ARCTIC
VOL. 73, NO. 4 (DECEMBER 2020)

InfoNorth

Are Arctic Seabirds able to Cope with Changing Sea Ice Conditions?

by Shannon Whelan

INTRODUCTION

Sea ice is the defining characteristic of Arctic marine ecosystems and has a central role in marine Arctic life. Ice thickness, extent, concentration, and phenology (i.e. annual timing) all influence the movement of marine inhabitants. Winter ice cover facilitates travel and hunting for predators, including polar bears and humans. Then, spring break-up initiates a pulse of marine productivity, where the base of ocean food chains ramps up and migratory animals sweep in to exploit these highly productive ecosystems.

In spring, some Arctic seabirds follow the receding ice edge to their summer breeding grounds where they have only a short window of time to raise young before the autumn freeze-up begins. A thick layer of sea ice that breaks up late can block seabirds from accessing their breeding sites, causing costly delays that prevent them from successfully raising young (Kooyman et al., 2007). However, a thin layer of ice that breaks up early can advance peaks in ocean productivity (Ji et al., 2013); if these peaks are too early, they may have passed by the time seabirds are feeding young, causing a "mismatch" between food availability and demands (Gaston et al., 2009). During mismatch years, when food availability is low while rearing young, breeding seabirds must spend more time and effort to meet energy demands and may still fail to produce young. These trophic mismatches between predators and prey are increasing because of climate change and could, therefore, shift population demography over time (Stenseth and Mysterud, 2002).

Climate change is disproportionately affecting the Arctic relative to other regions of the world (Post et al., 2009), leading to decreased sea ice extent (Serreze et al., 2007) and thickness (Lindsay and Zhang, 2005), and earlier spring break-ups (Stroeve et al., 2007). These changes are causing dramatic shifts that reverberate through Arctic ecosystems (Post et al., 2009), further increasing the potential for mismatches between predators and prey. While declines in sea ice cover over time are well documented, we know far less about how these changes have affected Arctic wildlife at finer spatiotemporal scales. At Coats Island, in northern Hudson Bay, Nunavut, where I work, the research team used to arrive in June via Twin Otter aircrafts on skis, landing on the ice; now planes arrive exclusively on tundra tires as the ice has usually long disappeared by then. Our daily camp logs report a change over four decades from dry, crisp 'Arctic' summers to feeling more damp, cold, and stormy like Newfoundland.

Inuit living in the eastern Canadian Arctic have widely reported many impacts of climate change on wildlife. In collaboration with Inuit, my research will provide complimentary information on what is happening underwater, where predator meets prey, and which is difficult to observe directly. Sea ice can have a moderating effect on coastal marine ecosystems where seabirds breed because ice cover reduces wind and wave action. Surface winds are 40% stronger during years of less sea ice in the western Arctic (Overland and Wang, 2010). Thus, increased surface winds associated with a reduction of ice cover could increase flight costs and change foraging behaviour of seabirds. At the same time, wind-induced wave action and turbidity might disadvantage seabirds because they are visual predators. Thus, earlier disappearance of ice could increase foraging effort and flight costs, which could lead to a reduction in breeding success.

The objectives of my research are to determine 1) the fine- and broad-scale (hours, meters vs days, kms) behavioural response of an Arctic seabird to ice and wind patterns and 2) the consequences of regional variation in sea ice and wind on seabird breeding success. To do so requires longitudinal population monitoring data spanning decades. Since 1981, a colony of Thick-billed Murres (akpa, *Uria lomvia*) have been studied on Coats Island, where researchers have observed breeding parameters each year (e.g. timing of breeding, chick growth, breeding success). This Coats Island Seabird Monitoring Program has been at the forefront of documenting effects of climate change on Arctic seabirds. Importantly, the study has stayed at the cutting edge of technological advances and integrated animal tracking into population monitoring since 1988 (3-dimensional tags since 2010). Flying requires extreme energy expenditure for Thick-billed Murres (Elliott et al., 2013a), and previous work showed that wind direction and speed influence fine-scale flight behaviours and diet (Elliott et al., 2014).

To determine the behavioural responses of seabirds to ice and wind patterns, I will test two alternative hypotheses about how murres may cope with variable ice and wind conditions. First, murres avoid foraging in inclement weather to avoid increased energetic costs. Under this hypothesis, I predict that birds will delay departing on foraging trips until strong winds cease, then depart when weather conditions improve, and blood samples from birds recaptured after inclement weather will have higher concentrations of blood components that indicate nutritional stress and fasting (i.e. hormones, metabolites). Alternatively, murres may adjust foraging behaviour in response to inclement weather to buffer increased flight costs. Under this alternative hypothesis, I expect that birds will reduce foraging range and therefore decrease the proportion of time spent flying during periods of strong winds, and blood samples from birds recaptured after inclement weather will have concentrations of blood components that indicate similar nutritional stress compared to samples taken from birds after mild weather. To determine the consequences of sea ice and wind variation on breeding success, I hypothesise that murres have greater breeding success in high-ice years because this ice-obligate species uses ice to locate and hunt prey (Fig. 1). I expect that chick growth rates are highest in high-ice years, and juvenile recruitment is greatest among cohorts reared during high-ice years.

FIG. 1. Thick-billed Murres are usually associated with ice. Arctic cod, a high-calorie prey item, are present under sea ice floes. Decreasing ice cover has been associated with a decline in the proportion of Arctic cod in murre diet at Coats Island, Nunavut. Photo credit: Kyle Elliott.

COATS ISLAND SEABIRD MONITORING PROGRAM

The Coats Island Seabird Monitoring Program was initiated by Dr. Tony Gaston from Environment and Climate Change Canada in 1981. The monitoring focuses on a breeding colony of 15 000 Thick-billed Murre pairs nesting on the steep, north-facing cliffs (Fig. 2) of Coats Island. The field teams are comprised of research associates from the nearby community of Coral Harbour, biologists and technicians from Environment and Climate Change Canada, and graduate students and researchers from Canadian universities.

Long-term studies such as this one are incredibly rare, especially in remote regions of the Arctic where logistical challenges can be extreme. Research teams have returned to the seabird colony almost every year since 1981. This is one of the few gap years because our research group cancelled the 2020 field season to reduce the potential for COVID-19 to spread to Northern communities.

This 40-year study has spanned a period of rapid climate change in the Arctic and is the longest continuous study of Arctic birds. It has provided some of the clearest evidence that in the summer, Hudson Bay has transitioned from being an Arctic ecosystem to a north Atlantic ecosystem. For example, Gaston et al. (2005) provided some of the first evidence that birds are breeding earlier with warming spring temperatures. Visual observations of diet, where prey species are identified as parents feed chicks, documented a shift from Arctic forage fish such as Arctic cod (*Boreogadus saida*) to an expansion of fish from southern waters, including Atlantic capelin (*Mallotus villosus)* (Gaston and Elliott, 2014), with a rapid ‘regime shift’ in the mid-1990s. In more recent years, polar bear encounters at the research site have increased in number and now occur earlier in summer (Smith et al., 2010). Many other completed and ongoing projects continue to clarify the multifaceted effects of climate change and seabird responses to these changes.

RESEARCH APPROACH

Although this project was delayed, we plan to continue data collection for this work in the summer of 2021 if possible. I will use a combination of historical population monitoring data (1981 – 2021) and newly collected biologging and physiology data (2010 – 21) from Thick-billed Murres breeding on Coats Island. We will build on previous data collection efforts through continued monitoring and by collecting a large dataset of movement behaviour across a longer time period (N = 160 birds over two months in 2021) to test whether and how murres cope with variable ice and wind conditions.

Movement Data

To address questions related to fine-scale movement behaviour of Thick-billed Murres requires 3-dimensional biologging (i.e. GPS-depth-accelerometers). From these data, I will be able to calculate the amount of time each bird spends in different behaviours (flying, diving, resting on the water surface, attending the colony), estimate their energy expenditure, and associate each individuals’ behaviour with sea ice and wind data. Using an extendable pole, I will capture adult murres at their breeding sites (Fig. 3) during incubation (N = 80) and chick-rearing (N = 80) in order to

FIG. 2. The Coats Island seabird colony in June 2019. Thick-billed Murres (~30 000) and glaucous gulls (~40) breed on the steep, exposed sections of cliff. The living quarters and outbuildings are situated just above the breeding colony, and researchers use a fixed-line system and rappels to access the colony from above. Photo credit: Shannon Whelan.

FIG. 3. Birds are captured via an extendable pole and scientific procedures are on conducted on cliffside. Here, Jupie Angootealuk and Shannon Whelan band a Thick-billed Murre with a unique number before deploying a GPS to track at-sea movements. Photo credit: Douglas Noblet.

deploy GPS-depth-accelerometers (18 g, Technosmart, EU). After taking a small blood sample (see below), I will attach the device to back feathers; three days after deployment, I will begin recapture efforts to retrieve the device and data.

Physiology Data

Small blood samples can reveal a large amount of information about an animal's condition and ability to meet energy requirements. The concentration of metabolites (e.g. glucose, ketones) and hormones (e.g.. corticosterone) can indicate recent foraging activity, individual differences in diet, and nutritional condition (Morales et al., 2020). Within 3 min of capture and recapture, I will take a one ml blood sample, immediately measure blood glucose and ketones using point-of-care devices (Morales et al., 2020), centrifuge to separate serum from red blood cells, and store frozen until radioimmunoassay can determine corticosterone concentrations.

Environmental Data

I will use a combination of publicly available remote sensing data and on-site weather measurements in the field. For historical sea ice, I will use daily mean sea ice concentration data obtained via remote sensing (Copernicus Marine Service, EU). During fieldwork, I will collect environmental data from a semi-permanent weather station on the colony for the duration of the field season (data available since 2016). At the station we will record local weather at 10 min intervals, including precipitation, cloud cover, wind direction, and wind speed, which will be used (alongside the station at Coral Harbour) to validate values estimated by the Env-DATA System (Dodge et al., 2013). Past estimates showed very high agreement.

Effects of Wind and Ice Conditions on Behaviour and Physiology

To determine the effects of ice and weather on murre behaviour, energetics, and physiology, I will first use the movement data to classify behaviour. I will use Hidden Markov Models (*momentuHMM*, McClintock and Michelot, 2018) that incorporate GPS location, wingbeat frequency, depth, and acceleration (Patterson et al., 2019). Using activity-specific metabolic rates (Elliott et al., 2013b), I will estimate daily energy expenditure for each individual based on activity budgets produced through behavioural classification. I will model behavioural (e.g. number of trips, time spent flying), energetic (i.e. daily energy expenditure), and physiological variables (e.g. concentrations of glucose, ketones, corticosterone) in response to sea ice concentration and weather variables (e.g. wind speed) while controlling for day of year and breeding stage (incubation/chick-rearing) as covariates.

Effects of Ice Conditions on Breeding Success

To test the effects of annual ice conditions on population demography, I will model breeding success, chick growth rates and condition, and juvenile recruitment in response to sea ice metrics (including date of sea-ice breakup, sea ice concentration) and time.

SIGNIFICANCE

The meat and eggs of Thick-billed Murres—also known as *akpa* in Inuktitut and *turr* among Newfoundlanders—are traditional foods in communities in Nunavut, Nunavik, and Newfoundland and Labrador. In particular, the Nunatsiavut government has recently partnered with the Coats Island research group to determine the relative contributions of breeding and non-breeding regions to contaminants in hunted murres, and my work will help improve our understanding of the breeding regions. My analysis of the 40-year dataset, which will examine demography and breeding success, will demonstrate the effects of climate change on murres and inform wildlife management.

The data collected in this study will further build a large, long-term dataset that can be used for many different research and wildlife management questions in the future. In particular, the GPS data could reveal marine wildlife hotspots of interest to local communities. The burst of development and increased shipping traffic in northern Hudson Bay has concerned the nearby community of Coral Harbour because it could have negative impacts on traditional wild foods. Auks, including Thick-billed Murres, are particularly sensitive to oiling, and an oil spill event near a massive colony such as Coats Island would have devastating effects. Residents recently began to monitor ship traffic through the strait between their community and the Coats Island murre colony. Moreover, the Department of Fisheries and Oceans is collaborating closely with Coral Harbour and other nearby communities to plan a marine protected area around Southampton Island (https://www.dfo-mpo.gc.ca/oceans/aoi-si/southampton-eng.html). As a generalist predator, the GPS location data from Thick-billed Murres reveals marine hotspots and critical habitat to maximise benefits to murres. Movement data collected in this project can be used to delineate the proposed marine protected areas, or placement of shipping lanes as the North undergoes continued development.

This study will determine how seabirds adjust their behaviour to changing climate and weather in the Arctic, and subsequent impacts on population demography. By combining 40 years of monitoring data with 10 years of modern biologging data, this project will be an exceptionally strong test of the effects of climate change on an Arctic species.

ACKNOWLEDGEMENTS

I am very honoured to receive the 2020 Jennifer Robinson Memorial Scholarship from the Arctic Institute of North America. I would like to thank the award committee, and Dr. Scott Hatch, Dr. Grant Gilchrist, and my dissertation advisor Dr. Kyle Elliott for supporting my application.

The Coats Island Seabird Monitoring Program takes place on Inuit-owned land, and I am especially grateful to our Inuit collaborators and the Nunavut Research Institute for facilitating this research. The priceless long-term monitoring data would not exist without the perseverance of Dr. Tony Gaston, research associates from Coral Harbour, as well as decades of field teams comprised of Environment and Climate Change Canada researchers, and graduate students. In particular, I would like to thank team members Josiah Nakoolak, Jupie Angootealuk, Alyssa Eby, Sam Richard, Sarah Poole, Douglas Noblet, Russell Turner, Allison Patterson, Dr. Emily Choy, and Dr. Holly Hennin.

Funding and logistical support for this research was provided by the Northern Scientific Training Program, Polar Knowledge Canada, Environment and Climate Change Canada, Canadian Foundation for Innovation, Natural Sciences and Engineering Research Council, and a Canada Research Chair in Arctic Ecology. A Weston Family Award in Northern Research, Fonds de Recherche du Québec – Nature et Technologie Scholarship, NSERC Postgraduate Scholarship, Mackenzie-Munroe Fellowship, and Society for Canadian Ornithologists Baillie Award provided additional support. During the off season, the Arctic Ecology Lab, Humphries Lab, and NRS Wildlife WiP Group challenged and sharpened many of the ideas presented.

REFERENCES

Dodge, S., Bohrer, G., Weinzierl, R., Davidson, S.C., Kays, R., Douglas, D., Cruz, S., Han, J., Brandes, D., and Wikelski, M. 2013. The environmental-data automated track annotation (Env-DATA) system: Linking animal tracks with environmental data. Movement Ecology 1(1):3. https://doi.org/10.1186/2051-3933-1-3

Elliott, K.H., Ricklefs, R.E., Gaston, A.J., Hatch, S.A., Speakman, J.R., and Davoren, G.K. 2013a. High flight costs, but low dive costs, in auks support the biomechanical hypothesis for flightlessness in penguins. Proceedings of the National Academy of Sciences 110(23): 9380–9384. https://doi.org/10.1073/pnas.1304838110

Elliott, K.H., Le Vaillant, M., Kato, A., Speakman, J.R., and Ropert-Coudert, Y. 2013b. Accelerometry predicts daily energy expenditure in a bird with high activity levels. Biology Letters 9(1): 20120919. https://doi.org/10.1098/rsbl.2012.0919

Elliott, K.H., Chivers, L.S., Bessey, L., Gaston, A.J., Hatch, S.A., Kato, A., Osborne, O., Ropert-Coudert, Y., Speakman, J.R., and Hare, J.F. 2014. Windscapes shape seabird instantaneous energy costs but adult behavior buffers impact on offspring. Movement Ecology 2(1): 17. https://doi.org/10.1186/s40462-014-0017-2

Gaston, A.J., and Elliott, K.H. 2014. Seabird diet changes in northern Hudson Bay, 1981–2013, reflect the availability of schooling prey. Marine Ecology Progress Series 513: 211–223. https://doi.org/10.3354/meps10945

Gaston, A.J., Grant Gilchrist, H., and Hipfner, J.M. 2005. Climate change, ice conditions and reproduction in an Arctic nesting marine bird: Brunnich's guillemot (*Uria lomvia* L.). Journal of Animal Ecology 74(5): 832–841. https://doi.org/10.1111/j.1365-2656.2005.00982.x

Gaston, A.J., Grant Gilchrist, H., Mallory, M.L., and Smith, P.A. 2009. Changes in seasonal events, peak food availability, and consequent breeding adjustment in a marine bird: A case of progressive mismatching. The Condor 111(1): 111–119. https://doi.org/10.1525/cond.2009.080077

Ji, R., Jin, M., and Varpe, Ø. 2013. Sea ice phenology and timing of primary production pulses the Arctic Ocean. Global Change Biology 19(3): 734 – 741.
https://doi.org/10.1111/gcb.12074

Kooyman, G.L., Ainley, D.G., Ballard, G., and Ponganis, P.J. 2007. Effects of giant icebergs on two emperor penguin colonies in the Ross Sea, Antarctica. Antarctic Science 19(1): 31 – 38.
https://doi.org/10.1017/S0954102007000065

Lindsay, R.W., and Zhang, J. 2005. The thinning of Arctic sea ice, 1988 – 2003: Have we passed a tipping point? Journal of Climate 18(22): 4879 – 4894.
https://doi.org/10.1175/JCLI3587.1

McClintock, B.T., and Michelot, T. 2018. momentuHMM: R package for generalized hidden Markov models of animal movement. Methods in Ecology and evolution 9(6): 1518 – 1530.
https://doi.org/10.1111/2041-210X.12995

Morales, A., Frei, B., Leung, C., Titman, R., Whelan, S., Benowitz-Fredericks, Z.M., and Elliott, K.H. 2020. Point-of-care blood analyzers measure the nutritional state of eighteen free-living bird species. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 40: 110594.
https://doi.org/10.1016/j.cbpa.2019.110594

Patterson, A., Grant Gilchrist, H., Chivers, L., Hatch, S., and Elliott, K.H. 2019. A comparison of techniques for classifying behavior from accelerometers for two species of seabird. Ecology and Evolution 9(6): 3030 – 3045.
https://doi.org/10.1002/ece3.4740

Post, E., Forchhammer, M.C., Bret-Harte, M.S., Callaghan, T.V., Christensen, T.R., Elberling, B., Fox, A.D., et al. 2009. Ecological dynamics across the Arctic associated with recent climate change. Science 325(5946): 1355 – 1358.
https://doi.org/10.1126/science.1173113

Serreze, M.C., Holland, M.M., and Stroeve, J. 2007. Perspectives on the Arctic's shrinking sea-ice cover. Science 315(5818): 1533 – 1536.
https://doi.org/10.1126/science.1139426

Stroeve, J., Holland, M.M., Meier, W., Scambos, T., and Serreze, M. 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters 34(9).
https://doi.org/10.1029/2007GL029703

Smith, P.A., Elliott, K.H., Gaston, A.J., and Grant Gilchrist, H. 2010. Has early ice clearance increased predation on breeding birds by polar bears? Polar Biology 33(8): 1149 – 1153.
https://doi.org/10.1007/s00300-010-0791-2

Stenseth, N.C., and Mysterud, A. 2002. Climate, changing phenology, and other life history traits: Nonlinearity and match – mismatch to the environment. Proceedings of the National Academy of Sciences 99(21): 13379 – 13381.
https://doi.org/10.1073/pnas.212519399

Shannon Whelan is the recipient of the 2020 Jennifer Robinson Memorial Scholarship. She is currently a doctoral candidate in the Department of Natural Resources at McGill University.
shannon.whelan2@mail.mcgill.ca