ENVIRONMENT AND CLIMATE CHANGE CANADA

ARCTIC COASTAL BIRDS & ECOSYSTEMS

2023 FIELD SEASON AND RESEARCH REPORT

FIELD SEASON OVERVIEW

The coastal Arctic is home to millions of breeding birds each summer, including a wide diversity of shorebirds. Although they are uncommon in many parts of Canada, shorebirds are the most abundant and diverse group of birds in coastal Arctic tundra. However, due to large and accelerating declines, the shorebirds are a group of significant conservation concern. Our research focuses on shorebirds as a key component of Arctic ecosystems, and we aim to better understand shorebird ecology and the Arctic ecosystems where they breed, to inform the management and conservation of these species.

Our work focuses on 1) understanding long-term changes in the breeding ecology of shorebirds and other tundra birds in relation to changing conditions in the Arctic, 2) using innovative tracking technology to follow shorebirds throughout the annual cycle to identify threats to populations elsewhere in their ranges, and 3) developing novel techniques to refine knowledge of population status. We collaborate extensively with international researchers working throughout the globe-spanning ranges of shorebirds, to better understand the challenges these species face in a world shaped by changes due to climate and human development.

In 2023, we conducted fieldwork at two of our long-term research sites: The East Bay Mainland camp at Qaqsauqtuuq on Southampton Island, NU, and our field site on Prince Charles Island in the Foxe Basin, NU (Figure 1). East Bay Mainland is one of the longest running monitoring sites in Arctic North America, with continuous datasets on Arctic-breeding bird communities, vegetation and climate that span a quarter century. At Prince Charles Island, 2023 was our fourth field season operating the camp, which was developed to provide a mid-Arctic site for studies of shorebirds and geese, and to offer a strategic location from which to monitor environmental changes in the Foxe Basin. Prince Charles Island is a key area for nesting Atlantic Brant, a goose species that has declined in recent decades in contrast to the boom in populations of Snow and Ross’ Geese; the infrastructure at our camp provides an excellent opportunity to monitor a nesting population of Brant. This year, in collaboration with the Canadian Wildlife Service,

Below: King Eiders in flight at Qaqsauqtuuq Migratory Bird Sanctuary

we established permanent sampling plots to monitor the nesting bird community, laying the foundation for continued monitoring at this site in years to come.

This year, we also completed breeding bird surveys in the Ikkattuaq Migratory Bird Sanctuary on Southampton Island, NU, as part of a special project that began in 2022 in collaboration with the Irniurviit Area Co-Management Committee (ACMC) to support the management objectives for this protected area. These surveys, in conjunction with archaeological surveys completed by an archaeologist from Inuit Heritage Trust during our 2022 field season, are designed to support ACMC priorities, employ local participants from Coral Harbour to assist in the surveys, and to develop capacity in the community to continue monitoring efforts in the protected area.

While we did not work at the Coats Island shorebird site in 2023, nor at the shorebird migration monitoring sites in southern James Bay (Figure 1), the existing data collected from these sites continues to be used in our research, and we are optimistic that studies will continue to make use of these sites in years to come.

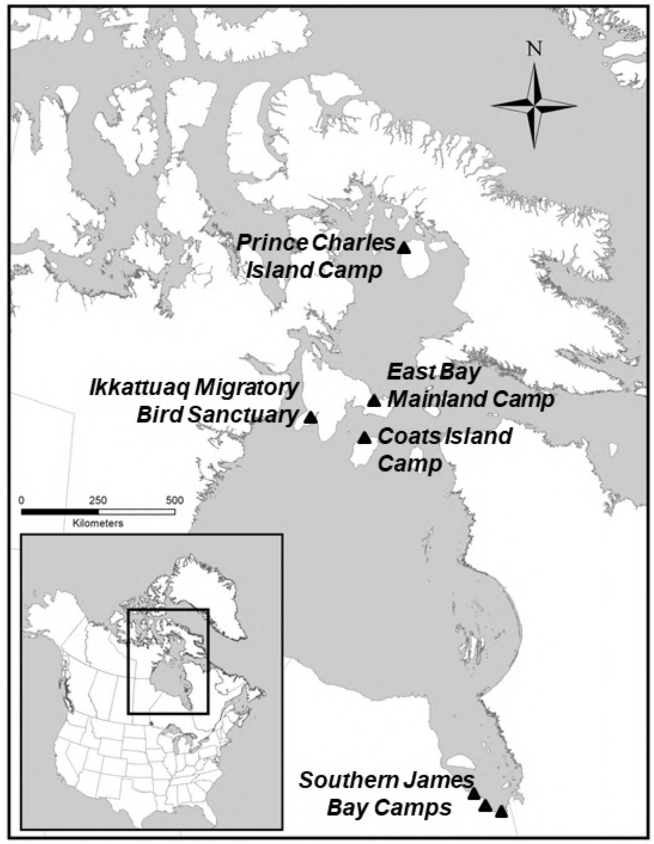


Figure 1. Map of ECCC shorebird research sites in the eastern Canadian Arctic and Subarctic James Bay.

EAST BAY MAINLAND

Shorebird nesting densities were much lower than average in the study plots at East Bay this year. With only 57 shorebird nests located, nesting density in 2023 was comparable to the worst years on record for this site since permanent sampling plots were established in 2004 (56 nests found in 2012 and 57 nests found in 2018; Figure 2).

In addition to low overall numbers, hatch rates in 2023 were lower than average for this site (15% success rate in 2023 compared to an average success rate of 25% since the start of monitoring). While there is considerable variability from year to year, the long-term trend in lower nest success over time appears to be more pronounced for certain species than others. We have noticed that biparental species such as the Ruddy Turnstone have experienced a steeper decline in annual hatch rates compared to uniparental species, such as Red Phalaropes and White-rumped Sandpipers. For these uniparental species, we have observed a lower, but relatively stable, hatch rate over time. We are currently studying these trends in greater detail, particularly to place them in the context of overall species population trends, changes in climate and migration timing, as well as local weather and predation pressure during the breeding season to understand the conservation implications of the trends being detected at long-term monitoring sites such as East Bay.

In addition to shorebird monitoring, this summer we accomplished several other scientific objectives. We deployed 19 light-level geolocators on Arctic Terns to contribute to SeaTrack, an international migration tracking initiative for this wide-ranging species. Previous deployments of these tracking devices at East Bay and other breeding sites have contributed to the identification of shared migration pathways and marine stopover sites for this species, and continued tracking will improve our understanding of Arctic Tern migration ecology. Additional species nesting in the study plots included Sabine's Gulls, a large number of Cackling Geese, and a reasonable number of Brant compared to recent years. We observed a banded Sabine's Gull that was first captured as a chick in 1999 during the early years of monitoring, making this individual 24 years old. We also installed a permanent, research-grade weather station at the East Bay camp, which will allow us to monitor climatic conditions at the site year-round and understand how conditions in the non-breeding season are changing over time, and how that may impact reproductive success for nesting birds.

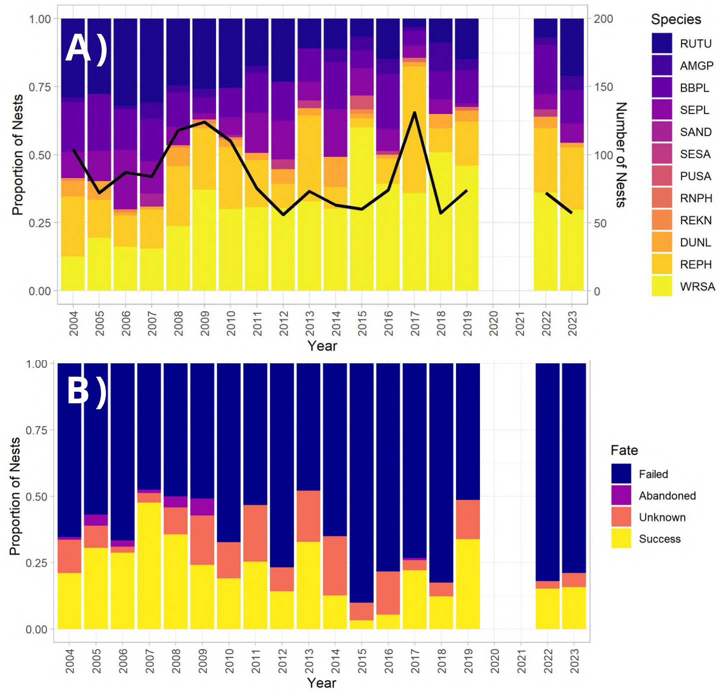


Figure 2. The number of shorebird nests (black line, panel A) monitored at East Bay in a 3 km by 4 km survey area between 2004 and 2023. Underlaid bars show species composition in panel A. Panel B shows proportional fate for each year. 2020 and 2021 are omitted as no data were collected during these years.

Overall, 2023 was a successful field season at East Bay. We look forward to continuing the long-term monitoring work at this important site in future years, and working with partners in Coral Harbour to address community research priorities. Our work at this site contributes to a better understanding of Arctic-nesting shorebird ecology, and supports international collaborations aimed at conserving shorebird populations throughout their ranges.

Left: This 24 year-old Sabine's Gull was banded as a chick at Qaqsauqtuuq. Photo courtesy of Brendan Kelly.

PRINCE CHARLES ISLAND

Our research at Prince Charles Island entered an exciting new phase in 2023. Beginning in 2016, we spent several years developing the infrastructure at this site, and then carried out a suite of studies comparing breeding bird density and habitat use at plots that were first visited in the late 1990s, assessing the impacts of increases in abundance of Snow and Ross' Geese on other birds, and conducting surveys of coastal areas for birds. On the basis of these studies, it has become apparent that the site and breeding bird community has undergone several important changes deserving of further study. To address this need, we have collaborated with the Canadian Wildlife Service to establish this site as a Program for Regional and International Monitoring (PRISM) "Tier II" site, where ongoing monitoring will occur for at least the next 5 years. A 6 km by 6 km permanent sampling area was established to monitor annual variability in shorebird nest density and reproductive success. Long-term monitoring at this site, under PRISM Tier II, will provide much needed information on demography and responses to environmental change at mid-Arctic latitudes.

The breeding season at the Prince Charles Island site was late this year, and nesting success for shorebirds was low. Of 82 shorebird nests monitored within the newly established plot area, we observed only 14 that survived to hatch, with an overall success rate of 17%, although 9 nests (10%) were still being incubated when the field crew departed. The successful nests were almost exclusively those of the Ruddy Turnstone (13 of 14 nests), and overall, we found a greater number of Ruddy Turnstone nests than in previous years (42 nests in 2023 compared to 11 in 2022 and 14 in 2019), although nest monitoring covered a broader area than past years. These observations are encouraging in light of the large decreases in the abundance and nest success of Ruddy Turnstones observed at East Bay, 500 km to the south. In contrast, for Red Phalarope, a species that was formerly abundant at this site in the 1990s, the larger survey area did not translate into more nests. We observed only 4 Red Phalarope nests in 2023; compared to an average of 40 nests per year for this species in 1996 and 1997, within a smaller search area. This pattern matches the observations of Inuit who have remarked on the decline of Red Phalarope numbers in recent decades. The extent and mechanism for these declines remain poorly understood as these birds spend most of the non-breeding season offshore, unlike other shorebird species that migrate over land and along coastal areas where migration monitoring surveys can be conducted.

Right: A Ruddy Turnstone incubates its nest. 2023 appeared to be a good breeding year at Prince Charles Island for this declining species.. Photo courtesy of Brendan Kelly.

In 2023, we continued to monitor numbers of Atlantic Brant breeding at our Prince Charles Island site, with hopes that this site has sufficient Brant numbers to support a larger study aimed at addressing knowledge gaps surrounding the factors driving large fluctuations in population over recent decades. Our reconnaissance efforts have been promising, with 48 Brant nests found in 2023, and 41 in 2022. These observations of high nest densities at this site corroborate findings from a GPS tracking study conducted by collaborators at the University of Saskatchewan, which suggested that many Atlantic Brant breed on this portion of Prince Charles Island. We also deployed 10 geolocator tags on Arctic Terns nesting at Prince Charles Island in collaboration with the international tracking study SeaTrack to help understand the migration habits of this species with the longest-distance migration of any bird in the world, with an annual round trip from pole to pole and back measuring up to 70,000 km! Arctic Terns typically return to the same breeding site each year, and once the devices are retrieved in 2024, these tags will provide the first-ever tracking data for terns nesting on Prince Charles Island, providing insight into migration routes and stopover areas, and allowing us to compare the routes used by these birds with those used by birds that breed at other locations.

IKKATTUAQ MONITORING SURVEYS

This year, we completed a second round of surveys in Ikkattuaq Migratory Bird Sanctuary to address several management priorities for the protected area. This project began in 2022, in collaboration with the Irniurviit ACMC. Few wildlife surveys have been conducted in this area in recent years, and baseline data for breeding densities of birds were lacking. Community representatives on the ACMC requested our assistance, so with the help of local research assistants from Coral Harbour, we conducted surveys in late June of 2022 and 2023 to document the abundance and distribution of birds using the PRISM protocol. In the field, we observed good numbers of Semipalmated Sandpiper, Red Phalarope, and Dunlin, and we are currently analyzing the data to provide estimates of abundance for the bird sanctuary. We will also be able to compare densities from within the sanctuary to those from elsewhere on Southampton Island, and throughout the region, using PRISM survey data collected previously.

An additional ACMC and community priority was to investigate two cultural sites located within the

Red Phalarope in Ikkattuaq Migratory Bird Sanctuary

A Sabine's Gull mobs Joseph Pingwartuk during field work. Joe participated in the IFTP prior to working for ECCC in 2022 and 2023.

bird sanctuary that were not yet registered in the territorial archaeological catalogue. We were able to make steps toward doing so with the help of Inuit Heritage Trust archaeologist Lesley Howse, who spent two weeks in Coral Harbour in 2022 interviewing elders and community members, visiting the cultural sites to begin cataloguing artifacts and features, and providing training on archaeological survey methods to local research assistants. In 2023, our bird survey team recorded the location of several additional cultural sites in the bird sanctuary and reported these locations to Inuit Heritage Trust for further investigation. We hope these efforts to document and understand these sites will continue, so they can serve as cultural and educational resources for the community.

This collaborative project gave us an opportunity to work closely with people interested in environmental monitoring in Coral Harbour and provided training opportunities to help facilitate future community-based monitoring efforts. While this project is nearing completion, we will continue to support and facilitate community involvement in environmental monitoring and management of the protected areas on Southampton Island.

INUIT FIELD TRAINING PROGRAM

This year was an exciting and ambitious year for the Inuit Field Training Program (IFTP). In response to feedback from participants and growing interest from other communities, we expanded the program this year to include two field locations and to host participants from three communities. At the East Bay Mainland research station in Qaqsauqtuuq Migratory Bird Sanctuary, seven participants from Coral Harbour and Naujaat were selected by local steering committees to take part in the eight-day program in late July, led by Dr. Grant Gilchrist, Solomon Nakoolak, and Mark Eetuk. For the first time this year, we were also able to offer a program based at the Prince Charles Island field station, in collaboration with the Arviq HTO in Sanirajak, who selected four youth from the community to participate. The ten-day Prince Charles Island program was led by Dr. Paul Smith, Cynthia Pialaq, and Sandy Kunuk. The participants shared the camp with a Canadian Wildlife Service field crew studying shorebirds at the site, giving a unique hands-on experience to learn from biologists conducting research during the peak of the breeding period in early July. The IFTP continues to be a priority for us, and with the help of the Inuit co-leaders, we look forward to providing mentorship and training opportunities for more young people in the years to come.

PROJECT HIGHLIGHTS

Much of the work at our field sites is done in partnership with universities and other organizations and through collaboration with other researchers. Students play an important role in our research, and we describe some of the 2023 highlights of these projects below. These students and post-doctoral fellows are supervised by Dr. Paul Smith, in collaboration with colleagues at Trent University, Carleton University, and the University of Windsor.

Right: MSc student Sara Bellefontaine and field technician Mark Dodds at the East Bay Mainland camp.

How much does climate affect the distribution of shorebirds breeding in the Arctic?

Christine Anderson – PhD, Carleton University; Postdoctoral Fellow ECCC

Christine completed and defended her PhD thesis in September 2023. Christine's research focused on understanding the impacts that climate change will likely have on breeding distribution of shorebirds in the Canadian Arctic. Climate change is recognized as one of the five key drivers of biodiversity loss, and the Arctic is one of the most rapidly changing regions on earth. Arctic-breeding shorebirds have several traits that have been linked with sensitivity to climate change and there is concern that environmental changes to shorebird breeding habitats may increasingly cause additional stress in these declining populations. Christine's research made several conclusions that will benefit the conservation and management of shorebirds in the Arctic moving forward. For instance, using data collected in two Arctic regions through the Program for Regional and International Shorebird Monitoring (PRISM), Christine determined that, over a 25 year timespan, changes in the occupancy of shorebird species was positively linked to their "species temperature index", indicating that shorebird breeding ranges may be shifting northwards in response to climate change. Additionally, when predicting the current breeding distributions of Arctic shorebirds, climate was not the most influential predictor variable, and in fact additional variables such as land cover, topography, snowmelt, and geology accounted for more than half of the explained variance in shorebird occupancy and that individual land cover variables were often stronger predictors than climate variables. If current shorebird habitat is not well captured by climate variables alone, the implication is that shorebirds responses to climate change are likely to be moderated by factors aside from climate, and that it is important to include these additional variables in projections of how shorebird habitat may shift in response to climate change. Christine also produced projections of how climate change may affect the area of suitable habitat for 13 shorebird species by 2075 (Figure 3). In an assessment of how six different modelling decisions contributed to the uncertainty in these estimates, the most influential modelling decision was the choice of method for variable selection. Choices about the modelling algorithm, global circulation model and the pool of variables used were minor sources of uncertainty, and carbon emissions scenarios had a negligible effect. The majority of these species are likely to lose suitable habitat, but there is a high degree of uncertainty in these estimates. With more land mass further north than other Arctic regions, Canada is an important refuge for shorebirds as the climate changes.

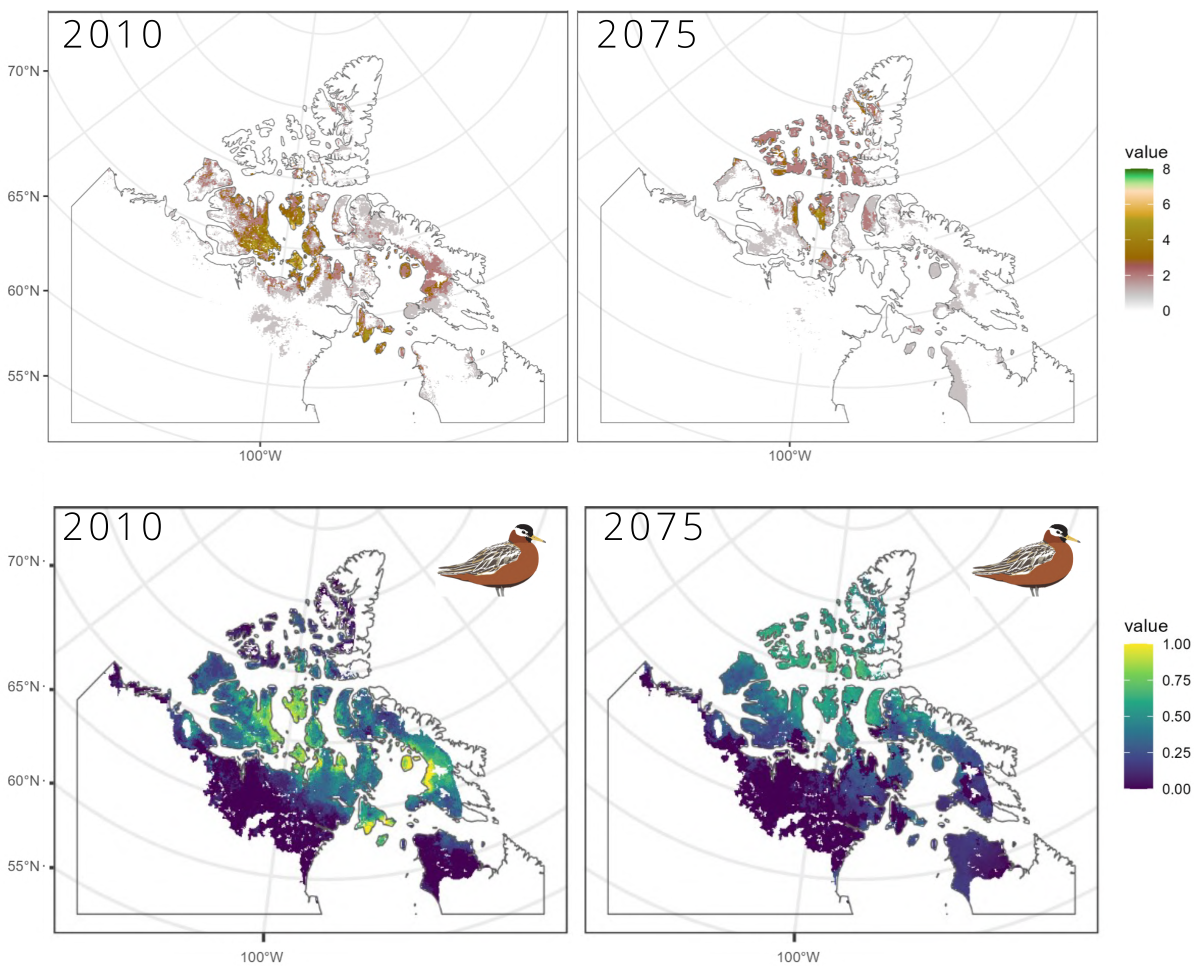


Figure 3. Consensus maps of the areas predicted to be suitable habitat for Arctic shorebird species in 2010 and 2075. In the top panels, the value in each cell is the number of species for which at least 50% of the 216 model configurations of 6 modelling decisions indicated suitable habitat. In the bottom panels, the value in each cell is the proportion of the 216 model configurations of 6 modelling decisions that indicated suitable habitat for Red Phalarope.

Using feather isotopes to assess sub-population annual survival of *rufa* Red Knots

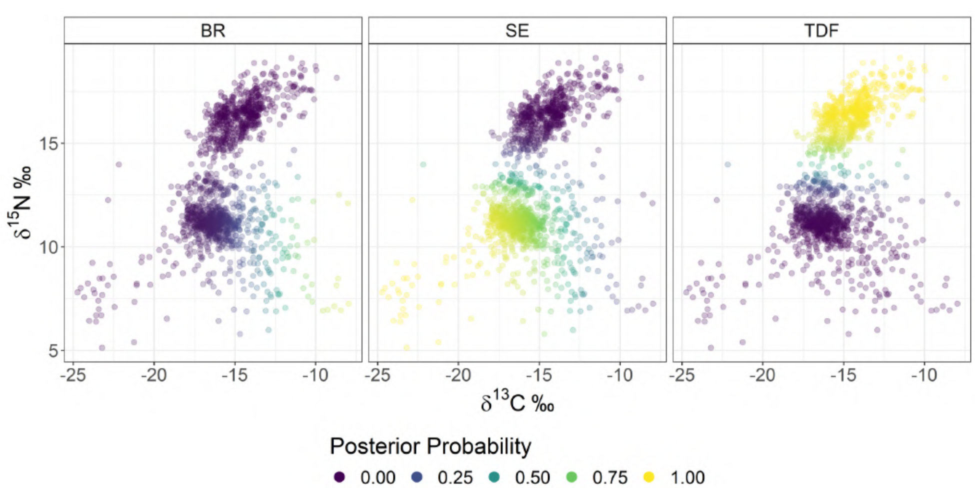
Anne Ausems – Postdoctoral Fellow, Trent University

Throughout their life cycle, migratory species encounter a wide range of potential threats during their annual movements from their breeding grounds to their wintering grounds. Shorebirds breeding in the Canadian Arctic migrate south during winter, sometimes as far south as the tip of South America. Depending on the local threats these animals encounter, their survival rates and therefore conservation needs vary.

The *rufa* Red Knot (*Calidris canutus rufa*) is listed as endangered in Canada, but it is hypothesized that only the portion wintering in southern South America and breeding in Nunavut is declining. The *rufa* Red Knot is generally sub-divided into three “designatable units”, separated by wintering grounds. Approximately 10% of individuals in the *rufa* Red Knot population are visually marked with plastic leg flags, and consistent efforts are made to resight and capture flagged birds around Delaware Bay providing data to calculate apparent annual survival rates. However, the wintering regions for these individuals remained unknown. Recently, stable isotope signatures were determined for thousands of feathers, making it possible to assign wintering regions based on the signatures of samples from birds observed on their wintering grounds.

Part of Anne’s postdoctoral work is to assign these wintering regions to birds with unknown origins and then calculate apparent annual survival rates for each region. In total, stable isotopes of 3500 feathers collected between 2004 and 2021 will be analysed for the project, of which 1500 have been completed. Winter regions are known for an additional 355 individuals, which were used to predict the winter regions for birds of unknown origin (Figure 4). The overall accuracy of winter region assignments, determined from a subset of samples from birds of known wintering regions, is 82.9%, with an accuracy of 80.2% for Southeast United States, 56.7% for Brazil, and 94.4% for Tierra Del Fuego. Preliminary estimates of apparent annual survival using the Cormack-Jolly-

Figure 4. Posterior probabilities of the assigned winter regions for birds of unknown origins. Rufa Red Knots winter in three distinct regions: northern Brazil (BR), the southeast US and Caribbean (SE), and Tierra del Fuego (TDF). Stable nitrogen (δ15N) and carbon (δ13C) isotope signatures of feathers to predict winter regions. The posterior probability indicates the likelihood that a feather with a specific stable isotope signature originates from each of the three winter regions.



Seber survival model indicate that survival has decreased over time (Figure 5); the next phase of this project is to conduct additional modelling to determine whether the survival rates differ by wintering population. Addressing this knowledge gap would allow conservation activities to be targeted more effectively to focus on areas where threats to the species are highest.

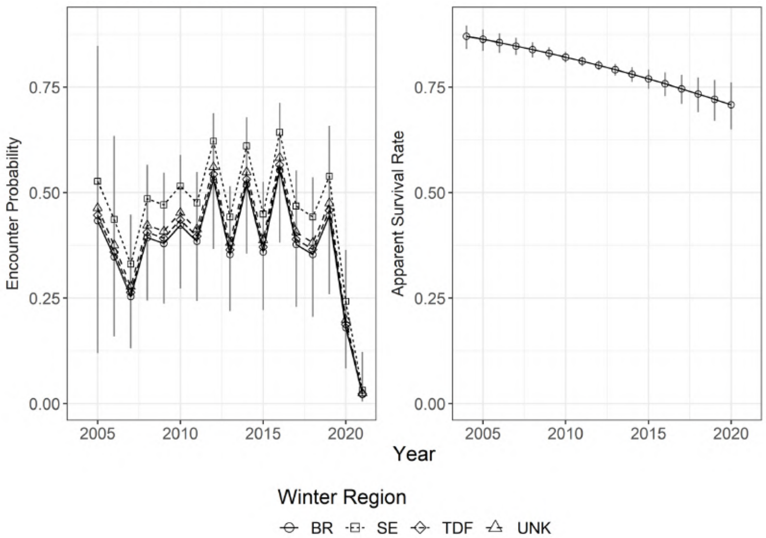


Figure 5. Red Knot apparent annual survival from resight data, for individuals assigned to northern Brazil (BR), southeast US and Caribbean (SE), and Tierra del Fuego (TDF) winter regions. Individuals not meeting a 75% probability for winter region assignment were placed in and unknown (UNK) category.

Physiological and behavioural responses of Arctic-breeding shorebirds to weather and habitat conditions

Sara Bellefontaine – MSc, University of Windsor

Sara completed and defended her MSc thesis in September 2023, after spending the summer at the East Bay Mainland field camp. Sara's thesis investigates the physiological and behavioural strategies used by shorebirds incubating nests in the Arctic. Arctic-breeding shorebirds balance thermoregulatory needs and vigilance against predators in an energetically demanding environment, and while previous research has showed that shorebirds exhibit selective preferences for nest sites, the characteristics of preferred shorebird nests do not predict increased breeding success. To better understand the mechanisms driving nest preferences in Arctic-breeding shorebirds, Sara hypothesized that nest site selection could be influenced by predictable physiological benefits to incubating birds as opposed to the probability of nest predation, which may be driven by more stochastic processes like predator density and

Below: White-rumped Sandpipers nest in a diverse set of habitats, including well-concealed nests (left) and open nests (right). Photos courtesy of Sara Bellefontaine.

hunting behaviour that would be difficult for a bird to evaluate when selecting a nest site.

Using historic data collected at Qaqsauqtuuq, Sara first examined long-term nest preferences in relation to wind conditions (Figure 6). Sara also collected field data using non-invasive heart rate recording technology, which can be used to calculate energy expenditure, to study energetic responses of two shorebird species to weather conditions across various nest types in a field study. Sara found that uniparental shorebird species where only one adult incubates the nest (Red Phalarope, White-rumped Sandpiper) preferred to have denser vegetation blocking the prevailing winds, while biparental species (Black-bellied Plover, Ruddy Turnstone, Semipalmated Plover) did not. Additionally, heart rate monitoring data confirmed that energetic demands are higher in colder windchill temperatures (Figure 7), and that at the species level, individuals selecting for greater nest concealment reduced energetic costs during incubation.

These results provide more evidence to understand the trade-offs associated with differing parental strategies between uniparental, concealed nesters and biparental, open nesters,

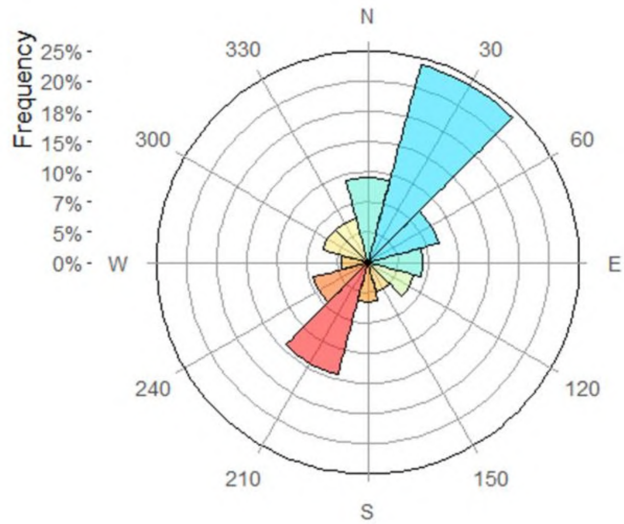


Figure 6. Frequency of wind directions across 13 years of shorebird breeding seasons at East Bay Mainland. Bar colour represents relative differences in ambient temperature associated with each wind direction.

and suggest that the variability observed in nest site preferences may be driven by multiple mechanisms, including thermoregulatory demands. More research is needed to understand the interaction between nest-selection mechanisms, probability of nest success, and the decisions made by adults during nesting, especially to evaluate how changes to habitat and weather conditions due to climate change and overgrazing by geese may modulate these effects at Qaqsauqtuuq and other sites.

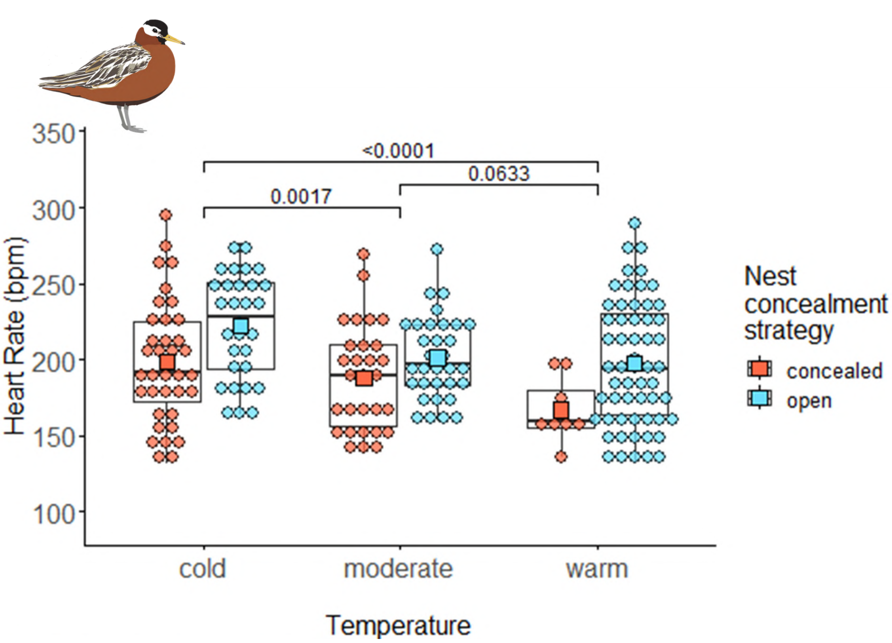


Figure 7. Distribution of raw data on Red Phalarope heart rate responses across windchill temperature categories: cold, <4˚C; moderate, 4˚C to 10˚C; warm, >10˚C. Colours represent different nest concealment strategies. Concealed birds are >80% concealed on the nest, and open birds are <45% concealed on the nest. Dots represent individual data points of Red Phalarope heart rate, and squares denote the means in each category.

Carry-over effects in Arctic-breeding shorebirds

Willow English - PhD, Carleton University

Above: Red Knots in flight. Increasingly, studies of the full annual cycle are informing conservation planning for threatened species. Photo courtesy Amie MacDonald.

Willow completed and defended her PhD thesis in January, 2023. Willow's research used tracking and physiological data to investigate the importance of 'carry-over effects' in Arctic shorebird breeding success, whereby conditions experienced by birds in one season can have impacts on the fitness of those birds in subsequent seasons. While it has been generally acknowledged that carry-over effects from the non-breeding season may be important in addition to local conditions on the breeding grounds in explaining breeding timing and success, only with recent technological advances that allow tracking individual birds through multiple seasons has it become possible to study these effects in detail. For one of her thesis chapters, currently being prepared for peer-review publication, Willow collected tracking and breeding data from 248 individuals of 8 species and subspecies of Arctic-breeding shorebirds at multiple sites across the Canadian Arctic and Alaska to estimate how the timing of nesting is related to local conditions like when snow melts, and prior conditions, measured by migration timing. Path analysis showed that the timing of breeding was dependent on both local and prior conditions, suggesting that both potentially affect reproductive success.

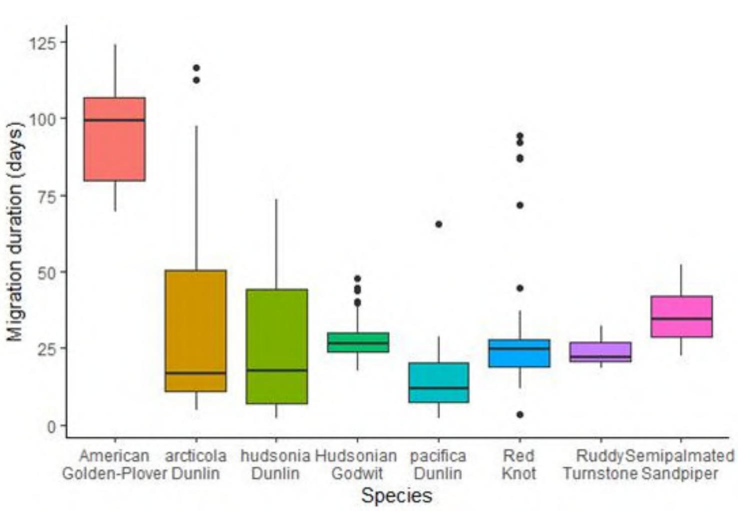


Figure 8. Length and variability of migration duration in Arctic-breeding shorebird species and subspecies.

Individual birds that arrived later to the breeding grounds did not leave the wintering grounds later, but instead took longer to migrate. Individuals that migrated longer distances arrived and nested later (Figure 8). This may be due to reduced habitat quality at key stopover sites or an inability to adjust their migration timing to spring coming earlier in the Arctic with advancing climate change. Overall, these results show that winter condition continue to affect birds during the breeding season, highlighting the importance of including carry-over effects when explaining variation in reproductive success, and the importance of considering the whole annual cycle when planning conservation measures for migratory species.Willow is currently working for the Canadian Wildlife Service in Ottawa; however, she returned to the Arctic during the summer to perform PRISM shorebird surveys in the areas surrounding Cambridge Bay and Gjoa Haven.

Amensalism in Arctic-breeding shorebirds and snow geese

Lisa V. Kennedy - PhD Candidate, Trent University

Hyperabundant populations of Lesser snow geese (*Anser caerulescens caerulescens*) in North America have well-documented negative impacts on Arctic tundra habitats, though the impacts on sympatric species such as shorebirds, including many declining species, are still poorly understood. Lisa's research assesses the direct and indirect effects of breeding snow geese on shorebirds during incubation by comparing breeding birds where snow goose-related impacts are well documented at East Bay, Southampton Island to a site where impacts from geese are negligible, on Coats Island, Nunavut Canada. Lisa evaluated incubation behaviour across a gradient of goose-impacted areas to determine if shorebirds have altered incubation recess duration and frequency in goose-impacted areas compared to sites without geese. Total time spent off the nest did not differ as a function of goose impacts. However, shorebirds nesting near a goose colony had significantly more recesses (off-bouts) from incubation, associated with a greater frequency of disturbances by geese. This increase in activity at the nest site and greater predation pressure at one of our study sites may explain why apparent nest survival in goose-impacted areas is so low. Lisa also assessed the potential direct and indirect effects of goose presence on the physiology and parasite burdens of sympatric shorebirds. The evidence suggests that shorebird condition is impacted more by fluctuations in lemming abundance than by proximity to snow goose colonies, possibly due to the relationship between lemming abundance and perceived predation risk by incubating birds. Lisa's final research chapter compares reproductive investment using egg volume as a measure of early season habitat quality across a gradient of goose impacts. Some species of shorebirds nesting at East Bay had larger eggs than at Coats Island, possibly because of earlier emergence and greater abundance of invertebrate prey due to the influx of nutrients from goose faeces. However, due to the low apparent nest survival of shorebird nests in areas near snow goose colonies, any local benefits of increased food availability for adult shorebirds during egg development is probably outweighed by impacts of other direct or indirect negative impacts.

Left: Remote camera footage monitoring a Black-bellied Plover nest at Qaqsauqtuuq shows family groups of geese consisting of adults and goslings (blue circle) flushing a male Black-bellied Plover (yellow circle) off the nest (red circle). These studies help understand the indirect effects geese are having on tundra ecosystems.

Estimating seasonal survival rates for endangered *rufa* Red Knots

Amie MacDonald – Birds Canada

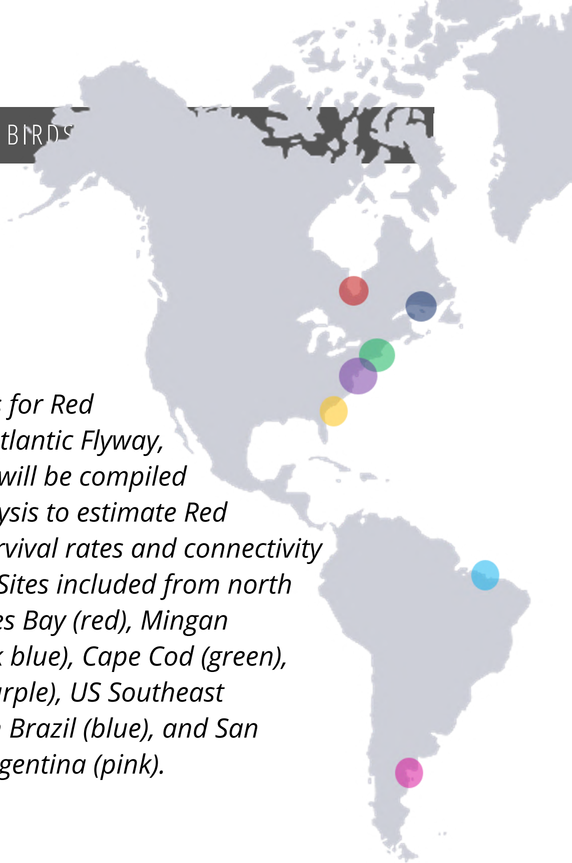


Figure 9. Key sites for Red Knots along the Atlantic Flyway, from which data will be compiled into a single analysis to estimate Red Knot seasonal survival rates and connectivity among key sites. Sites included from north to south are James Bay (red), Mingan Archipelago (dark blue), Cape Cod (green), Delaware Bay (purple), US Southeast (yellow), northern Brazil (blue), and San Antonio Oeste, Argentina (pink).

Amie completed her MSc in 2019 and is now a biologist with Birds Canada, where she continues to collaborate with Environment and Climate Change Canada's Arctic Coastal Birds and Ecosystems research group to study demography of endangered *rufa* Red Knots (*Calidris canutus rufa*). Red Knots are long distance migrant shorebirds that breed in the Canadian Arctic and migrate to three key nonbreeding areas in the southeastern United States and Caribbean, Maranhão in northern Brazil, and Tierra del Fuego in Argentina and Chile. Many Red Knots stage in Delaware Bay during northbound migration where they feed primarily on horseshoe crab eggs. Overharvesting of horseshoe crabs in Delaware Bay in the late 1990s was linked to dramatic declines in Red Knots in the early 2000s and Red Knots were subsequently listed as endangered in Canada. Following implementation of a more rigorous horseshoe crab harvest management framework, survival rates for Red Knots staging in Delaware Bay appear to have rebounded. However, despite high survival, the Red Knot population has not returned to pre-decline numbers, possibly due to differential survival between wintering populations or at periods in the annual cycle that cannot be estimated using survival data from birds staging in Delaware Bay, Increasingly, there is a need to measure Red Knot survival over a finer timescale and estimate seasonal survival rates to understand factors limiting population recovery and temporal and spatial variation in vital rates for Red Knots throughout the annual cycle. For example, if insufficient refuelling in Delaware Bay due to low horseshoe crab egg availability continues to be a limiting factor for Red Knot population recovery, we may see lower survival rates during the period between birds leaving Delaware Bay and arriving at post-breeding stopover sites. Alternatively, some observations suggest that the extreme long-distance migrants may be dying at higher rates than Red Knots that do not migrate as far as Tierra del Fuego, in which case we might expect to see lower survival rates for birds that spend the nonbreeding season in Tierra del Fuego compared to those that spend the nonbreeding seasonal in Brazil, the Caribbean, or the southeastern United States.

Right: Reporting sightings of banded birds, such as this Red Knot observed at East Bay, contributes to a better understanding of migration habits and survival rates. Photo: Willow English

Amie is currently working with many partners to compile Red Knot resighting data that exist from key sites across the Atlantic Flyway into a single dataset to estimate seasonal survival rates for Red Knots during the pre-breeding, breeding, early post-breeding, late post-breeding, and nonbreeding periods. She will use these data to estimate survival rates at seven sites from northern Ontario to southern Argentina (Figure 9) in the seasons where Red Knots are present at these sites. Additionally, analytical techniques will allow her to simultaneously estimate transition rates among these sites, such that transitions follow the Red Knot annual cycle and provide insight into connectivity.

The first phase of this project entails developing a custom multi-stage model to handle the complexities of the analysis, which Amie has been building and testing using simulated data to ensure it is performing as expected and will yield accurate results. Amie has built the model step-by-step, adding in one additional layer of complexity associated with the Red Knot annual cycle at a time. Recently, the full model was tested 30 times on 30 different simulated datasets. Amie then compared the survival estimates produced by the model to the values used to simulate the data – if the model performed perfectly, they would be the same. Of the 15 survival rates estimated across the different seasons and locations, all yielded a less than 4% mean difference from the known values (Figure 10). Amie is now applying this model to real data, which will provide insight into where Red Knots are experiencing the highest levels of mortality, and where conservation efforts will have the greatest benefits.

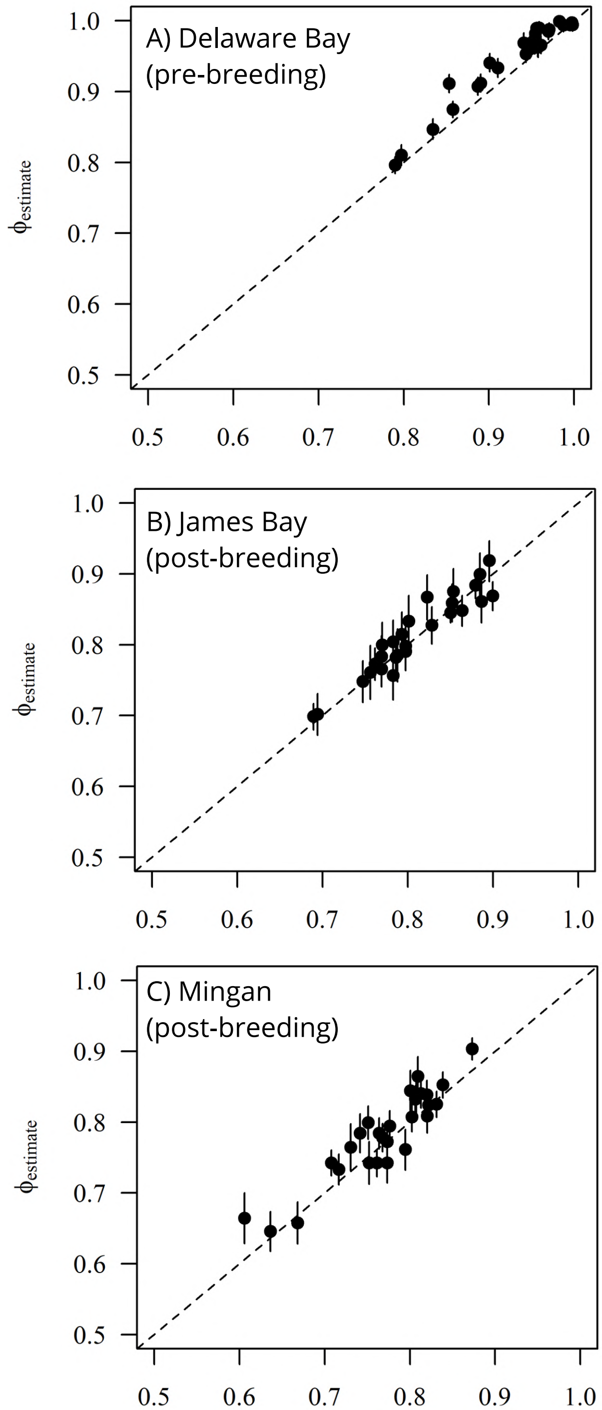


Figure 10. Results of the simulations used to test the model developed for this analysis from three sites during specific seasons. The vertical axis represents the survival estimate from the model, and the horizontal axis represents the known value used to simulate the data. Each point is a separate run of the model using a different simulated dataset and the vertical lines represent 95% credible intervals. If the model performed perfectly, all points would sit on the dotted line. Note that these are simulated data and do not represent real survival estimates from these sites.

Using GPS satellite tracking to advance understanding of Red Knot migration habits and breeding grounds

Genevieve Perkins - Ninox Consulting & Stephanie Feigin - Wildlife Restoration Partnerships

The Red Knot has undergone dramatic declines in recent decades and researchers have sought to improve knowledge about the species' ecology in an effort to understand these declines. Red Knots migrate up to 15,000 km between wintering areas in South America and breeding grounds in the Arctic, and over the past decades researchers have been studying the migration ecology of this species using tracking technology deployed on individuals, to better understand how threats experienced at various stages of their annual migration have contributed to observed declines. While much has been learned about Red Knot migration from past studies, older tracking technologies are limited in their precision and coverage for northern areas (VHF nanotags and MOTUS network), and the need to recover tags from individuals to retrieve data (geolocators) which has left several gaps in our knowledge of Red Knot movements on the Arctic breeding grounds. GPS technology offers several advantages in precision and global coverage, and transmitters have become small enough to be deployed on Red Knots in recent years.

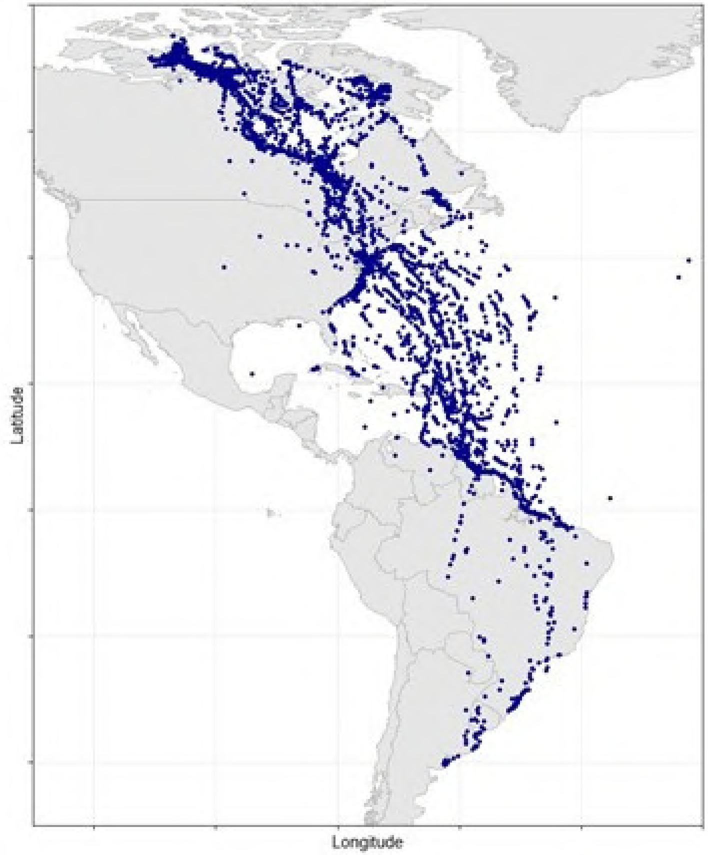


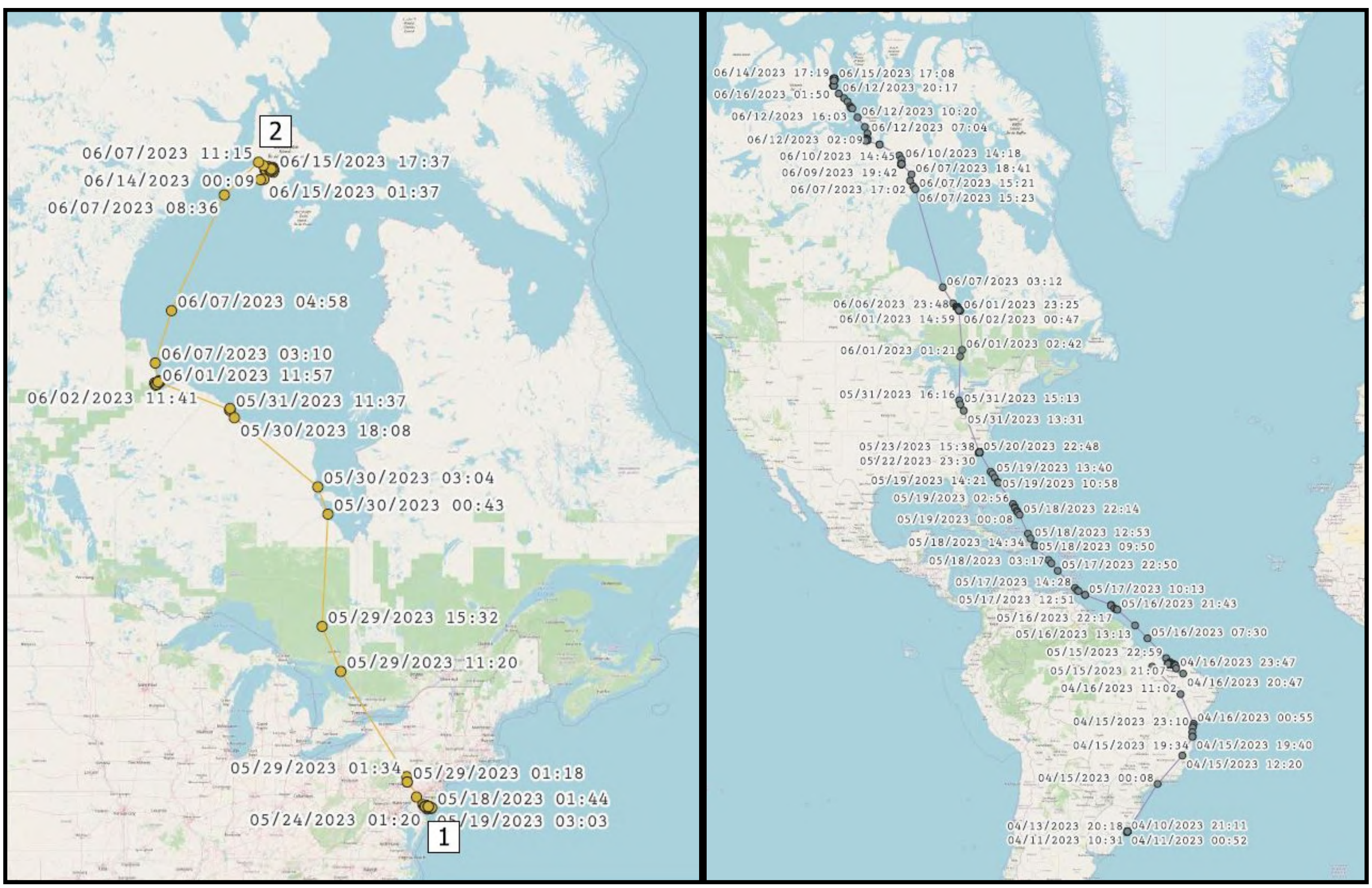
Figure 11. Distribution of Red Knot locations from compiled GPS datasets (2020 – 2023).

A Red Knot wades through a tundra wetland on the Arctic breeding grounds.

To better understand the movement patterns and breeding regions of Red Knots, ECCC has partnered with USFWS, Wildlife Restoration Partners, Dominion Energy and affiliated partners to deploy, compile and summarize GPS satellite tag data for Red Knots. Since 2020, 241 individual birds have been fitted with high precision GPS satellite tags (Sunbird, PinPoint and PTT tags) enabling individuals to be tracked in near real time at fine geographic scale (+/- 3m, with PinPoint tags), and high temporal resolution (multiple locations per day). This project compiles the data from several tracking efforts into consistent Movebank archives, and will provide an opportunity to examine the movement of this endangered species both within the Canadian Arctic and along several migration routes (Figure 11). One important project being addressed with these new data is a study of the range and habitat use of Red Knots within Arctic breeding grounds, being conducted by PhD candidate Stephanie Feigin. The improved spatial and temporal data resolution of GPS tags enables exploration of Red Knot movements and habitat use previously not possible with earlier tracking technology (Figure 12).

Tracking studies remain and important tool for understanding the movements and ecology of this wide-ranging bird. By deploying cutting-edge devices and compiling the resulting tracks in accessible archives, the current round of tracking data contributes will allow us to address remaining knowledge gaps, and refine conservation actions and redirect priorities as our knowledge of the threats to this species evolves.

Figure 12. Two sets of satellite tracks from Red Knots that migrated to breed in the Arctic in 2023. Maps courtesy of Stephanie Feigin, unpublished data.



Empirical evidence linking hyperabundant geese to the decline of shorebirds at Prince Charles Island, Nunavut

Jean-Louis Martin - Centre National de la Recherche Scientifique (CNRS; France), Tanguy Daufresne - Institut National de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE; France), Elodie Courtois - Naturalist Expertise, Instrumentation and Analysis (ENIA; French Guiana)

Quantitative data on the presence and abundance of shorebirds are rare for Arctic sites, particularly at time scales that permit evaluation of how environmental changes have impacted communities and habitats. The objective of this study, led by researchers from the Centre National de Recherche Scientifique (CNRS) and supported by the Institut Polaire Emile-Victor (IPEV) and ECCC, was to revisit a site they had studied in 1996 and 1997 and repeat a suite of surveys to collect comparable data and evaluate changes that had occurred over two decades. The project was scheduled to span two field seasons starting in 2019; however, due to the COVID-19 pandemic the second year of data collection occurred in 2022. In addition to monitoring the abundance and reproductive success of breeding birds in the study plot, data was also collected to evaluate changes in habitat at precise locations visited in the 1990s, and predation pressure was evaluated using an artificial nest experiment using the same protocols as the original study. In 2022, when it became clear that goose presence had multiplied at the site and was having a profound impact, an additional collaboration was developed with Dr. Elodie Courtois (CNRS) to experimentally measure the impacts of goose-mediated vegetation changes on greenhouse gas flux in tundra habitats.

The most evident change at the site from two decades prior was the increased presence of snow geese. In the 1990s, the density of geese at the site was low – just a few individuals per km2. In 2019, there were more than 250 snow goose nests per km2; which represents over 500 adult geese per km2 and likely double that number after nests hatched. In 2022, the density of snow geese had reduced by 80% at the site, to 46 nests per km2; which matched a general trend present at other monitoring sites in the Canadian Arctic of reduced snow goose numbers and breeding success in 2022, potentially linked to late snow melt and the emergence of highly pathogenic avian influenza during the spring migration. Goose numbers in 2023 increased to near double

Below: Paired photographs taken at the same locations in 1996/1997 (left) and 2019 (right). In the 1990s the yellow or straw-coloured vegetation was comprised of herbaceous plants; in 2019 these grassy areas were primarily transformed to moss.

the 2022 numbers (to 81 nests per km2), indicating that 2022 may have indeed been a poor breeding year for geese. Despite the observed fluctuation in snow goose numbers in recent years at this site, the study has confirmed that compared to two decades prior, geese have had major impacts on the tundra habitat on Prince Charles Island. These habitats have transformed from well-vegetated sedge meadows in 1996/1997 to saturated moss in 2019 and 2022. Virtually all of the herbaceous growth in these areas is consumed by grazing geese, which has the effect of preventing any accumulation of vegetation or litter.

In addition to the changes in habitat structure at the site, the study has confirmed a marked decline in shorebird and passerine species that depend on well-vegetated areas for nesting. Previously, these species made up a considerable portion of the richness of the avian community at the site, particularly Red Phalarope that went from being the most abundant nesting shorebird in earlier surveys to the rarest in 2019 and 2022. Over the same period, there has been an important reduction in Lapland Longspur numbers also. However, species like American Golden-Plover and Black-Bellied Plover that utilize dry tundra habitats for nesting were not observed to have undergone the same declines (Figure 13).

Another key comparison in this study was quantifying changes in nest survival over the study period, both by monitoring the survival of natural clutches, and by repeating an artificial nest predation experiment on the same transects as in 1996 and 1997. Survival of natural nests at 24 days in 1996/97 was close to 80% for the most abundant species of the wet tundra (Red Phalarope) and dry tundra (Ruddy Turnstone) and close to 40% for Lapland Longspur. Natural survival could not be reliably calculated for 2019/22 for the Red Phalarope and Lapland Longspur due to the small number of nests found, however survival seems to have remained similar for the Ruddy Turnstone based on preliminary analyses. Artificial nest transects suggest an increase in nest predation pressure between the two periods regardless of the habitat type; artificial nest survival was between 23-39% in 1996/97 and was less than 13% in 2019/22. The disappearance of herbaceous vegetation could explain the pattern in humid environments,

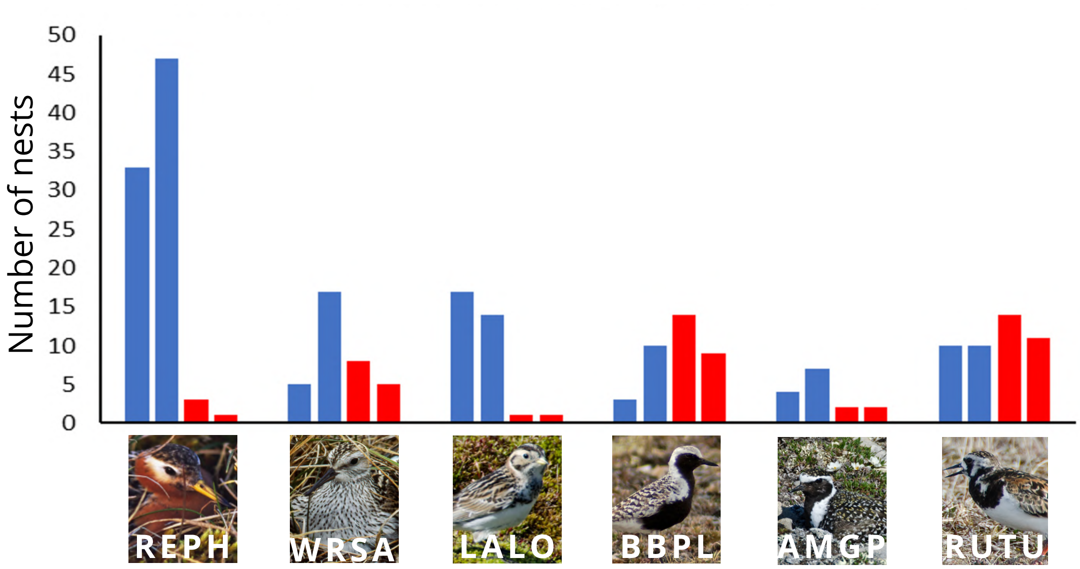


Figure 13. Comparison of the number of nests found in 1996/97 (blue bars) and 2019/22 (red bars) for the primary shorebird and passerine species. The most notable changes between the two periods are the decline in Red Phalarope (REPH) and Lapland Longspur (LALO) nests. White-rumped Sandpiper (WRSA), Black-bellied Plover (BBPL), American Golden Plover (AMGP), and Ruddy Turnstone (RUTU) nests appear to be stable, potentially due to their reduced dependance on wet tundra habitats that have been heavily impacted by geese at the site.

however the similarly high predation of artificial nests in dry tundra suggest there may be an additional mechanism. Arctic fox was the primary predator for artificial nests, and an additional explanation for poor nest survival across habitats could be the absence of lemmings, a key prey species for foxes, in 2019/22 compared to 1996/97 when lemmings were very abundant. In addition to having fewer prey options when lemming abundance is low, Arctic foxes can remain at high densities by opportunistically switching to goose nests, which may lead to greater predation for all nesting birds as a consequence.

This project has been a productive collaboration between ECCC and an international team of researchers from the CNRS, and was instrumental in developing the research infrastructure at Prince Charles Island upon which further studies will be based while contributing to Arctic ecological knowledge. Further results will be published in peer-reviewed manuscripts currently under production. Overall, the study permits a rare quantitative opportunity to assess the impacts that hyperabundant geese have had on Arctic ecosystems, particularly in an area that did not previously support an expansive goose colony.

Ecosystems measurements and greenhouse gas flux on Prince Charles Island wet tundra habitats

Elodie Courtois - Naturalist Expertise, Instrumentation and Analysis (ENIA; French Guiana); Tanguy Daufresne - Institut National de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE; France); Jean-Louis Martin - Centre National de la Recherche Scientifique (CNRS; France)

High latitude ecosystems store approximately one third of global terrestrial carbon, and climate warming is likely to have numerous consequences on biotic interactions. Climate-mediated changes will add to and interact with the profound transformations caused by the increase in goose populations, and, after observing first hand the alterations to the landscape at Prince Charles Island resulting from changes in the goose population, we initiated a collaboration with Dr. Elodie Courtois, a climatologist, to further understand the impact of geese on the environment by studying gas exchanges between soil and atmosphere in relation to goose grazing. The direction and amplitude of climate and herbivory effects on soil ecosystem parameters can vary greatly, and in particular the flux in

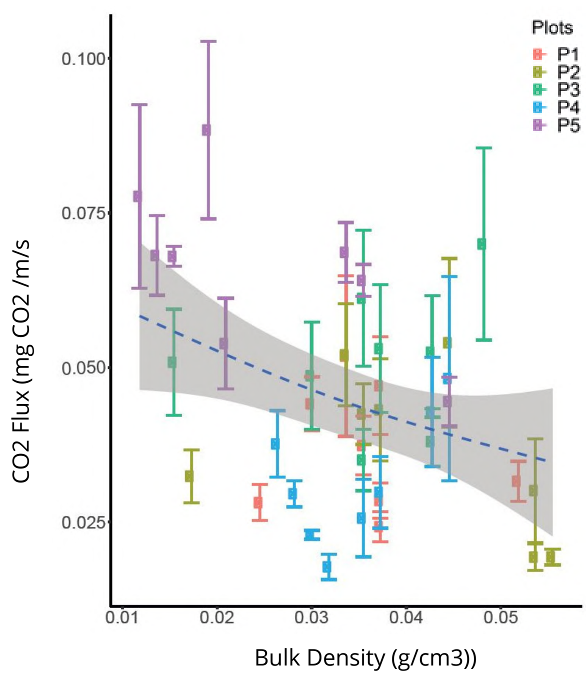


Figure 14. CO2 fluxes per plot (mean +/-standard deviation) in relation to soil bulk density.

greenhouse gases (GHG) in northern wetlands, which generate a significant amount of methane (CH4) emissions and are sensitive to increasing temperatures and changes in hydrological regimes. In 2022, the research team established a pilot project on Prince Charles Island to estimate the influence of geese on several ecosystem parameters: GHG flows (CO2, CH4 and N2O), decomposition via a method derived from the "tea-bag-index", and nutrient availability. Exclosures were established preventing access to geese, and regular surveys were conducted to measure ecosystem parameters outside the exclosure where grazing occurred, and inside where no geese could access.

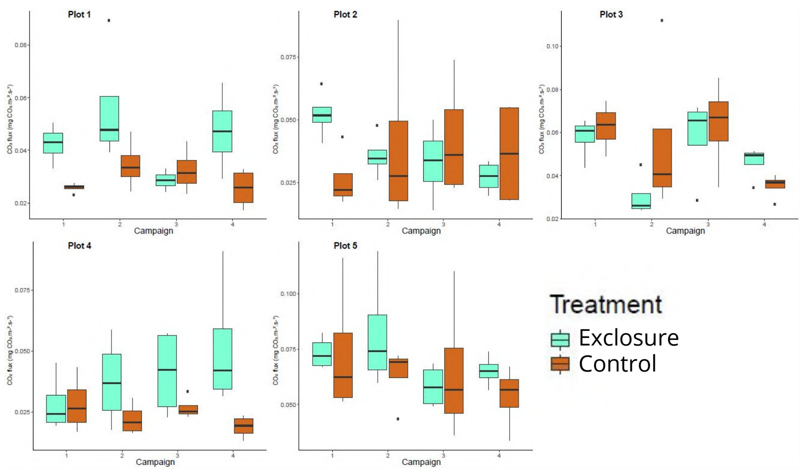


Figure 15. Paired measurements of CO2 fluxes for four survey intervals and five plots, measured inside exclosures and outside as a control.

Preliminary analyses have been completed for the data collected in 2022, and indicate that variation between CO2 fluxes measured across ion-exchange membranes at each exclosure were partially explained by soil bulk density, soil water content and NH4 soil content (Figure 14). Overall, CO2 fluxes were higher inside exclosure than on control for 4 plots over 5 (Figure 15). This is consistent with findings from other exclosure experiments on Artic tundra showing a decrease on soil CO2 fluxes from grazed ecosystems. Interestingly, one site displayed a clear pattern of increased CO2 fluxes inside the exclosure compared to control over the course of the experiment (Figure 15). This trend is not explained by herbivory pressure since the site did not exhibit a higher herbivory pressure than the other plots, and indicates that more research is needed to understand the observed patterns.

While still preliminary in nature, these ongoing analyses represent the first estimates of GHG flows on Prince Charles Island. More importantly, for this type of wet tundra strongly affected by geese, this study permits a direct comparison of parameters measured between habitats with and without significant modification due to geese, which we hope will lead to a better understanding of how hyperabundant geese continue to impact the tundra ecosystems where they breed.

Left: Photo of an exclosure erected to quantify the impact that grazing geese have on tundra habitats at Prince Charles Island.

INUIT PARTICIPATION

Josiah Nakoolak has been a part of Environment Canada research teams at East Bay and Coats Island every year since 1997. His wisdom and knowledge is essential to the safe operation of the field camps. Josiah also acts as a mentor for younger field assistants.

Mark Eetuk was a keen participant in the Inuit Field Training Program in 2018, and worked at East Bay in 2019 and 2022 as a research assistant. Mark returned to join the team again in 2023, including as a mentor for the Inuit Field Training Program.

Joseph Pingwartuk worked as a research assistant in 2023 at Qaqsauqtuuq and Ikkattuaq Migratory Bird Sanctuaries through the Inuit Field Research Assistant program, participating in shorebird research, PRISM surveys, and goose banding. Joseph first participated in the Inuit Field Training Program in 2019 and stood out as a hard worker and eager learner.

Arcene Kolit-Matoo participated as a research assistant conducting PRISM surveys in Ikkattuaq this summer. Arcene participated in the Inuit Field Training Program in 2019, and his positive attitude made him a great addition to the survey team.

Solomon Nakoolak has been a senior mentor for participants in the Inuit Field Training Program since the first session in 2018. Solomon brings a rich experience to the role, and his knowledge, curiosity, and desire to help others make him a natural fit in the field camp. In 2023, in addition to the Inuit Field Training Program, Solomon assisted in Ikkattuaq shorebird surveys.

Right: Joseph Pingwartuk (left) and Josiah Nakoolak (right) at Qaqsauqtuuq in 2023.

Adamie Samayualie works at Prince Charles Island as a guide and research assistant. Adamie started working at Prince Charles Island in 2016 and 2017 when the camp was established, and his enthusiasm and work ethic are an important part of the field team.

Paolassie Ottokie works at Prince Charles Island as a guide and research assistant. Paolassie has worked with us since 2017 during the first field season at this site, and his knowledge and hard work make him a great asset to have as part of our field team.

Rachel Niego-Akavak joined the team at Prince Charles Island for the first time in 2023, through the Inuit Field Research Assistant program. Rachel made great contributions to the shorebird research crew.

CURRENT AND RECENTLY COMPLETED STUDENTS

Christine Anderson (PhD, Carleton University) completed her PhD thesis in September 2023 and has started a postdoc with ECCC in Ottawa. Christine's thesis investigated the effects of climate change on the distributions of shorebirds breeding in the eastern Canadian Arctic. Christine has also played an active mentorship role in the delivery of the Inuit Field Training Program.

Anne Ausems (Postdoctoral Fellow, Trent University) is studying survival of Red Knots from different wintering areas using mark-recapture data and stable isotopes from feather samples collected during migration.

Sara Bellefontaine (MSc, University of Windsor) completed her MSc thesis in September 2023 and has started working as a contract data analyst for ECCC. Sara's thesis studied the physiological and behavioural responses of Arctic-breeding shorebirds to weather and habitat conditions, to investigate the trade-offs in nest-site selection that influence nesting success.

Sarah Bonnett (MSc candidate, Trent University) is studying the breeding success of Lapland Longspurs across an elevation gradient in an area where mining activity will induce hydrological changes.

Willow English (PhD, Carleton University) completed her PhD thesis in January 2023. Her thesis investigated the links between migration and breeding ecology of Arctic shorebirds in order to understand the role of carry-over effects. Willow is now working as a biologist for the Canadian Wildlife Service in Ottawa, modernizing the State of Canada's Birds report and website, and coordinating Canada's Breeding Bird Survey. Willow has also remained involved in Arctic work as part of a PRISM survey team in 2023.

Lisa Kennedy (PhD candidate, Trent University) is studying the effects of increasing goose populations on the nesting behavior and physiology of shorebirds breeding in the Canadian Arctic.

Below: Solomon Nakoolak (left), Joseph Pingwartuk (centre), and Christine Anderson (right) stop for a lunch break during fieldwork in Ikkattuaq MIgratory Bird Sanctuary

RECENT POPULAR PRESS AND OUTREACH

SOI Foundation. 2023. **Arctic Birds Researcher: Career pathways in the Sustainable Blue Economy.** Dr. Smith was profiled by SOI Foundation as part of a video series on career paths that contribute knowledge and innovation to sustainable development economy. Available at (requires registration): *https://soifoundation.org/en/bfp/explore-science-careers/*

Nannis, Anas (Producer). 2023. **Peep: The Great Migration**. Dr. Smith was interviewed during the production of this docuseries about the migration of a semipalmated sandpiper from the Arctic to South America. Docuseries. Available at: *https://tv1.bell.ca/fibetv1/shows/peep-the-great-migration*

Bognar, J., A. Brum, C. Buidin, J. Burger, A. Dey, T. Diehl, C. Espoz Larrain, C. Fedrizzi, S. Feigin, J. Finger, S. Gates, F. Labra Rodríguez, R. Lathrop, D. Merchant, L. Niles, D. Paludo, M. Peck, V. Petry, Y. Rochepault, C.D. Santos, H. Sitters, J. Smith, P. Smith, J. Trimble, R. Sacatelli, Aiviit Hunters & Trappers Association, Centro Bahi Lomas, ICMBio, Conserve Wildlife Foundation of New Jersey, National Wildlife Research Centre, NJ Endangered & Nongame Species Program, Royal Ontario Museum, and US Fish & Wildlife Service. 2022. **Tracking the Red Knot: The nine thousand mile journey of a nine-inch shorebird.** ArcGIS Story Map. Available at: *https://storymaps.arcgis.com/stories/c22de70e09ab458186cce9b1bc4912a5*

McKee, J. 2022. **Injury or Illusion? Why a Bird With a Broken Wing May Not Be What It Appears.** National Audubon Society. Dr. Smith was interviewed for his perspectives on injury feigning, following the publication of a review paper in a prominent journal. Available at: *https://www.audubon.org/news/injury-or-illusion-why-bird-broken-wing-may-not-be-what-it-appears*

Leber, J. 2022. **How Migrating Snow Geese Helped Stretch My Perspective.** Audubon Magazine: National Audubon Society. A short piece profiling the overabundance of geese, and the harvest support program in Nunavut to manage geese and increase food security. Available at: *https://www.audubon.org/magazine/spring-2022/how-migrating-snow-geese-helped-stretch-my*

Below: A Black-bellied Plover performs a distraction display to draw attention away from its nest.

RECENT SCIENTIFIC PUBLICATIONS

Anderson, C. 2023. **Predicting the effects of climate change on the breeding distribution of Arctic shorebirds.** PhD thesis, Carleton University. 143pp.

Anderson, C., L. Fahrig, J. Rausch, and P. A. Smith. 2023. **Climate variables are not the dominant predictor of Arctic shorebird distributions**. PLOS ONE 18:e0285115.

Anderson, C., L. Fahrig, J. Rausch, J.-L. Martin, T. Daufresne, and P.A. Smith. 2022. **Climate-related range shifts in Arctic-breeding shorebirds.** Ecology and Evolution, 13:e9797.

Bart, J., and P.A. Smith. 2022. **Arctic PRISM in Canada: Completion Report for Phase I.** 113pp.

Bellefontaine, S. 2023. **Physiological and behavioural responses of Arctic-breeding shorebirds to weather and habitat conditions.** MSc thesis, University of Windsor. 129pp.

Burns, C.T., M.L. Burns, S. Cannings, M.L. Carlson, S. Coulson, M.A.K. Gillespie, T.T. Hoye, D. MacNearney, E. Oberndorfer, J.J. Rykken, and D.S. Sikes. 2022. **Arctic Pollinators**. Arctic Report Card 2022, M.L. Druckenmiller, R.L. Thoman, and T.A. Moon, eds., doi: 10.25923/3zy4-th20

Buxton, R.T., S. Hamit, J.J.W. Geauvreau, S. Davis, P.A. Smith, and J. Bennett. 2022. **Balancing research, monitoring, and action to recover Canada's Species at Risk.** Environmental Science and Policy 132: 198-205.

Christin, S., C. Chicoine, T. O'Neill Sanger, M. Guigueno, J. Hansen, R. Lanctot, D. MacNearney, J. Rausch, S. Saalfeld, N.M. Schmidt, P. Smith, P. Woodard, E. Hervet, and N Lecomte. 2023. **ArcticBirdSounds: an open-access, multi-year, and detailed annotated dataset of bird songs and calls.** Ecology 104:e4047

Cooke, S.J., S. Michaels, E.A. Nyboer, L. Schiller, D.B.R. Littlechild, D. Hanna, C.D. Robichaud, A. Murdoch, D. Roche, P. Soroye, J.C. Vermaire, V.M. Nguyen, N. Young, J.F. Provencher, P.A. Smith, G.W. Mitchell, S. Avery-Gomm, C.M. Davy, R.T. Buxton, T. Rytwinski, L. Fahrig, J.R. Bennett, and G. Auld. 2022. **Reconceptualizing conservation.** PLoS Sustainability and Transformation 1(5): e0000016.

Davis, E., P.A. Smith and D. MacNearney. 2022. **Long-term studies at the Qaqsauqtuuq Migratory Bird Sanctuary, East Bay, Southampton Island, 1999-2022.** PRISM Tier II report. 50pp.

English, W. 2022. **Carry-over effects in Arctic-breeding shorebirds: a cross-species perspective.** PhD thesis, Carleton University. 144pp.

Flemming, S.A., P.A. Smith, L.V. Kennedy, A.M. Anderson, and E. Nol. 2022. **Habitat alteration and fecal deposition by geese alter tundra invertebrate communities: Implications for diets of sympatric birds.** PLoS ONE 17(7): e0269938.

Grishaber, N. 2022. **Relationships between birds densities and distance to mines in Northern Canada.** M.Sc. Thesis, Trent University. 143pp.

Holmes, G.I., E. Nol, and P.A. Smith. Submitted. **Attempts to mitigate mining development: Deterrents fail to change nesting behaviour of Arctic-nesting birds.** Avian Conservation and Ecology.

McGuire, R.L., C.J. Latty, S. Brown, S. Schulte, S. Hoepfner, S. Vassallo, and P.A. Smith. 2022. **No evidence that cameras affect shorebird nest survival on the coastal plain of Arctic National Wildlife Refuge, AK.** Ibis 164: 329-335.

Perkins, M., I. Stenhouse, R.B. Lanctot, S. Brown, J. Bêty, M. Boldenow, J. Cunningham, W. English, R. Gates, G. Gilchrist, M. Giroux, K. Grond, B. Hill, E. Kwon, J. Lamarre, D. Lank, N. Lecomte, D. Pavlik, J. Rausch, K. Regan, M. Robards, S.T. Saalfeld, F. Smith, P. Smith, B. Wilkinson, P. Woodard, and N. Basu. (2023). **Factors influencing mercury exposure in Arctic-breeding shorebirds.** Ecotoxicology 32, 1062–1083.

Reeve, C., J.A. Robichaud, T. Fernandes, A.E. Bates, A.J. Bramburger, J.W. Brownscombe, C.M. Davy, H.A.L. Henry, B.C. McMeans, E.R.D. Moise, S. Sharma, P.A. Smith, E.K. Studd, A. O'Sullivan, A.O. Sutton, P.H. Templer, and S.J. Cooke. 2023. **Applied winter biology: threats, conservation and management of biological resources during winter in cold climate regions**. Conservation Physiology 11:coad027.

Smith, A.C., A. Binley, L. Daly, B.P.M. Edwards, D. Ethier, B. Frei, D. Iles, T.D. Meehan, N.L. Michel, and P.A. Smith. 2023. **Spatially explicit Bayesian hierarchical models for avian population status and trends.** Ornithological Applications duad056.

Smith, P. A., A.C. Smith, B. Andres, C.M. Francis, B. Harrington, C. Friis, R.I.G. Morrison, J. Paquet, B. Winn, and S. Brown. 2023. **Accelerating declines of North America's shorebirds signal the need for urgent conservation action.** Ornithological Applications 125:duad003.

Wen, X., J.R. Bennett, T. Rytwinski, S. Karimi, M. Spetka, J.J. Taylor, and P.A. Smith. 2023. **A review of terrestrial temporarily conserved areas in Canada, the United States, and Mexico.** Conservation Biology 00:e14160.

Wong, J.B., S. Lisovski, R.T. Alisauskas, W. English, A.-L. Harrison, D.K. Kellett, M. Maftei, A. Nagy-MacArthur, R.A. Ronconi, P.A. Smith, M.L. Mallory, and M. Auger-Méthé. 2022. **Variation in migration behaviors used by Arctic Terns (*Sterna paradisaea*) breeding across a wide latitudinal gradient.** Polar Biology 45:909-922.

While in the field, all wildlife sightings are recorded to document trends in observations over the years. Caribou are frequently observed passing by the site in the spring and summer.


Midnight sun panorama at the East Bay Mainland field camp

RESEARCH PARTNERS AND FINANCIAL SUPPORT

The research projects described in this report are a combined effort of many people and organizations. Dr. Paul Smith (Environment and Climate Change Canada, ECCC) leads the program together with key collaborators Dr. Erica Nol (Trent University), Jennie Rausch (Canadian Wildlife Service, CWS), Dr. Grant Gilchrist (ECCC), Lisa Pirie-Dominix (CWS), Dr. Lenore Fahrig (Carleton University), Dr. Joe Bennett (Carleton University), Christian Friis (CWS), Dr. Jean-Louis Martin (CNRS), Dr. Tanguy Daufresne (INRAE), Dr. Elodie Courtois (ENIA), Dr. Oliver Love (University of Windsor), Dr. Christina Semeniuk (University of Windsor), Paul Woodard (CWS), Larry Niles (Wildlife Restoration Partnerships; WRP), Stephanie Feigin (WRP), and Wendy Walsh (USFWS). Technical leadership and coordination is provided by Doug MacNearney, Holly Hennin, Cynthia Pialaq, and Kristen Lalla (ECCC).

These projects are logistically complicated and labour intensive, requiring a large, dedicated crew of students and biologists. In 2023, our field crews at East Bay Mainland, Prince Charles Island, and Ikkattuaq included James Alexander, Christine Anderson, Sara Bellefontaine, Mark Dodds, Samuel Dyck, Joel Edwards, Isaac Finkelstein, Rebecca Jardine, Brendan Kelly, Arcene Kolit-Matoo, Kristen Lalla, Amanda Leonardis, Doug MacNearney, Josiah Nakoolak, Solomon Nakoolak, Rachel Niego-Akavak, Paolassie Ottokie, Zachary Peck, Cynthia Pialaq, Joseph Pingwartuk, Alysha Riquer, Adamie Samayualie, Paul Smith, and Paul Woodard.

Research in Canada's north is expensive and funding for this work is necessarily provided by a network of partnerships that includes but is not limited to: Environment and Climate Change Canada Wildlife Research Division, the Canadian Wildlife Service – Northern Division, Trent University, Carleton University, University of Windsor, Polar Continental Shelf Program, ArcticNet, the Nunavut Wildlife Management Board via the Nunavut Wildlife Research Trust, Agnico Eagle Mines Ltd., Baffinland Iron Mines, Northern Scientific Training Program, United States Fish and Wildlife Service, Polar Knowledge Canada, CanNor, Institut Polaire Français Paul-Émile-Victor (IPEV), Oceans North, the Natural Sciences and Engineering Research Council, and the W. Garfield Weston Foundation.

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