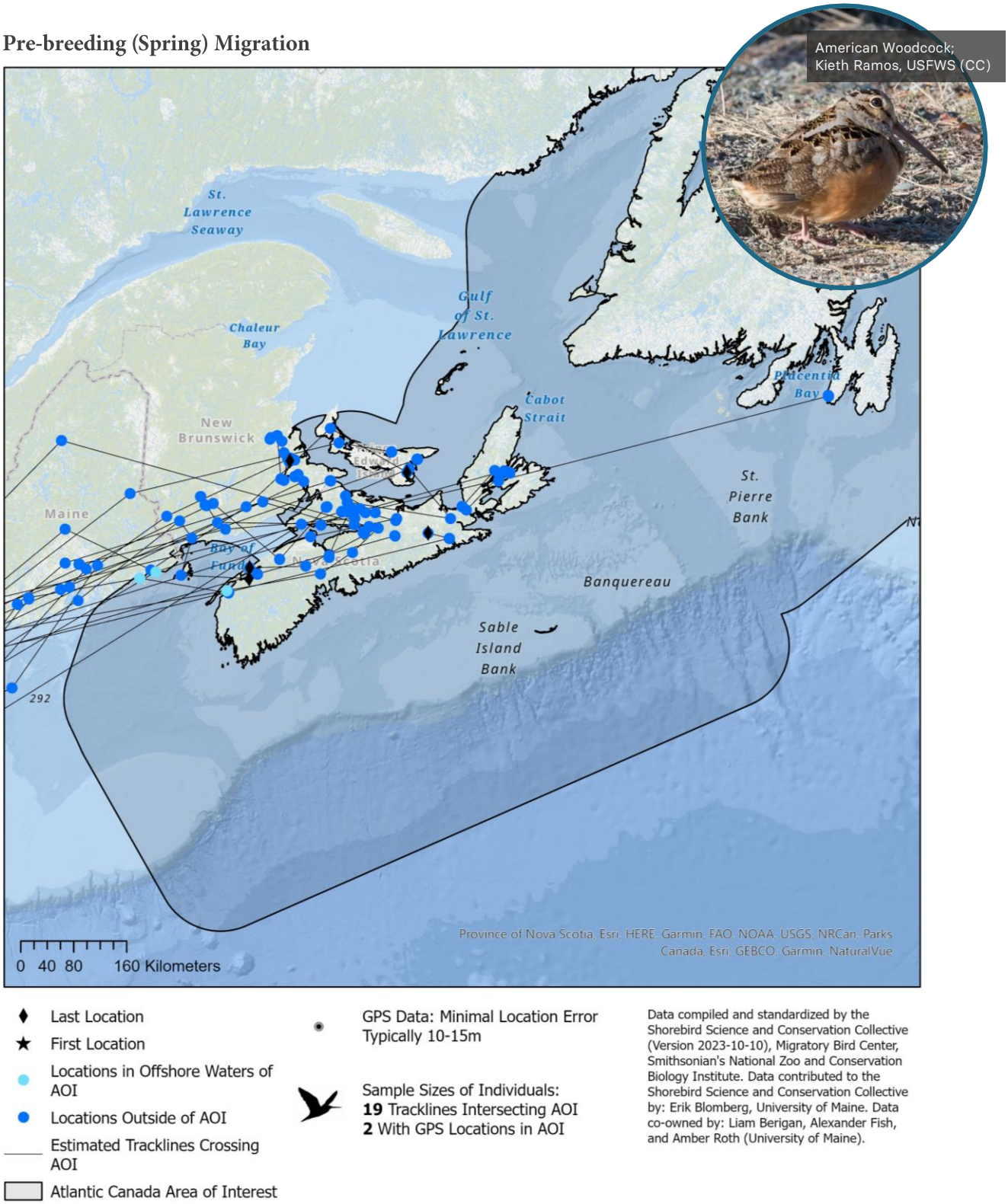


Figure 6. Tracked American Woodcock ($n = 19$) with estimated movements in CWS' AOI during pre-breeding (spring)migration. Two individuals had tag transmissions within the AOI, 17 additional birds had a trackline intersecting the AOI. See Table 5 for additional tagging information.

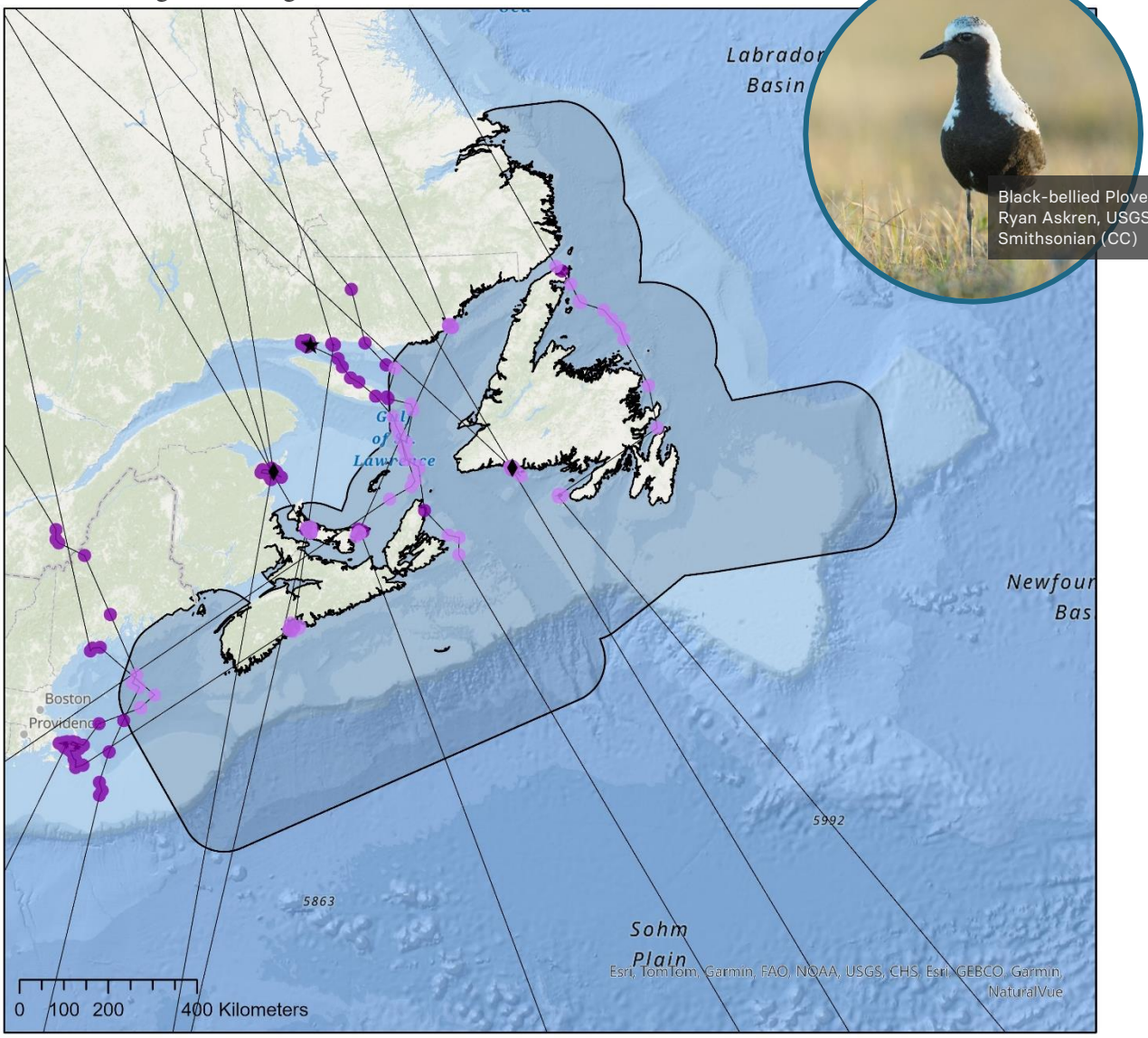
Table 5. Tagging information for the tracked American Woodcock with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
MD-2020-11	Maryland, USA	Maryland, USA	2020
NC-2022-35	North Carolina, USA	North Carolina, USA	2022
NS-2022-07	Nova Scotia, Canada	North Carolina, USA	2022
Additional Birds w/ Tracks Intersecting AOI			
FL-2022-06	Florida, USA	Florida, USA	2022
MD-2019-01	Maryland, USA	Maryland, USA	2019
MD-2021-18	Maryland, USA	Maryland, USA	2021
NC-2019-02	North Carolina, USA	North Carolina, USA	2019
NC-2020-06	North Carolina, USA	North Carolina, USA	2020
NC-2020-18	North Carolina, USA	North Carolina, USA	2020
NC-2021-21	North Carolina, USA	North Carolina, USA	2021
NC-2022-34	North Carolina, USA	North Carolina, USA	2022
NC-2022-36	North Carolina, USA	North Carolina, USA	2022
NC-2022-42	North Carolina, USA	North Carolina, USA	2022
NC-2022-44	North Carolina, USA	North Carolina, USA	2022
NJ-2018-04	New Jersey, USA	North Carolina, USA	2019
NJ-2018-05	New Jersey, USA	New Jersey, USA	2019
NJ-2019-18	New Jersey, USA	North Carolina, USA	2020
NS-2019-01	Nova Scotia, Canada	North Carolina, USA	2019
NS-2019-02	Nova Scotia, Canada	Maryland, USA	2019
NS-2019-03	Nova Scotia, Canada	Virginia, USA	2019
NS-2019-04	Nova Scotia, Canada	Virginia, USA	2019
NS-2019-05	Nova Scotia, Canada	South Carolina, USA	2019
NS-2019-06	Nova Scotia, Canada	New Jersey, USA	2019
NS-2022-08	Nova Scotia, Canada	New Jersey, USA	2022
NS-2022-09	Nova Scotia, Canada	North Carolina, USA	2022
NS-2022-10	Nova Scotia, Canada	North Carolina, USA	2022
VA-2020-51	Virginia, USA	Virginia, USA	2020
VA-2021-94	Virginia, USA	Virginia, USA	2022

American Woodcock tracks contributed by: Erik Blomberg, University of Maine
Data Type: GPS Data
Duty Cycle: One location every one to two days

Black-bellied Plover

Post-breeding (Fall) Migration



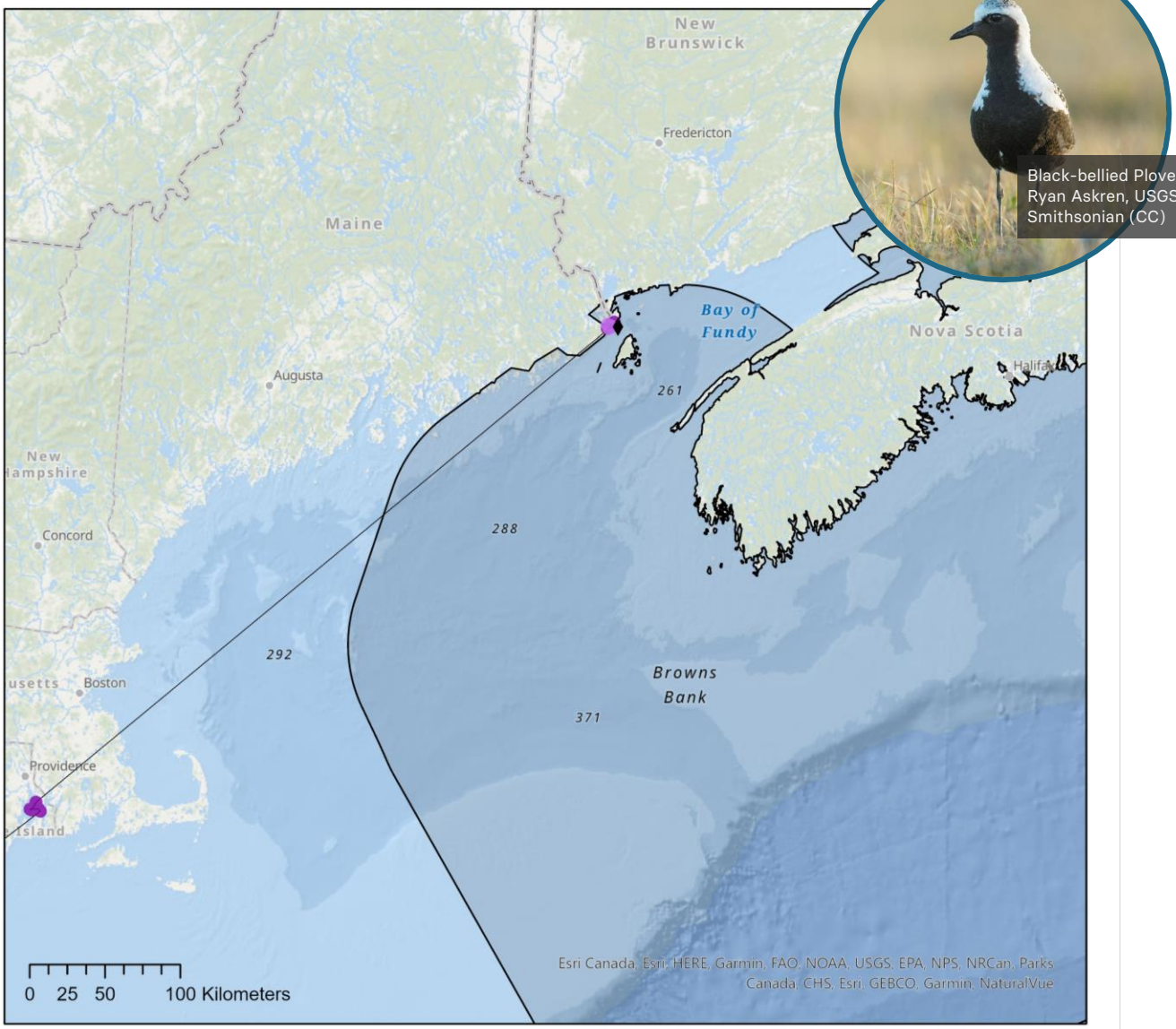
Black-bellied Plover; Ryan Askren, USGS/ Smithsonian (CC)

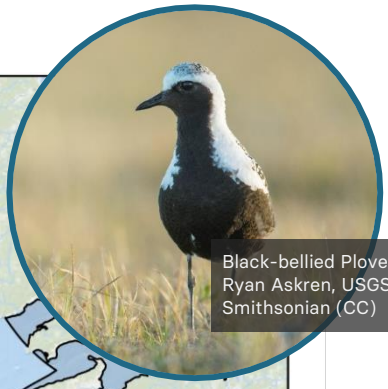
- Last Location
- First Location
- Estimated Locations in Offshore Waters of AOI
- Estimated Locations Outside of AOI
- Estimated Tracklines Crossing AOI
- Atlantic Canada Area of Interest
- Argos Data: Moderate Location Error Typically Between 250 and 1,500 m
- Sample Sizes of Individuals:
  10 Tracklines Intersecting AOI
  9 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: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada. Data co-owned by: Paul Woodard (Canadian Wildlife Service, Environment and Climate Change Canada).

Figure 7. 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. See Table 6 for additional tagging information.

Pre-breeding (Spring) Migration





Black-bellied Plover; Ryan Askren, USGS/ Smithsonian (CC)

Figure 8. Tracked Black-bellied Plover ($n = 1$) with tag transmissions in CWS' AOI during pre-breeding (spring)migration. See Table 6 for additional tagging information.

Table 6. Tagging information for the tracked Black-bellied Plovers with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
Anuri	Nunavut, Canada	Massachusetts, USA	2017
Florian	Québec, Canada	Saragasso Sea, Atlantic Ocean	2015
Kanataupullunga	Nunavut, Canada	Camagüey, Cuba	2016
Nammagaaq	Nunavut, Canada	Curaçao	2017
Nuliaq	Nunavut, Canada	Pará, Brazil	2017; 2018
Quqsuqtuq	Nunavut, Canada	Maranhão, Brazil	2015; 2016
Tallimat	Nunavut, Canada	Saint Catherine, Jamaica	2016
Tallirmiq	Nunavut, Canada	Camagüey, Cuba	2016
Tungujuqtuq	Nunavut, Canada	Saragasso Sea, Atlantic Ocean	2015
Additional Bird w/ Tracks Intersecting AOI			
Aupajaangajuq	Nunavut, Canada	Falcón, Venezuela	2016

Black-bellied Plover tracks contributed by: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada

Data Type: Argos Data

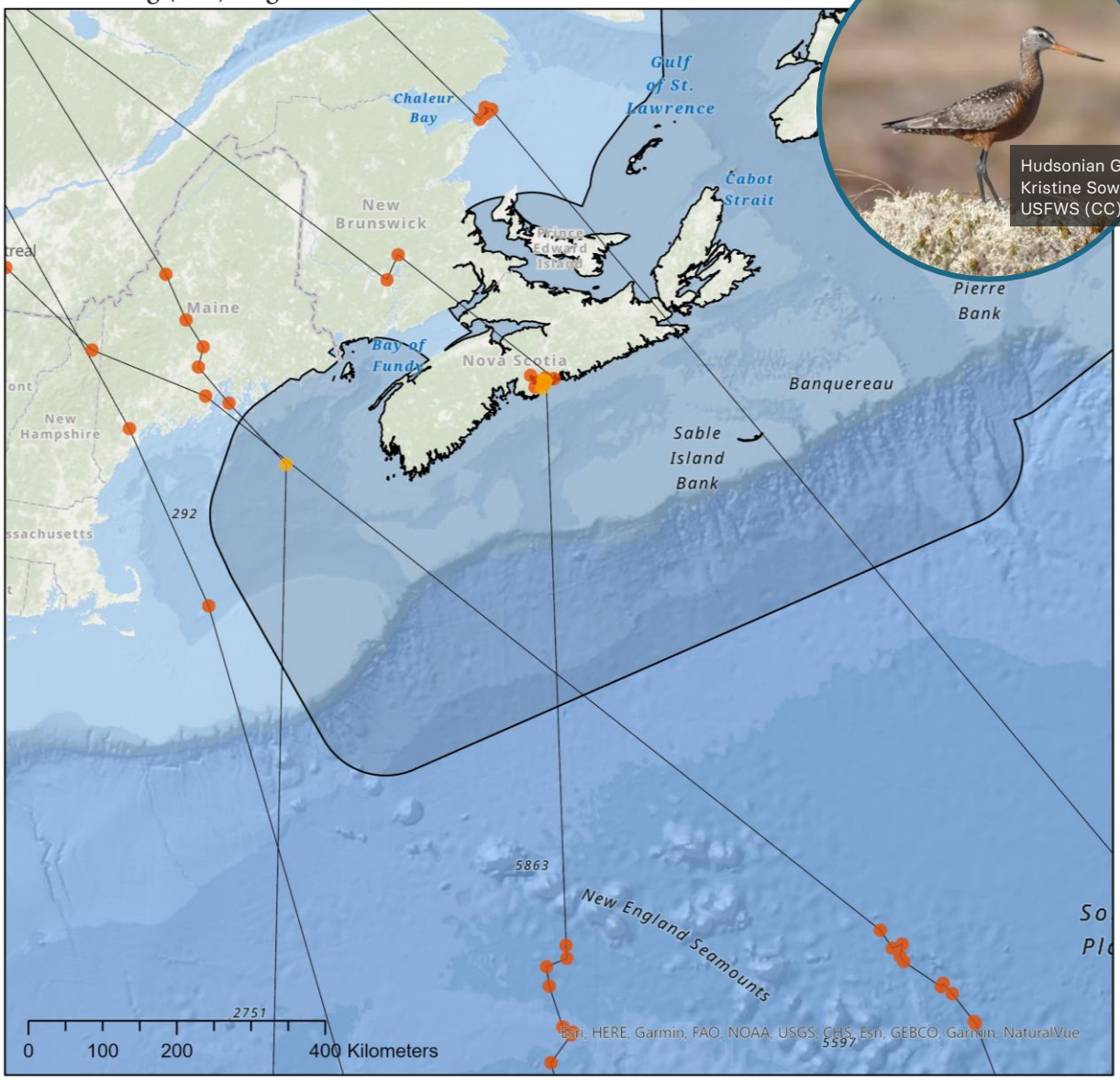
Duty Cycle: Multiple locations every two days

Hudsonian Godwit

Federally Threatened Species in Canada

Post-breeding (Fall) Migration

Hudsonian Godwit; Kristine Sowl, USFWS (CC)



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 9. 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. See Table 7 for additional tagging information.

Table 7. Tagging information for the tracked Hudsonian Godwits with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
KCH	Lagos, Chile	Lagos, Chile	2019
Sig	Northwest Territories, Canada	Magallanes, Chile	2013
Additional Birds w/ Tracks Intersecting AOI			
Delta	Northwest Territories, Canada	Pará, Brazil	2016
Kendall	Northwest Territories, Canada	Santa Cruz, Argentina	2013

Hudsonian Godwit tracks contributed by: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada and Nathan Senner, University of Massachusetts Amherst

Data Type: Argos Data

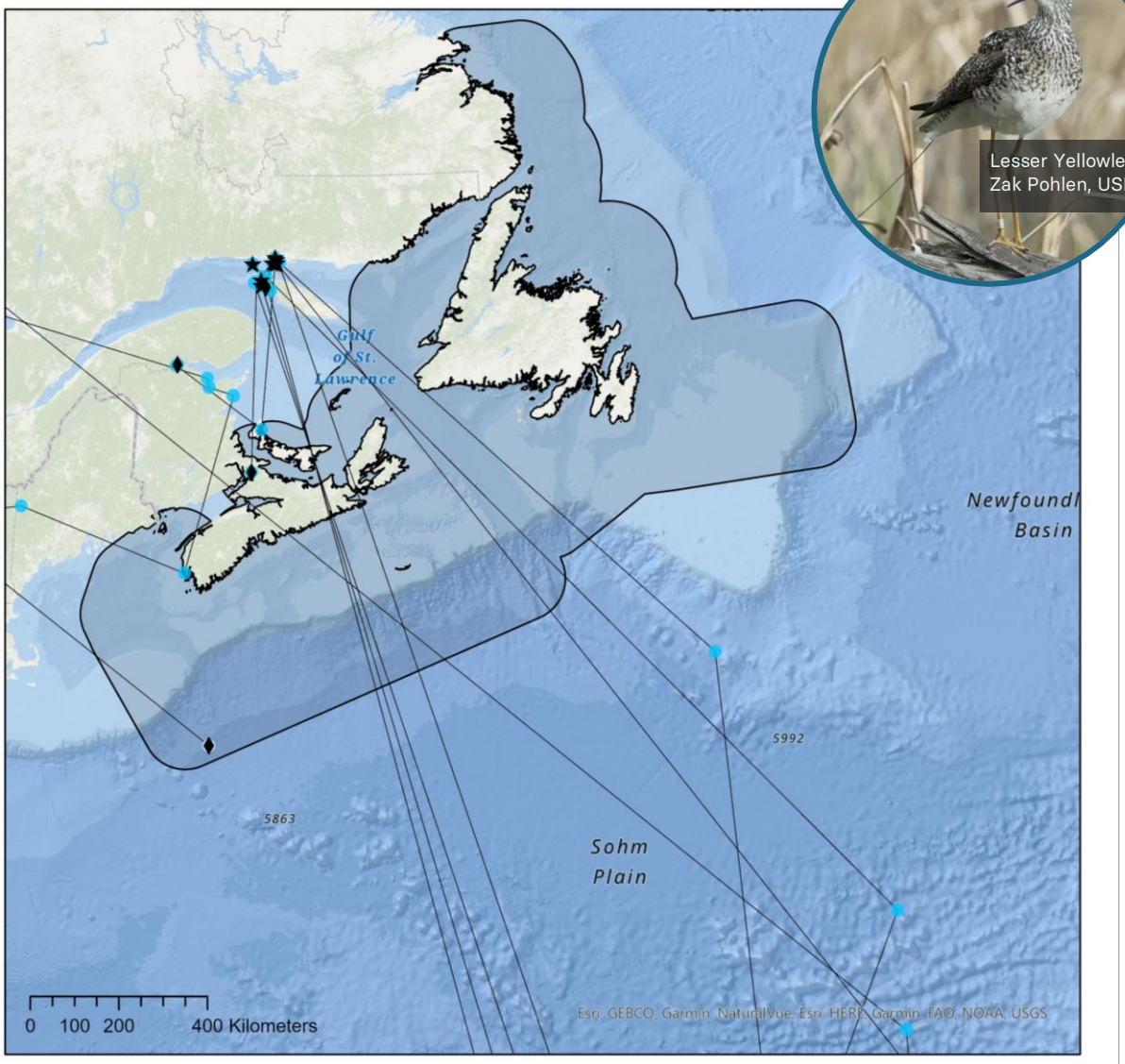
Duty Cycle: Multiple daily locations

Lesser Yellowlegs

Federally Threatened Species in Canada

Post-breeding (Fall) Migration

Lesser Yellowlegs;
Zak Pohlen, USFWS (CC)



- Last Location
- First Location
- Estimated Locations in Offshore Waters of AOI
- Estimated 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:
12 Tracklines Intersecting AOI
1 With GPS Location in AOI

* Some of these tags also recorded a small number of Argos locations in the same location as the GPS points

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: Jim Johnson and Callie Gesmundo (U.S. Fish and Wildlife Service) and Katie Christie (Alaska Department of Fish and Game). Data co-owned by: Laura McDuffie (U.S. Geological Survey, Alaska Science Center), Christian Friis (Canadian Wildlife Service, Environment and Climate Change Canada), Christopher Harwood (U.S. Fish and Wildlife Service), Benoit Laliberté (Canadian Wildlife Service, Environment and Climate Change Canada), Erica Nol (Trent University), Jennie Rausch (Canadian Wildlife Service, Environment and Climate Change Canada), Audrey Taylor (University of Alaska Anchorage), Jay Wright (Ohio State University), Joint Base Elmendorf-Richardson, U.S. Department of Defense.

Figure 10. 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 See Table 8 for additional tagging information.

Table 8. Tagging information for the tracked Lesser Yellowlegs with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
A79 (179751)	Manitoba, Canada	New England Seamounts, Atlantic Ocean	2019
Additional Birds w/ Tracks Intersecting AOI			
1E4 (179772)	Ontario, Canada	Maranhão, Brazil	2019
A89 (181615)	Québec, Canada	Rocha, Uruguay	2019
A92 (181622)	Québec, Canada	Prince Edward Island, Canada	2019
HAC (179765)	Québec, Canada	Maranhão, Brazil	2020
HAP (179768)	Québec, Canada	Buenos Aires, Argentina	2020
HAU (179767)	Québec, Canada	Demerara-Mahaica, Guyana	2020
HMA (179766)	Québec, Canada	New Brunswick, Canada	2020
5A4 (175316)	Ontario, Canada	New York, USA	2018
HAA (183505)	Québec, Canada	Rio Grande do Norte, Brazil	2020
HAH (183503)	Québec, Canada	Piauí, Brazil	2020
HAL (183506)	Québec, Canada	Ceará, Brazil	2020

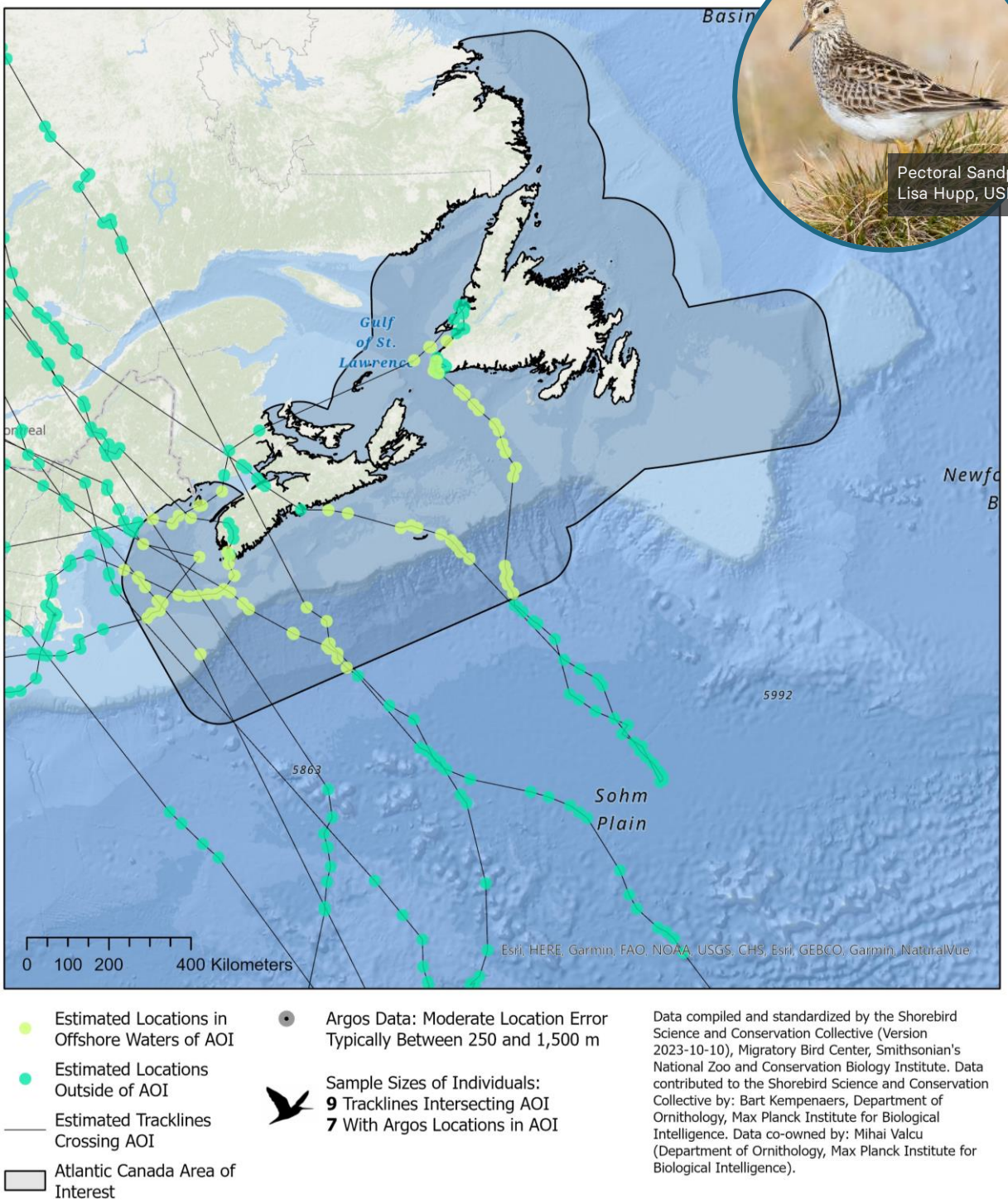
Lesser Yellowlegs track contributed by: Jim Johnson and Callie Gesmundo, U.S. Fish and Wildlife Service, and Katie Christie, Alaska Department of Fish and Game

Data Type: GPS Data; GPS & Argos Data

Duty Cycle: GPS, One location every two to four days; GPS & Argos, One to two locations every two to four days

Pectoral Sandpiper

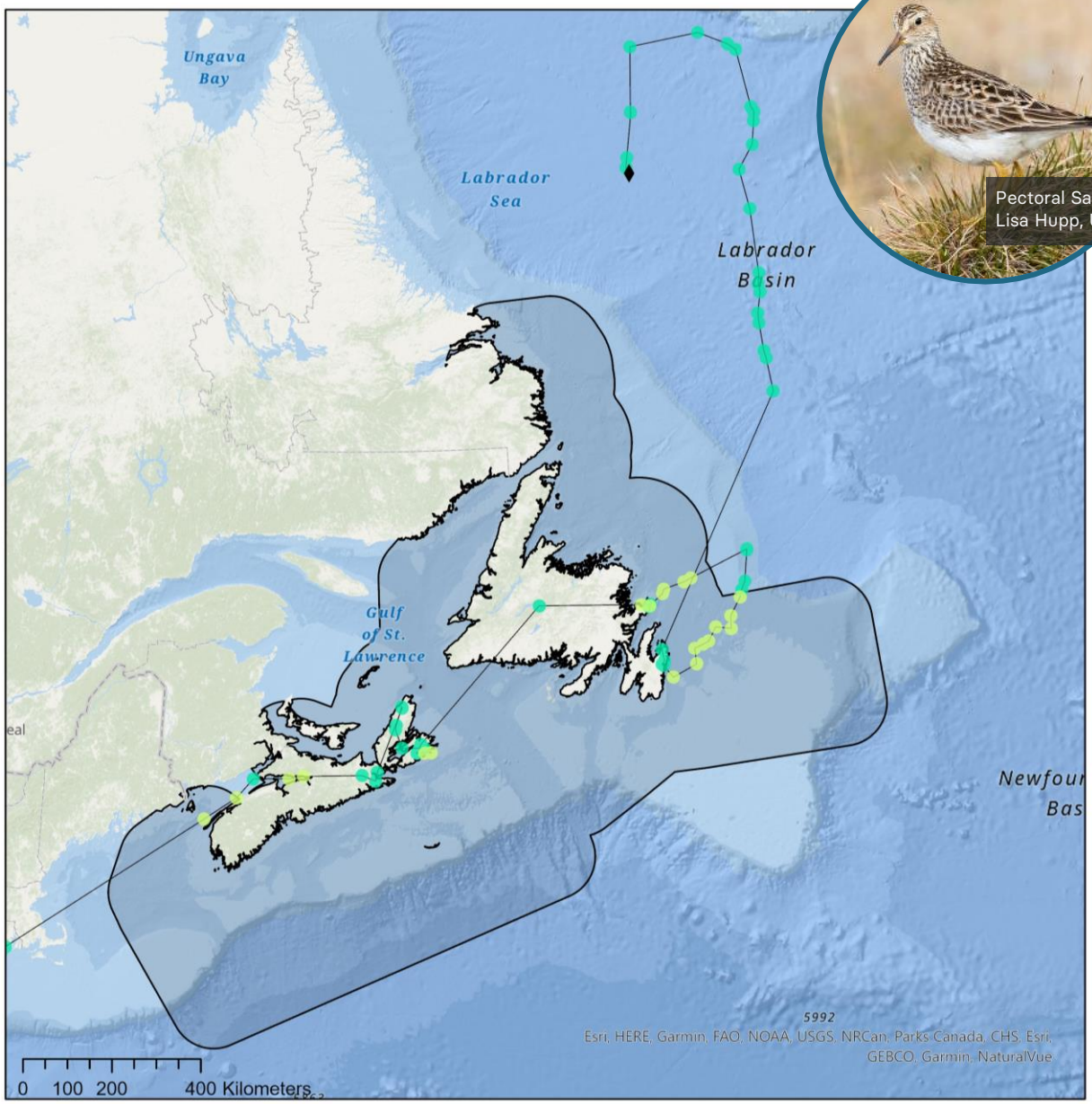
Post-breeding (Fall) Migration




Pectoral Sandpiper; Lisa Hupp, USFWS (CC)

Figure 11. 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. See Table 9 for additional tagging information.

Pre-breeding (Spring) Migration




Pectoral Sandpiper; Lisa Hupp, USFWS (CC)

Figure 12. Tracked Pectoral Sandpiper ($n = 1$) with tag transmissions in CWS' AOI during pre-breeding (spring) migration. See Table 9 for additional tagging information.

Table 9. Tagging information for the tracked Pectoral Sandpipers with estimated movements in CWS' AOI

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
143729	Alaska, USA	Rondônia, Brazil	2016
143775	Alaska, USA	Santa Fe, Argentina	2016
158150	Alaska, USA	Dominica	2016
52723	Alaska, USA	Beni, Bolivia	2018
66655	Alaska, USA	Caribbean Sea	2019
66664	Alaska, USA	Cerro Largo, Uruguay	2019
66683	Alaska, USA	Buenos Aires, Argentina	2020
Additional Birds w/ Tracks Intersecting AOI			
158149	Alaska, USA	200km north of Venezuela (offshore)	2016
52789	Alaska, USA	Antigua, Antigua and Barbuda	2018

Pectoral Sandpiper tracks contributed by: Bart Kempenaers, Department of Ornithology, Max Planck Institute for Biological Intelligence

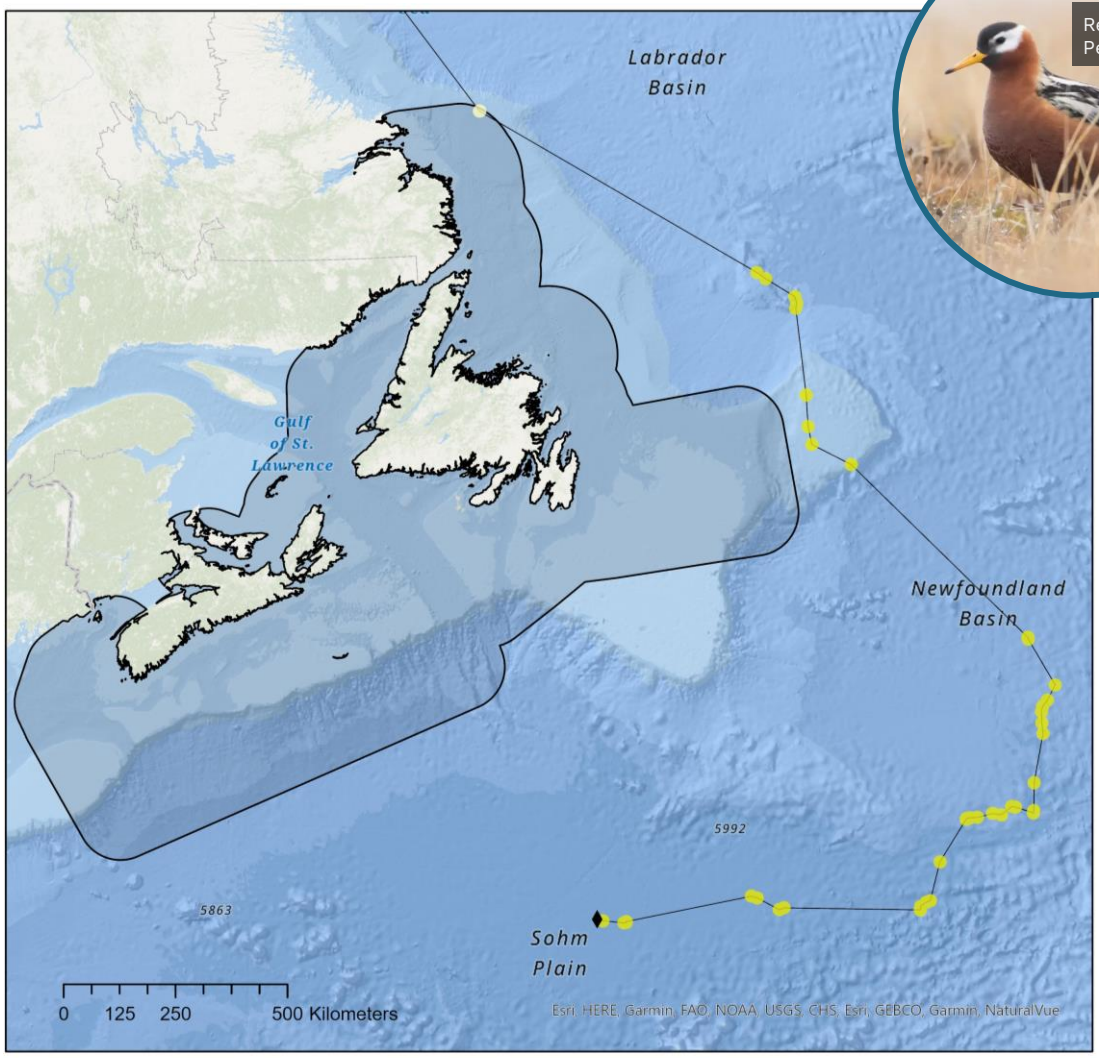
Data Type: Argos Data

Duty Cycle: Multiple daily locations

Red Phalarope

Post-breeding (Fall) Migration

Red Phalarope, Peter Pearsall, USFWS (CC)



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: Rick Lanctot, U.S. Fish and Wildlife Service. Data co-owned by: Stephen Brown (Manomet), Kyle Elliott (McGill University), Willow English (Carleton University), Autumn-Lynn Harrison (Smithsonian Migratory Bird Center), Nicolas Lecomte (Université de Moncton), Amy Scarpignato (Smithsonian Migratory Bird Center), Marie-Andrée Giroux (Université de Moncton), Rebecca McGuire (Wildlife Conservation Society), Jean-François Lamarre (Polar Knowledge Canada, Canadian High Arctic Research Station, Université du Québec à Rimouski), Christopher Latty (U.S. Fish and Wildlife Service), Sarah Saalfeld (U.S. Fish and Wildlife Service), Shiloh Schulte (Manomet), Paul Smith (National Wildlife Research Centre, Environment and Climate Change Canada).

Figure 13. Tracked Red Phalarope ($n = 1$) with tag transmissions in CWS' AOI during post-breeding (fall) migration. See Table 10 for additional tagging information.

Table 10. Tagging information for the tracked Red Phalarope with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individual w/ Tag Transmissions in AOI			
179789	Nunavut, Canada	Sohm Plain, Atlantic Ocean	2019

Red Phalarope track contributed by: Rick Lanctot, U.S. Fish and Wildlife Service
Data Type: Argos Data
Duty Cycle: Multiple daily locations

Whimbrel

Post-breeding (Fall) Migration

Whimbrel; Rachel Richardson, USGS Alaska Science Center (CC)

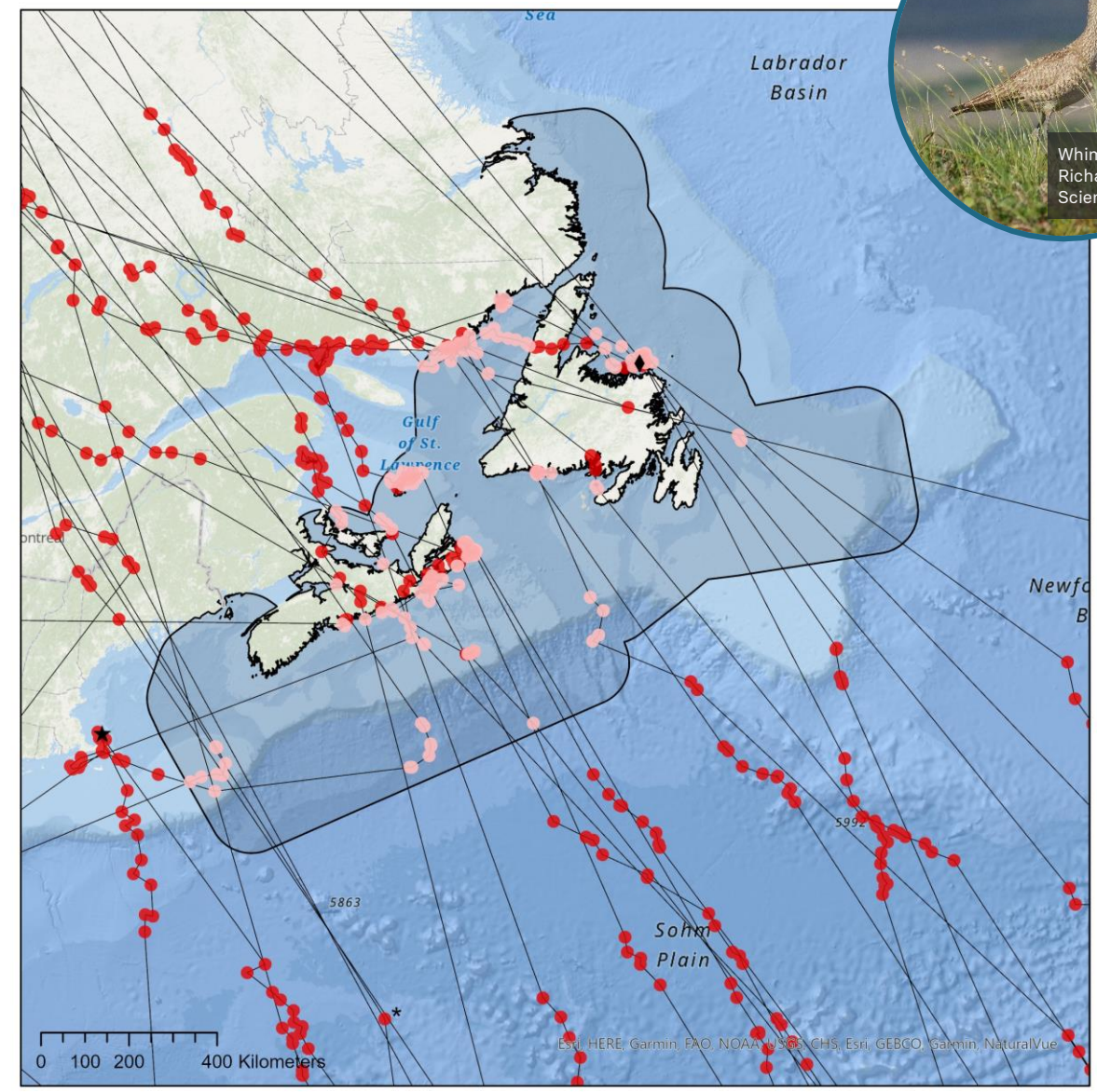


Figure 14. Tracked Whimbrels (n = 15) with estimated movements in CWS' AOI during post-breeding (fall) migration. 12 individuals had tag transmissions within the AOI, three additional birds had a trackline intersecting the AOI. See Table 11 for additional tagging information.

Table 11. Tagging information for the tracked Whimbrels with estimated movements in CWS' AOI.

Individual Bird ID	Tagging Location	Furthest South Location	Years Detected in AOI
Individuals w/ Tag Transmissions in AOI			
103520-Pingo	Northwest Territories, Canada	Maranhão, Brazil	2012; 2013
103521-Akpik	Northwest Territories, Canada	Maranhão, Brazil	2012
103522-Taglu	Northwest Territories, Canada	Maranhão, Brazil	2012; 2013
123745-Aolayaatok	Northwest Territories, Canada	Pará, Brazil	2013
123746-Banks	Northwest Territories, Canada	Pará, Brazil	2013
123748-Southhampton	Northwest Territories, Canada	Maranhão, Brazil	2013
133734-Arvoknar	Northwest Territories, Canada	Pará, Brazil	2014
133735-Upinraaq	Northwest Territories, Canada	Maranhão, Brazil	2014; 2015; 2016
176012-Ahanu	Massachusetts, USA	Maranhão, Brazil	2019
50121-Miller	Virginia, USA	Pará, Brazil	2010
74854-Mackenzie	Northwest Territories, Canada	Ceará, Brazil	2012; 2013
88043-Hope	Virginia, USA	Maranhão, Brazil	2011; 2016
Additional Birds w/ Tracks Intersecting AOI			
133736-Taimunga	Northwest Territories, Canada	Maranhão, Brazil	2014
84206-Chinquapin	Georgia, USA	Saramacca, Suriname	2010
NM	Manitoba, Canada	Pará, Brazil	2019

Whimbrel tracks contributed by: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada, and Erica Nol, Trent University

Data Type: Argos Data; GPS Data

Duty Cycle: Argos, Multiple daily locations; GPS, One daily location

Density Maps of Tracked Shorebirds near AOI

We summarized the number of shorebird species (**Figure 15a)** and individuals (**Figure 15b**) tracked 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.

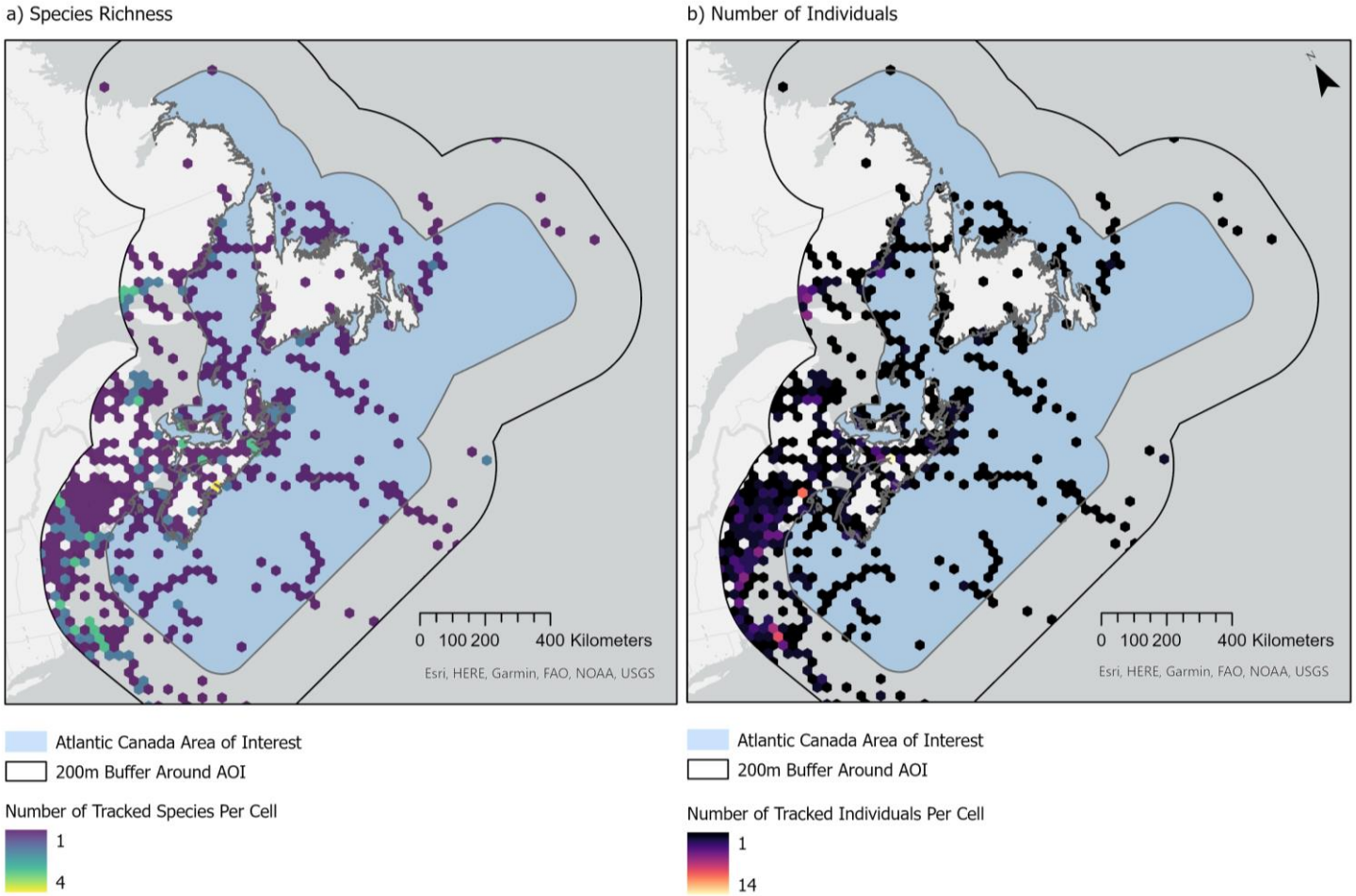


Figure 15. Density of tracked **a)** species and **b)** individual shorebirds contributed to the Shorebird Collective within 200 km of CWS' AOI. Each cell is a 30km hexagon, and counts per cell are summed from the number of species or individuals with an estimated location in the cell at the original sampling interval of the tag.

Seasonal Timing of Movements Through Atlantic Canada

We examined the seasonal timing of movements of tracked shorebirds through the 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 CWS' 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 16**). Tracking data is limited for pre-breeding (spring) migration, so additional data (such as eBird data) is needed to clarify pre-breeding migration timing patterns.

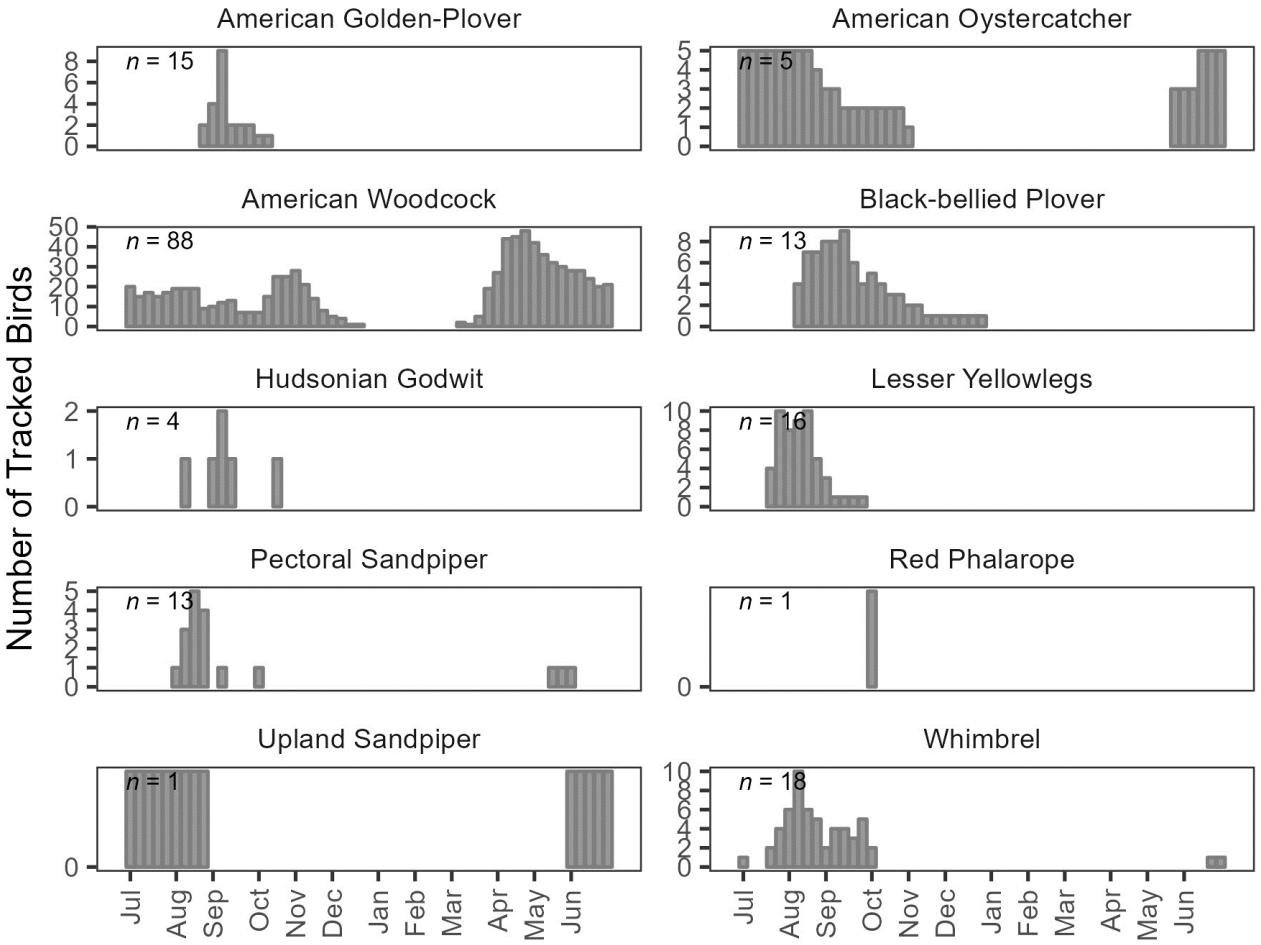


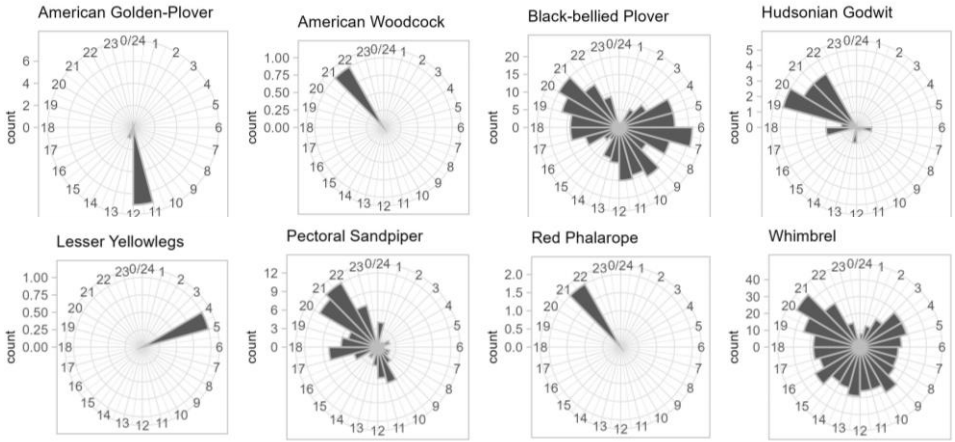
Figure 16. The number of shorebirds contributed to the Shorebird Collective, grouped by species, and tracked within 200 km of CWS' AOI throughout the year.

Timing of Transmissions in Offshore AOI

We examined the timing of transmissions from tagged shorebirds that occurred over offshore waters of CWS' AOI (**Figure 17**). 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 17a**). 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** (sunset in Halifax, NS on Sept 1 is typically around 20:00 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 17** 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

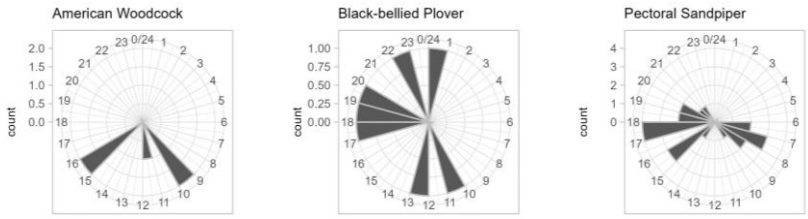


Figure 17. Counts of the number of transmissions that occurred in CWS' AOI. Timestamps were rounded to the nearest hour in ADT (America/Halifax time) prior to calculating counts. Note the limited sample sizes for some species (especially Lesser Yellowlegs and Red Phalarope) and during pre-breeding (spring) migration.

Flight Altitude Information

Data on the flight heights of shorebirds are currently limited, and only three shorebirds with transmissions in the AOI were tracked with devices that also recorded altitude. These three American Woodcocks 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, National Renewable Energy Lab (CC); Black-bellied Plover with leg flag and <5g solar satellite tag, 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 collision risk 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*).

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 contributing organizations to the Shorebird Collective can be found at: https://nationalzoo.si.edu/migratory-birds/shorebird-collective.

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]

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Hudsonian Godwit Tracks:

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Associated Citation: Linscott, J. A., Navedo, J. G., Clements, S. J., Loghry, J. P., Ruiz, J., Ballard, B. M., Weegman, M. D., & 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:

Jim Johnson*[1], Callie Gesmundo*[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.

Katherine Christie*[23], Jim Johnson[1]

Unpublished data, Alaska Department of Fish and Game, U.S. Fish and Wildlife Service

Pectoral Sandpiper Tracks:

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Red Phalarope Track:

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Whimbrel Tracks:

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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.

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Appendix I: Tag Types & Summary of Methods

Data Cleaning and Estimation of Movement Paths

Argos and GPS data have spatial error and, at times, record erroneous positions (e.g., timestamps in the future, latitudes and longitudes that don't exist, etc.). The Shorebird Collective runs a standard set of filters on each dataset to remove obvious false detections. For tags collecting Argos data, we use statistical models to estimate the most probable location of an animal accounting for error patterns associated with Argos data and estimate 95% confidence ellipses around locations (Jonsen 2023[3]). Those locations are then used to estimate the most probable movement path of the animal. For individuals with tags that only record GPS data, movement paths are estimated assuming no spatial error surrounding the recorded location.

In this report we use the term "**location**" or "**tag transmission**". For tags collecting the following types of data this means:

Tag Data Types Collected	Description of "Location" or "Tag Transmission"
Argos only	The most probable latitude and longitude point location for the individual at the timestamp the position was recorded
GPS only (in this study, some PinPoint GPS Argos tags)	The latitude and longitude point location recorded by the tag
GPS with some Argos locations (some PinPoint GPS Argos tags)	The most probable latitude and longitude point location for the individual at the timestamp the position was recorded

We also use the term "**trackline**". For tags collecting the following types of data this means:

Tag Data Types Collected	Description of "Trackline"
Argos only	The most probable movement path of the individual determined by estimating locations accounting for spatial error
GPS only (in this study, some PinPoint GPS Argos tags)	A moment path created assuming no spatial error of recorded latitude or longitude locations
GPS with some Argos locations (some PinPoint GPS Argos tags)	The most probable movement path of the individual determined by estimating locations accounting for spatial error

Assignment of Breeding and Wintering Areas

To estimate the proportion of individuals moving through CWS' AOI, we assigned tracked individuals to breeding and wintering areas. We did this because birds breeding or wintering in different areas may have differential exposure to the offshore AOI (see clearly separated full annual cycle tracklines for Black-bellied Plovers in the western, central, and eastern portions of the Western Hemisphere, **Figure A1.a**). When an individual was tagged during migration, we followed its movement path to a breeding or wintering area (if possible) and assigned it to a relevant group. In many cases, tags stopped recording locations during post-breeding migrations (e.g., purple tracklines that stop abruptly over the Atlantic, **Figure A1.a**), resulting in fewer full annual cycle tracklines assigned to wintering areas.

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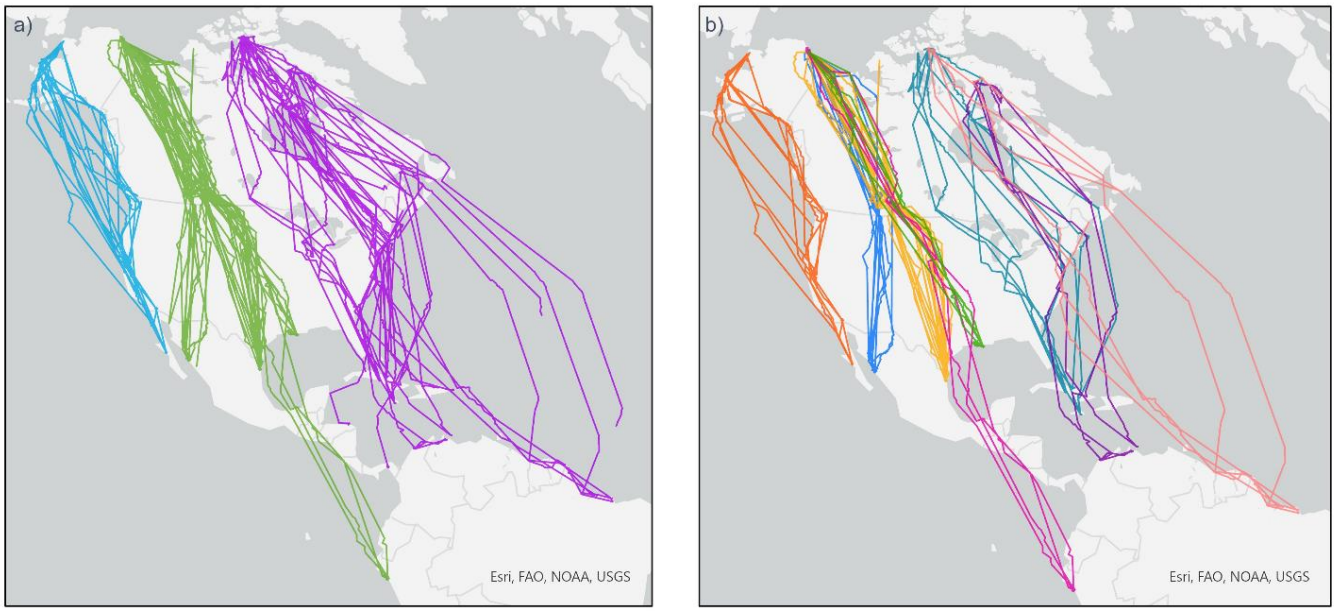

Data compiled and standardized by the Shorebird Science and Conservation Collective (Version 2023-10-10), Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute. Data contributed to the Shorebird Science and Conservation Collective by: Jennie Rausch, Canadian Wildlife Service, Environment and Climate Change Canada and Autumn-Lynn Harrison, Smithsonian Migratory Bird Center. Data co-owned by: Paul Woodard (Canadian Wildlife Service, Environment and Climate Change Canada), Lee Tibbitts (USGS Alaska Science Center), and David Newstead (Coastal Bend and Bays Estuary Program).

Figure A1. Full tracklines for Black-bellied Plovers tracked with Argos and GPS satellite tags from different **a)** breeding and **b)** wintering areas.