POPULATION SIZE AND HABITAT USE OF BREEDING SEABIRDS IN NORTHEAST GREENLAND

Field studies 2017-18

Scientific Report from DCE – Danish Centre for Environment and Energy No. 337 2019

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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Data sheet

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Abstract: This report describes the results from fieldwork carried out on breeding seabirds in Northeast Greenland as part of the Northeast Greenland Environmental Study Program. Results of GPS-tracking of Sabine's gulls and ivory gulls are described, as well as surveys of thick-billed murre colonies and a variety of studies on little auks.

Keywords: *Alle alle,* ivory gull, little auk, *Pagophila eburnea,* Sabine's gull, thick-billed murre, *Uria lomvia, Xema sabini*

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Front page photo: An ivory gull colony near Station Nord. Photo © Henrik Haaning Nielsen

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Preface

This report describes the fieldwork carried out in the summers of 2017 and 2018 under project 6.2 (Population size and habitat use of breeding seabirds in Northeast Greenland) of the Northeast Greenland Environmental Study Program financed by the Greenland Government. The overall aim of the Environmental Study Program was to collect information on the ecology and temporal and spatial sensitivity of this very little studied marine ecosystem, to help with environmental planning and regulation, in order to meet the goal of minimal environmental impact of potential future hydrocarbon exploration and exploitation.

Specifically, the Environmental Study Programme should help answer the following three questions:

1) How to conduct and regulate increased **seismic** activities in the Greenland Sea so that significant impacts from **underwater noise** on marine mammal populations are avoided or minimized?
2) How to regulate **discharge of drilling mud and chemicals** from exploration drilling in the Greenland Sea, so it is certain that significant impacts are avoided, and the best solution is selected based on specific information on toxicity and degradation in the High Arctic environment?
3) How to minimize the environmental impacts if an **oil spill** occurs based on:
   a. Planning of exploration activities so the most sensitive areas and periods are avoided.
   b. Planning of oil spill preparedness and response so efficient and environmentally beneficial response options for the Greenland Sea are available and can be selected operationally using a Net Environmental Benefit Analysis (NEBA).

Project 6.2 (part of Theme 6. Marine Birds; identification of offshore hot spots, coastal abundance and foraging areas, top predators) contributes mainly to question 3a.

Acknowledgements

We thank the Danish Meteorological Institute for access to their caravan at Henrik Krøyer Holme. Thanks to Glenn Yannic, Université Savoie Mont Blanc, for supplying preliminary results of ivory gull tracking that allowed us to locate an active colony, and to Olivier Gilg, Université de Bourgogne Franche Comté, for much useful information about ivory gulls in Northeast Greenland. Thanks also to Jørgen Skafte and colleagues at the Villum Research Station and all personnel at Station Nord for practical assistance and good company, to Pawel Otulak from Milsar for generous advice and assistance, to Åge Hammeken Danielsen and Aqqalu Barselajsen for assistance with the thick-billed murre survey, and to the pilots from Norlandair and Air Greenland for getting us safely to and from our destinations.

Sammenfatning

Som en del af Miljøundersøgelsesprogrammet for Nordøstgrønland gennemførtes i 2017 og 2018 forskellige kolonibaserede feltstudier af havfugle, med henblik på at identificere vigtige områder i yngletiden. Logistiske udfordringer gjorde, at ikke alle planlagte undersøgelser har kunnet gennemføres. Følgende undersøgelser er gennemført:

I 2017 udførtes GPS-sporing af ynglende sabinemåger på Henrik Krøyer Holme ved Nordøstvandet. På grund af kraftig redeprædation fra polarræv var de indsamlede data begrænsede, og dækkede kun perioden omkring æglægning. Sabinemågerne fouragerede langs iskanten nord og syd for kolonien, op til 30-40 km væk.

I 2018 udførtes GPS-sporing af ismåger fanget ved Station Nord og i en nyopdaget koloni 18 km derfra. Uheldigvis var det ikke muligt som planlagt at spore ismåger fra Henrik Krøyer Holme, og de sporede fugle udnyttede kun i begrænset omfang Nordøstvandet og Grønlandshavet i almindelighed. I stedet fouragerede de i Wandelhavet nord for Nordostrundingen. Vi fik gode data fra 10 fugle over en periode op til en måned, hvorunder de tilsammen udførte 292 fourageringsture på sammenlagt mere end 41.000 km. Tre typer af fourageringsture kunne identificeres, og kan formodentlig generaliseres til Grønlandshavet:

- Lange ture på op til flere tusind km i pakisen, hvor fuglene bruger meget tid på at søge efter formodentlig rige fødekilder, som kunne være sælkadavere.

- Kortere, gentagne ture til de nærmeste isfri havområder, hvor fuglene formodentlig søger efter fisk eller krebsdyr.

- Enkeltindivider udførte talrige ture til den kalvende gletsjer Marsk Stig Bræ, hvor de formodentlig søgte efter krebsdyr som dør af osmotisk chok i forbindelse med opblanding af saltvand og smeltevand.

- Endvidere brugte alle sporede individer tid ved Station Nord, hvor de søgte føde ved køkkenet. Denne aktivitet fyldte dog ikke meget i deres daglige tidsbudget.

I 2018 gennemførtes feltarbejde i søkongekolonien Kap Høegh. Her installeredes et automatisk overvågningskamera, som i forbindelse med GPS-sporing og øvrige studier udført i kolonien af samarbejdspartnere fra det Franske Polarinstitut vil kunne indsamle vigtige data om søkongernes brug af Grønlandshavet.

Den planlagte fly-baserede optælling af ismågekolonier i Østgrønland er udført i 2019 og vil blive afrapporteret senere.

Eqikkaaneq

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Timmisartumik Kalaallit Nunaata kangiani naajavaarsunnik kisitsineq pilersaarutaasimasoq 2019-imi naammassineqarpoq kingornatigullu nalunaarusiarineqassalluni.

Summary

As part of the Northeast Greenland Environmental Study Program, various colony-based studies of seabirds were carried out in 2017 and 2018, with the aim of identifying important areas during the breeding season. Logistical challenges led to not all planned studies being completed. The following studies were completed:

In 2017, GPS tracking of Sabine's gulls took place at Henrik Krøyer Holme at the Northeast Water polynya. Because of heavy nest predation from Arctic foxes, the amount of data collected was limited, and only the egg-laying period was covered. The Sabine's gulls foraged along the ice edge north and south of the colony, at distances up to 30-40 km.

In 2018, GPS tracking of ivory gulls took place at Station Nord and a newly discovered colony 18 km from there. Unfortunately, it was not possible to track ivory gulls at Henrik Krøyer Holme, and the tracked birds only used the Northeast Water polynya, and the Greenland Sea in general, to a very limited extent. Instead, they foraged in the Wandel Sea north of Nordostrundingen. We obtained good data from 10 birds over a period up to one month, during which time they completed a total of 292 foraging trips covering more than 41,000 km. Three types of foraging trips could be identified, and these types can probably be generalised to the Greenland Sea:

- Long trips of up to several thousand km into the pack ice, where the birds spend much time searching for presumed rich food sources, which might be seal carcasses.

- Shorter, repeated trips to the nearest areas of ice-free sea, where the birds presumably search for fish and crustaceans.

- Specific individuals made numerous trips to the calving glacier Marsk Stig Bræ, where they presumably foraged on crustaceans killed by osmotic chock when salt water and meltwater mix.

- In addition, all tracked individuals spent time at Station Nord, where they foraged at the kitchen. However, this activity did not take up much of their daily time budget.

In 2018, field work was carried out in the little auk colony at Kap Høegh. Here, an automatic monitoring video camera and a time-lapse camera were installed, which in combination with GPS tracking and other studies carried out in the colony by collaborators from the French National Centre for Scientific Research (CNRS) will provide important data on the little auks' use of the Greenland Sea.

The planned air-based survey of ivory gull colonies in East Greenland was carried out in 2019, and results will be reported elsewhere.

1. Introduction

1.1 Background

The aim of project 6.2 of the Northeast Greenland Environmental Study Program was to improve the existing limited knowledge on foraging ecology, habitat use and population size of breeding seabirds in Northeast Greenland, through colony-based studies in the North East Water polynya and the Scoresby Sound area.

Two important breeding seabird communities occur in Northeast Greenland waters:

In the Scoresby Sound area, very large and internationally important colonies of little auk *Alle alle* occur. This species is so numerous that it constitutes an important part of the marine food web. Birds from these colonies depend on dynamic ice-edge habitats in the Greenland Sea, both during breeding and when moulting after the breeding season. The area also houses the entire East Greenland breeding population of thick-billed murre *Uria lomvia*, as well as most of the black-legged kittiwake *Rissa tridactyla* population.

The North East Water polynya houses a unique high-Arctic bird community, including globally rare species such as ivory gull *Pagophila eburnea*, Sabine's gull *Xema sabini* and occasionally Ross' gull *Rhodostethia rosea*, as well as isolated populations of northern fulmar *Fulmarus glacialis* and black-legged kittiwake. The population size, habitat use and foraging behaviour of these species are poorly known.

In the Greenland red list, Ross' gull, black-legged kittiwake, ivory gull and thick-billed murre are listed as Vulnerable, and Sabine's gull as Near-Threatened. Globally, the ivory gull is red-listed as Near-Threatened. Little auk is not threatened, but because Greenland houses most of the World population, it has a special responsibility for the species.

Thick-billed murre, black-legged kittiwake and ivory gull are subjects of OSPAR recommendations because of their threatened status in OSPAR Region 1, which includes East Greenland. These recommendations advocate improved research and monitoring for these species, and the activities included in this project will contribute to this aim.

1.2 Planned activities

The activities originally planned as part of project 6.2 were described like this:

1. A detailed study of foraging ecology, diet and habitat use of Sabine's gull and ivory gull at an important colony near the North East Water polynya (Henrik Krøyer Holme) in 2017. GPS loggers and transmitters will be used to map foraging areas and quantify foraging behaviour, and diet will be studied using analysis of food samples as well as stable isotopes. If possible, data on population size and breeding success will also be collected for the same species plus Arctic tern. Aerial photographic surveys of nearby colonies of black-legged kittiwake and northern fulmar will be carried out during flights to or from the study site.

2. An aerial survey of colonies of ivory gulls throughout Northeast Greenland to be carried out in 2017. This effort will form part of a pan-Arctic survey of this declining species, and will also update the existing information which is out of date as ivory gulls are highly dynamic in their site choice.
3. Boat-based photographic surveys of thick-billed murre and black-legged kittiwake colonies in the Scoresby Sound area in 2017. The existing data are out of date and need updating, particularly for thick-billed murres which are declining rapidly in East Greenland. An aerial survey of little auk colonies in this area will also be included.
4. Continuation of the long-term study of little auk at Kap Høegh, including data collection on foraging ecology, habitat use, demography and migration. This colony has been studied since 2007 by the CNRS, which has a long-term program in the colony, and in several field seasons there has been collaboration with Greenland Institute of Natural Resources (GINR) and Aarhus University.

1.3 Adjusted fieldwork programme

This report describes the fieldwork carried out in 2017 and 2018 under project 6.2. Several adjustments to the plan outlined above have been necessary:

- No ivory gulls bred at Henrik Krøyer Holme in 2017, and data collection for this species was thus not possible. Preliminary tracking data on Sabine's gull were collected. During a new field season in 2018, extensive tracking data on ivory gulls were collected around Station Nord, where previously unknown colonies were located. See chapter 2.

- Due to technical problems with the Twin Otter aircraft, the survey aircraft contractor, Norlandair, cancelled the aerial survey of ivory gull colonies survey in 2018. The survey was therefore postponed to 2019 and forms part of an internationally coordinated survey of the species throughout the Arctic countries. Additional funding has allowed extension of the survey to cover southeast Greenland. Results of this survey are under analysis and will be reported elsewhere.

- A photographic survey of the thick-billed murre colonies in the Scoresby Sound area was carried out by GINR in 2018. An aerial survey of little auk colonies in the area was also included in connection with the ivory gull survey in 2019. The results of this survey are under analysis.

- We deployed GPS and TDR loggers on little auks to map foraging areas, coordinated with a ship-based oceanographic survey (RV Lauge Koch) doing transects of little auk density. Unfortunately, the loggers provided by Ecotone failed and provided very little useful data. However, Ecotone delivered replacement data loggers, which were deployed in 2019, and results from this work are under analysis. We are now also working on combining the ship-based data from RV Lauge Koch with data from little auk accelerometer data loggers from the same period deployed in another project by the French team. Accelerometers will provide information on foraging behaviour. This analysis is not yet ready, but will potentially fulfil the original goal of mapping foraging areas in 3D.

2. Colony-based studies of ivory gull and Sabine's gull

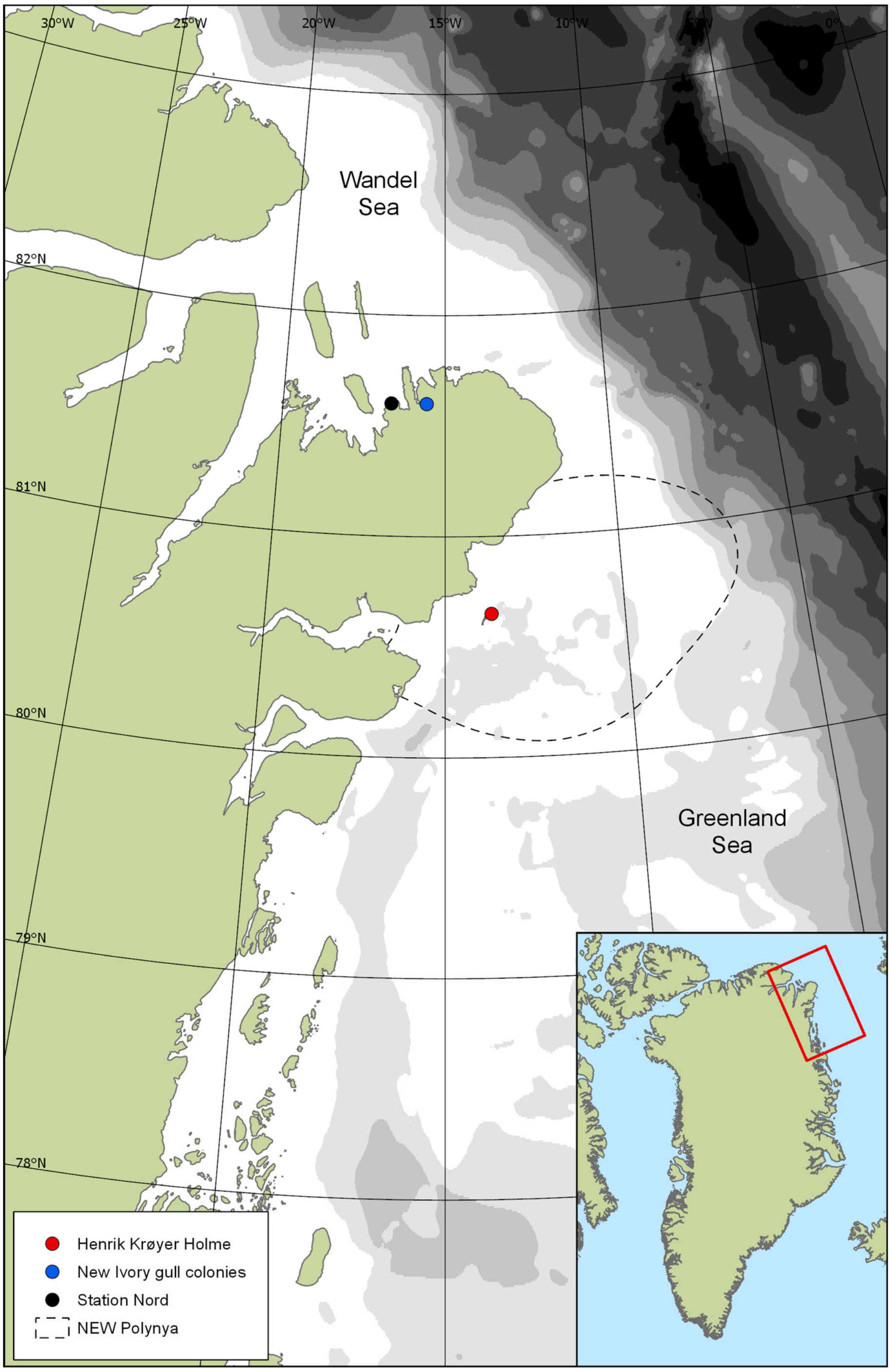


Figure 1. Map of the overall study area where Sabine's and ivory gulls were tracked in 2017 and 2018. Study locations are shown with coloured dots.

2.1 Sabine’s gull at Henrik Krøyer Holme 2017

2.1.1 Study site

Fieldwork was carried out at Henrik Krøyer Holme (80.65° N, 13.71° W) in July 2017. This small archipelago consists of three islands and a number of small islets (Fig. 2). The central island is located approx. 15 km from the mainland shore (Amdrup Land) and has an area of approx. 10 km^2. The islands are fairly low-lying (max elevation approx. 27 m), and consist of fractured limestone from the Carboniferous and Permian periods. Fossil corals are abundant. The climate is High Arctic desert, and vegetation is extremely sparse. For a more detailed description, see Bay et al. (1995).

The islands are located next to the North East Water polynya (Karnovsky et al. 2007), which is generally ice-free in spring and summer in contrast to other parts of the East Greenland Shelf. However, Henrik Krøyer Holme are often linked to the mainland by fast ice well into the summer, and this was the case in 2017 (Fig. 2).

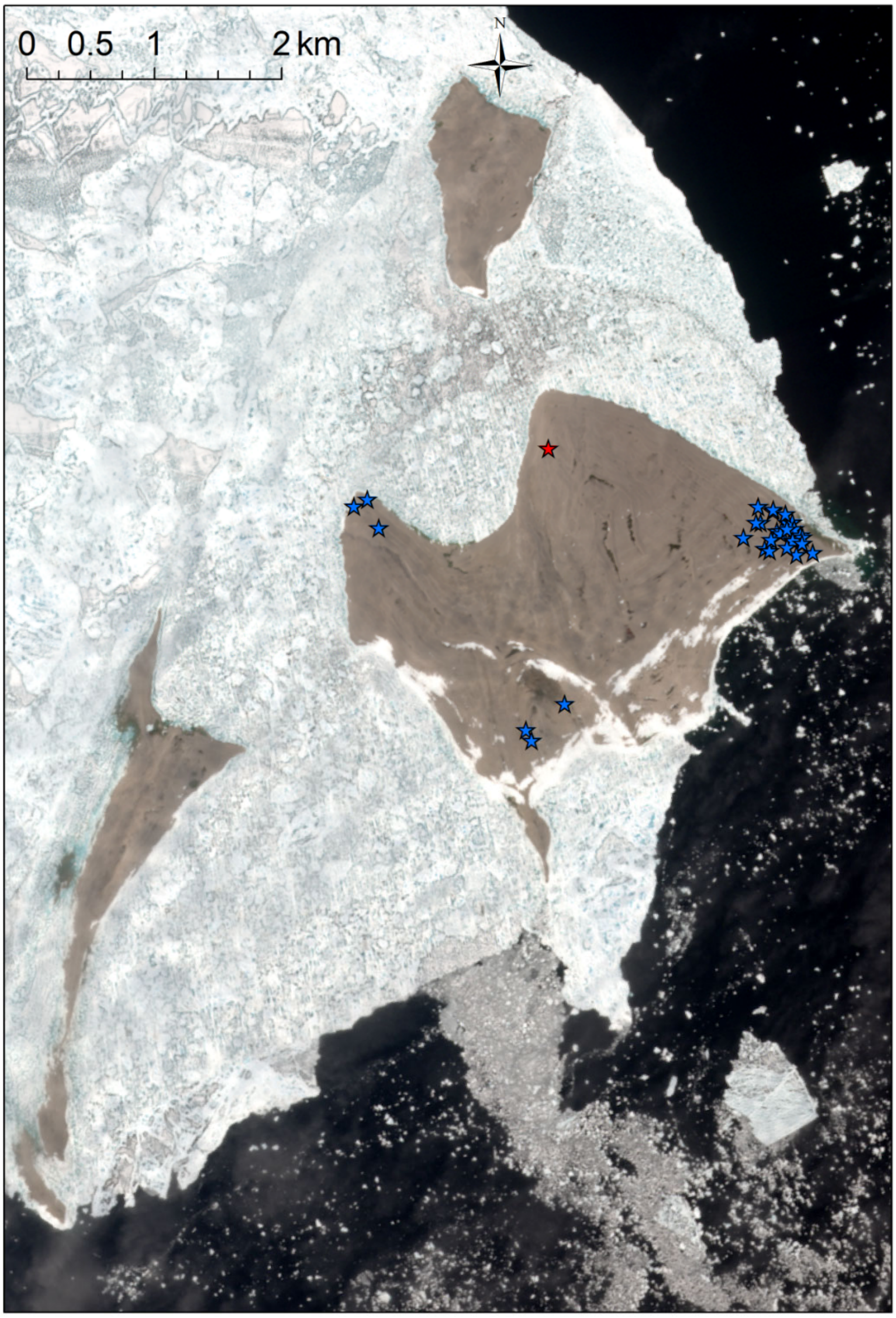
Henrik Krøyer Holme are the most important breeding site in Greenland for ivory gull and Sabine’s gull, and in general one of the most important seabird colonies in Northeast Greenland (Falk et al. 1997, Boertmann & Mosbech 2012). However, previous reports indicate that ivory gulls do not breed every year on the islands (O. Gilg, pers. comm.). The islands have only been visited by ornithological researchers on few occasions, most importantly in 2003 and 2007 when satellite tracking of ivory gulls was carried out (Gilg et al. 2008).

We arrived at Henrik Krøyer Holme 2 July 2017 and left again 21 July, travelling by DHC-6 Twin Otter from Station Nord. Due to the complete fast ice cover, we were only able to work on the central island. We quickly discovered that no ivory gulls bred on this island in 2017, and there was no indication of breeding on the other islands. Our studies were therefore limited to Sabine’s gulls. Our campsite was near the northern tip of the central island (Fig. 2), where the Danish Meteorological Institute has a permanent automatic weather station, and where the airstrip is located.

2.1.2 Study species

Sabine’s gull is a small gull (body mass approx. 200 g), which breeds in the high Arctic and migrates to wintering areas in highly productive upwelling areas in the Benguela and Humboldt Currents (Day et al. 2001, Stenhouse et al. 2012, Davis et al. 2016). The breeding biology of Sabine’s gull is relatively well studied in Arctic Canada (Stenhouse et al. 2001, Mallory et al. 2012), and there is one small study from northeast Greenland (Forchhammer & Maagaard 1991). Very little information exists on diet and foraging areas. During the breeding season, adult Sabine’s gulls may feed both on terrestrial and freshwater invertebrates (mainly insects), and on marine prey such as small fish and crustaceans (Day et al. 2001).

Figure 2. Map of Henrik Krøyer Holme, showing the campsite (red asterisk) and all Sabine's gull nests found (blue asterisks). The three sub-colonies are apparent at the eastern (Østpynten), western (Vestpynten) and southern (Sydpynten) ends of the central island. The background image is a high-resolution, true-colour satellite photo (Sentinel-2) from 20 July 2017.



2.1.3 Methods

During our first days on the island, we spent much time searching for gull colonies and nests. Subsequently, we mainly concentrated our efforts at the largest subcolony (Østpynten). We noted nest content at every visit, and attempted to establish whether nests were active (defended by the breeding pair). We analysed the nest data using a nest survival model in MARK (Cooch & White 2012), to estimate daily survival probability.

We attempted to capture incubating Sabine's gulls by several methods, but generally found that birds were extremely suspicious of any change to the area around the nest and often refused to settle on the nest. We also found that birds were unwilling to settle on the nest when we exchanged their eggs with dummies, so all successful captures were made without removing the eggs (in two cases we caught birds on empty nests). No eggs were damaged during capture.

Spring-loaded tent traps were completely unsuccessful, probably because they were very visible and impossible to camouflage among the pale pebbles of the vegetationless beach ridges where the gulls nested. Self-triggered drop cage traps did not work much better, although we did capture one bird in this way. The most successful capture method consisted simply of a noose made from monofilament nylon fishing line and placed along the edge of the nest. The line passed through the eye of an aluminium tent peg fixed at one side of the nest, and the noose was loosely fixed along the nest rim with pebbles. The line extended 30-40 m from the nest, and when the incubating bird settled on the nest (usually after 1-2 minutes), we gently pulled the line until the noose was tightened around the legs of the bird, which was held in place by the tent peg. This method was 100% effective, all birds settling on the nest were caught (n = 7). All successful captures took place at Østpynten.

All birds caught received a standard metal ring (Zoological Museum, Copenhagen) as well as a colour ring (orange with a two-letter code in black). The combined mass of the two rings was 0.8 g. Birds were weighed using Pesola spring scales, and wing length and head plus bill were measured. Feathers were collected for subsequent genetic sexing. We deployed the currently smallest available GPS device with solar panel and remote download, the NanoRadioTag-3 from Milsar, Poland (www.milsar.com). This device weighs only 3.4 g. We attached the device with a leg-loop harness made from Teflon ribbon (Bally Mills) and fastened using aluminium wire clamps. The combined mass of the device and harness was 5.2 g, or approx. 2.6% of the body mass of an adult Sabine's gull. Handling time was approx. 15 minutes.

Of our ten devices, two did not work and remaining eight were deployed on breeding Sabine's gulls. One bird was caught 10 July, one 13 July, one 14 July, one 15 July, and the remaining four 16 July. The devices were programmed to attempt a GPS fix every hour, and to attempt to upload data to a base station every minute. Upload was only possible when we were present in the colony with the base station, as there was no direct line of sight between our camp and the colony.

2.1.4 Distribution and population size

We identified three subcolonies on the central island of Henrik Krøyer Holme, located respectively near the eastern, western and southern tips of the island (Fig. 2). The eastern colony (Østpynten) was much larger and denser than the other two, and was located close to open water. Estimating the number of breeding pairs was difficult, due to low nest density and very high levels of nest predation and subsequent re-nesting. Overall, we estimate that 40-60 pairs attempted to breed in 2017, including 30-40 pairs at Østpynten (see also below).

2.1.5 Breeding biology and nest survival

Nests were shallow scrapes in gravelly raised beaches, with no nest lining. We found the first nest (with 1 egg) on 3 July, and regularly found new nests throughout our stay on the island (until 19 July). In total, we found 32 active nests, including 4 actively defended nests where we never found eggs (we captured birds on two of these). Most likely many of the nests we found represented re-nesting after loss of the first clutch, and laying phenology was therefore difficult to establish. Most nests contained 1 or 2 eggs, only at the southern subcolony did we find two nests with 3 eggs.

Nest predation appeared very high, in many cases eggs disappeared one or two days after we found the nest. There were two Arctic foxes on the island during our stay, and we observed at least one of them actively predating nests and retrieving cached eggs. It is possible that the foxes did not find the southern subcolony during our stay on the island, at least we saw no signs of nest predation there. Two nests visited with a 5-day interval in this subcolony had not lost eggs in the meantime, and a third nest only visited once contained 3 eggs.

Daily nest survival rate was estimated as 0.720 (S.E. 0.053), which corresponds to an overall nest success probability of 0.001 over a 21-day incubation period.

2.1.6 Foraging: incidental observations

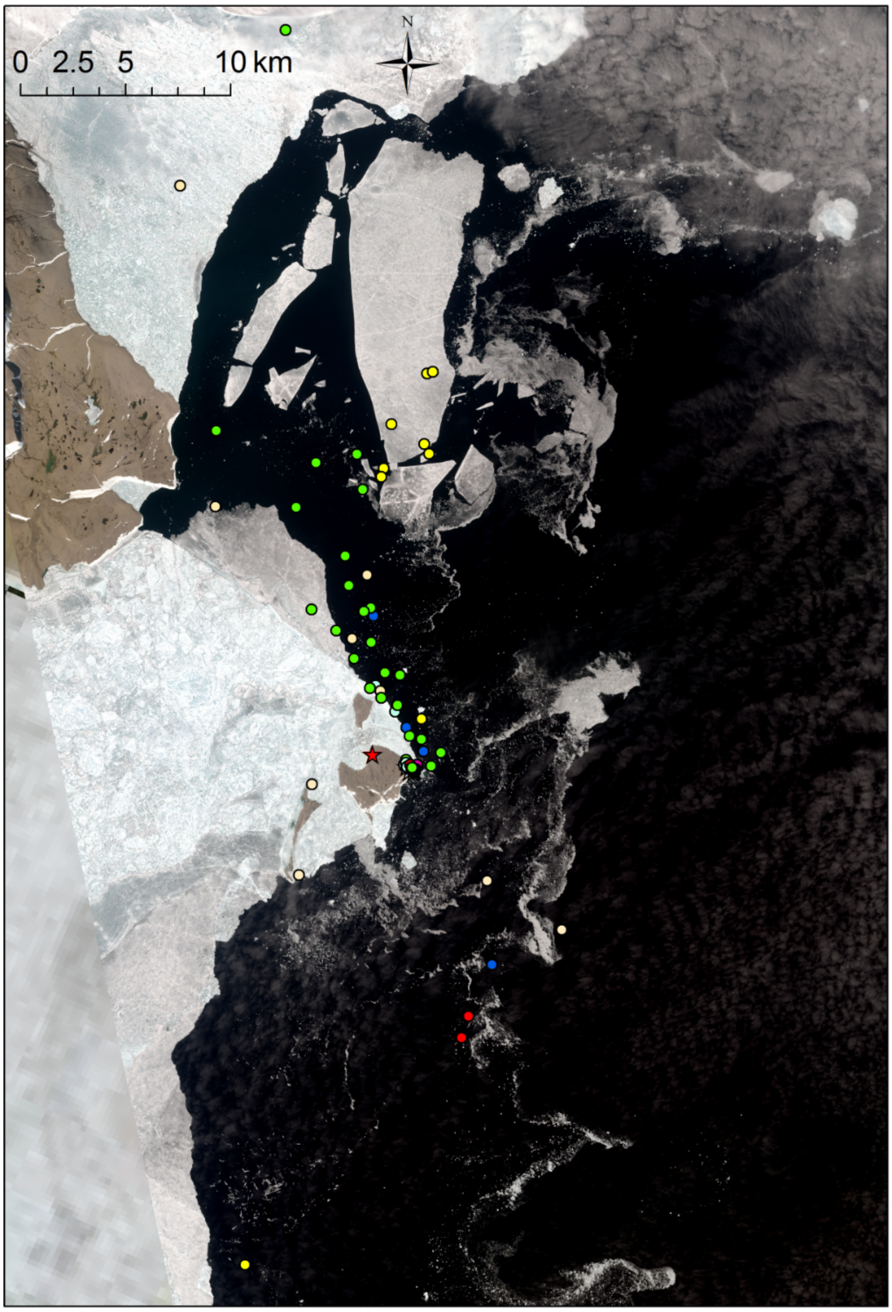
Sabine's gulls were regularly seen foraging at small ponds between beach ridges, singly or in pairs. These ponds were also favoured by grey phalaropes *Phalaropus fulicarius* and ruddy turnstones *Arenaria interpres*. The gulls appeared to feed on chironomid midges, probably both larvae and adults.

We observed apparent courtship feeding on several occasions. One captured bird regurgitated a partially digested fish. The fragment was approx. 5 cm long, and the original length of the fish was probably around 10 cm.

2.1.7 GPS tracking

We deployed eight GPS devices on adult Sabine's gulls. One bird had deserted its nest the following day, and we never managed to download any data from this device. Another bird managed to remove the harness and device, because the wire clamps were not securely closed. We thus obtained relevant data from six birds for up to six days (14-20 July). A high proportion of the attempted hourly GPS fixes were unsuccessful, probably because of low battery levels, and we therefore were not able to identify individual trips and determine e.g. trip duration. In total, we obtained 221 positions (range 17-80 per bird), including 50 (range 2-23 per bird) outside the colony. Sabine's gulls apparently foraged along ice edges and in the marginal ice zone, up to 35 km north and 25 km south of the colony (Fig. 3). This area corresponds to 'fauna and flora area' no. 12 identified by Aastrup & Boertmann (2009).

Figure 3. Map showing hourly GPS positions of six adult Sabine's gulls tagged at Henrik Krøyer Holme, during the period 14-20 July 2017. Each colour indicates one bird. The campsite is indicated by the red asterisk. The background image is a high-resolution, true-colour satellite photo (Sentinel-2) from 20 July 2017. Note that ice cover was highly dynamic and changed over the study period, in particular the large ice floe north of the colony broke off the ice edge to the west around 17 July, i.e. within the study period.



2.2 Ivory gull at Station Nord 2018

2.2.1 Study site

A quick aerial survey of Henrik Krøyer Holme on 15 July 2018 revealed that no ivory gulls were breeding, or even present, on the main island. Fieldwork was therefore carried out around Station Nord, the Danish air base which serves as a logistics base for research operations in North Greenland and the northernmost part of Northeast Greenland. Ivory gulls occur daily at the station, where they feed on scraps from the kitchen. In addition, a nearby active colony was located, based on tracking data from four ivory gulls marked by a French research team in the preceding weeks (G. Yannic, pers. comm.). The research team was thus present at Station Nord (81.60 °N, 16.66 °W) in the period 15-29 July.

The presence of a helicopter at Station Nord made it possible to visit the newly discovered colony site (81.60 °N, 15.57 °W, 18 km due east of Station Nord). On 19 July, we spent about 8 hours at the colony, which was located on a series of small (2-5 m high), unvegetated moraine knolls in an otherwise completely snow-covered landscape (Fig. 4). Satellite photos taken later in the season showed that the colony was located at the edge of a very flat ice cap, near a frozen bay (Fig. 5). Additional tracking data indicated the presence of two more colonies a few km further east, and on 27 July we surveyed these sites from the helicopter.

Figure 4. Section of the ivory gull colony visited 19 July 2018 (colony A in Fig. 5). Photo © Henrik Haaning Nielsen.

2.2.2 Study species

Ivory gull is a medium-sized gull (body mass approx. 550 g), which breeds in the high Arctic and migrates to wintering areas along ice edges in the Davis Strait, the Labrador Sea, and the Bering Sea (Mallory et al. 2008, Gilg et al. 2010, Spencer et al. 2014). The species is regarded as a sea ice specialist throughout the year, and for this reason is considered threatened by global climate change, particularly in the wintering areas (Gilg et al. 2016). Ivory gulls nest in a wide variety of habitats occasionally including icebergs (Boertmann et al. 2010, Nachtsheim et al. 2016); the main requirement seems to be safety from land-based predators. The breeding biology is reasonably well known (Mallory et al. 2008), but very little information exists on diet and foraging ecology during the breeding season. Ivory gulls are opportunist feeders, and may e.g. feed on fish, marine invertebrates, lemmings, carcasses of seals killed by polar bears or humans, human refuse etc. (Mallory et al. 2008).

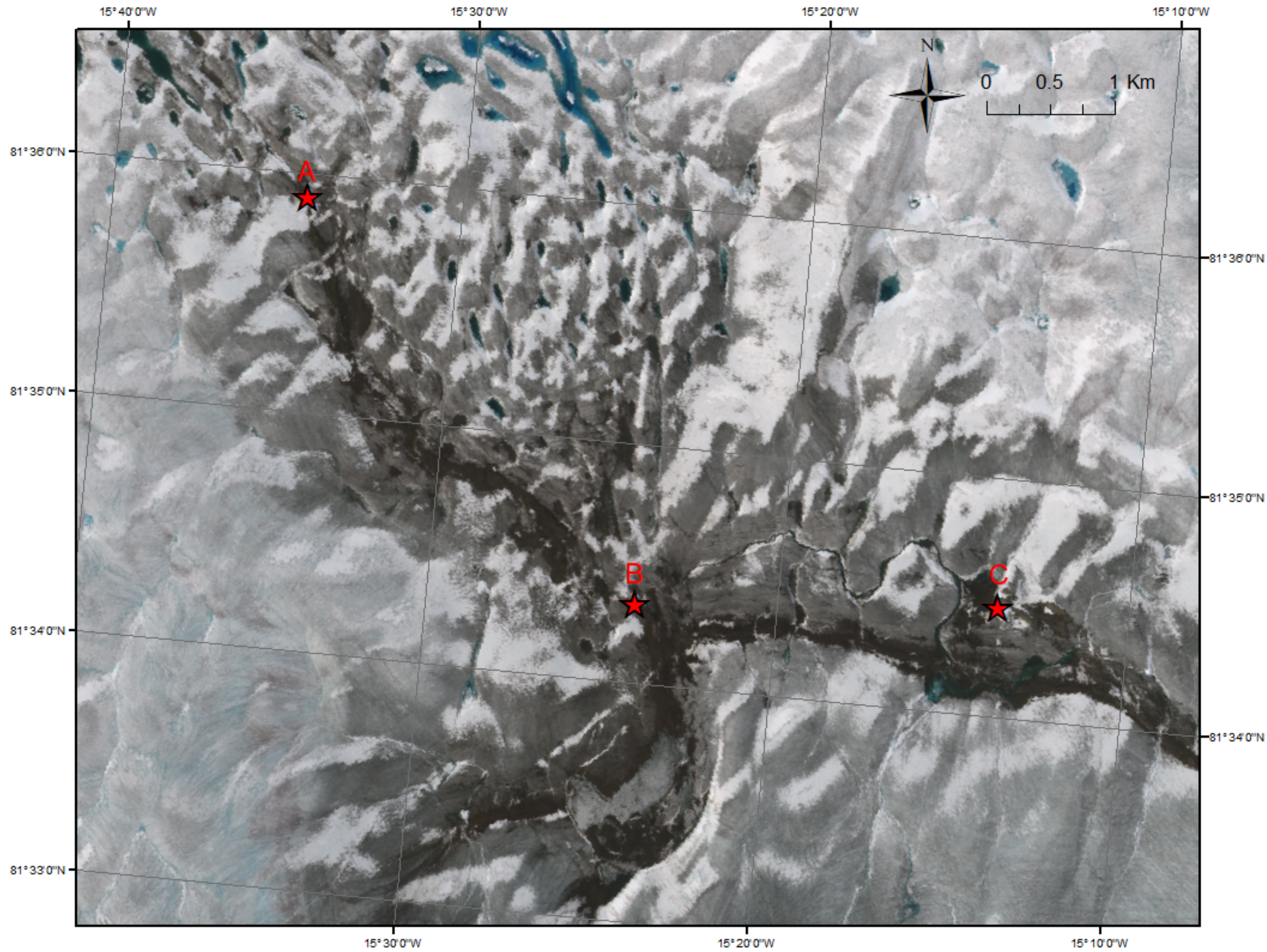


Figure 5. Map of the colony area 18-25 km east of Station Nord. The three colonies located in the area are shown with red asterisks. Colony A was visited 19 July 2018. The background image is a high-resolution, true-colour satellite photo (Sentinel-2) from 14 August 2018.

2.2.3 Methods

We trapped ivory gulls at the Station Nord kitchen, using baited, spring-loaded and self-released tent traps from Moudry Traps, Czech Republic (www.moudry.cz). During our visit at the ivory gull colony on 19 July, we trapped incubating adults with the same traps, but without bait. Eggs were removed and replaced with wooden painted dummy eggs, kept warm, and switched back immediately after capture.

All birds caught received a standard metal ring (Zoological Museum, Copenhagen) as well as a colour ring (white with a two-letter code in black). The combined mass of the two rings was 1.9 g. Birds were weighed using Pesola spring scales, and length of head plus bill was measured. Feathers were collected for subsequent genetic sexing. We deployed combined GPS/accelerometer devices with solar panel and remote download, (RadioTag-14) from Milsar, Poland (www.milsar.com). This device weighs 10.4 g. We attached the device with a leg-loop harness made from Teflon ribbon (Bally Mills) and fastened using aluminium wire clamps. The combined mass of the device and harness was 12.2 g, or approx. 2.2% of the body mass of an adult ivory gull. Handling time was approx. 20 minutes.

We deployed eighteen GPS devices on adult ivory gulls. Three birds were caught 17 July, seven in the colony 19 July, three 21 July, three 24 July, and four 26 July. Two birds did not receive a GPS device. Of the 20 birds caught, 5 (all caught at Station Nord) were previously marked in 2009 (4) or 2010 (1) at the same location by O. Gilg (pers. comm.). The devices were programmed to attempt a GPS fix every 5 minutes, to collect a 10-second 10-Hz accelerometer burst sample also every 5 minutes, and to attempt to upload data to a base station every minute. Furthermore, the devices were programmed to switch to a winter mode during September to April, with GPS locations every hour and no accelerometer data.

The base station was mounted on the roof of a building near the kitchen, connected to a power supply. Data were thus collected from the devices every time a tagged bird was in the vicinity. The base station remained in place and permanently powered until 16 August. Data download appeared to work at a distance of up to several km. During our 27 July helicopter flight to the colony sites, we brought the base station and attempted to download data from tagged birds present in the colonies.

2.2.4 Distribution and population size

We identified three ivory gull colonies in the area 18-25 km east of Station Nord (Fig. 5). The westernmost colony (colony A in Fig. 5), where we captured ivory gulls on 19 July, was the largest and contained about 110 active nests, dispersed over 9 knolls. The largest and central knoll (Fig. 4) contained about 74 active nests. During the 27 July helicopter flight, we counted 1 ivory gull at colony B and 44 at colony C (Fig. 5). Overall, we estimate that at least 160 pairs attempted to breed in the area in 2018. Nest density was high, with inter-nest distances down to 1 m (Fig. 4).

2.2.5 Breeding biology

Nests were shallow cups constructed of the prevailing moraine material (Fig. 4). A few nests contained small amounts of vegetation, mainly moss. On 19 July, eggs were hatching in the visited colony. Of the seven nests on which we caught birds, 5 had eggs (4 had 2 eggs, 1 had 1 egg) and 2 had newly hatched chicks. We saw other nests with pipping eggs, and a few chicks up to several days old walking about the colony. Overall, probably half of the nests had hatched at this date. We saw no 3-egg clutches, and only few 1-egg clutches.

The colony is located far from other areas of ice-free land or open sea, and presumably very safe from land-based predators (Arctic foxes or polar bears). We did not observe any potential avian predators during our visit to the colony.

2.2.6 Foraging: incidental observations

Ivory gulls were observed foraging at the Station Nord kitchen every day. Usually, only 2 or 3 birds were present at any time, with the maximum number seen being 7. Birds fed on various scraps from the kitchen, including everything from roast pork to snow contaminated by dishwater. A substantial proportion of ivory gulls were colour-ringed in previous years by O. Gilg and colleagues, and non-systematic observations of these birds indicated that no individuals were daily visitors to the kitchen. When present, individuals spent up to several hours at the site. We did not have opportunity to observe ivory gulls foraging in natural habitat. During our visit to the colony, we did not observe any gulls regurgitating food, or any other visible traces of meals.

2.2.7 GPS tracking

We deployed 11 devices on ivory gulls at Station Nord, but two tagged individuals left the Station Nord area more or less immediately and did not return before the base station was recovered. Of the 7 devices deployed in the colony 19 July, only one managed to upload data to the base station during the helicopter overflight 27 July, and none of the birds appeared to visit Station Nord so that data could be uploaded there. We thus have substantial tracking data from 10 individuals. All the individuals tagged at Station Nord showed attachment to the colony area, and 7 of the 9 birds appeared to be actively nesting for at least part of the tracking period (GPS positions highly clustered at one point, presumably the nest, with 2 at colony A, 3 at colony and 2 at colony C).

The 10 birds were tracked for a total of > 190 days (range 5-29 days per bird), generating > 54,000 positions. During this time, they were in total away from the colony for > 125 days and travelled > 41,000 km. The appendix shows all tracks obtained for each of the 10 individuals.

Space use

Overall, the tracked ivory gulls used areas to the north of the colonies, mainly in and along the shores of the Wandel Sea (Fig. 6). Birds used both coastal areas, areas of open sea near the edge of the fast ice, and pack ice areas north to 83.7 °N and east to 16.7 °E. Only during two trips did one bird make use of the northernmost part of the North East Water polynya south to 80.8 °N. Another bird made one very long trip eastwards in the pack ice to the area north of Svalbard.

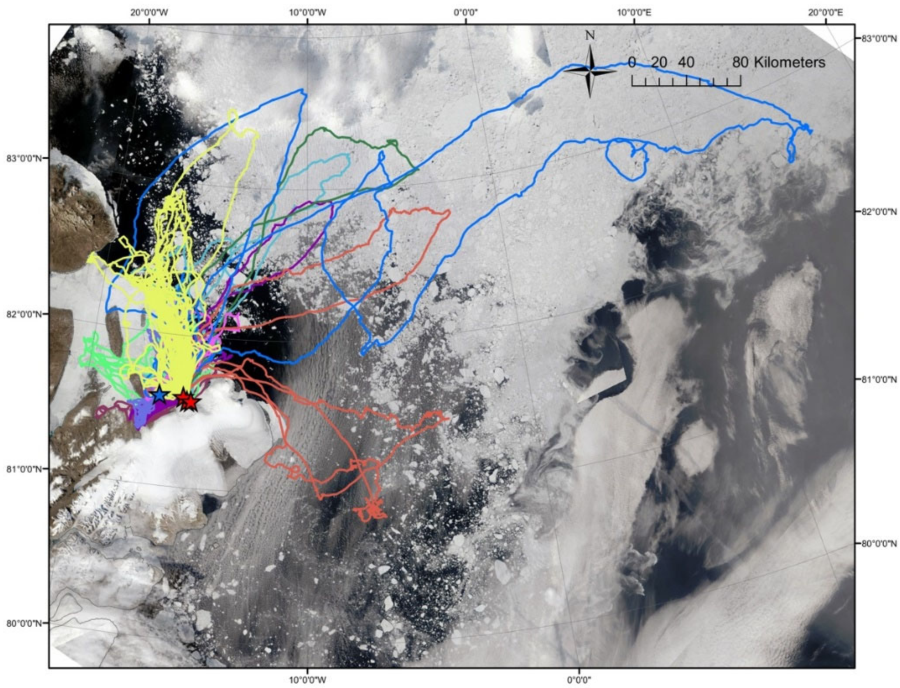


Figure 6. All tracks of ivory gulls equipped with GPS devices in the Station Nord area in July-August 2018. Each colour indicates one bird. The symbols indicate the location of Station Nord (blue asterisk) and colonies A, B and C (red asterisks). The background image is a true-colour satellite photo (NASA Worldview) from 13 August 2018.

Foraging trips into the pack ice were long and meandering (Fig. 6), presumably indicating that birds spent much of the time searching for highly dispersed food patches. The nature of these food patches is unknown, but likely include seal carcasses, e.g. remains of polar bear kills.

Trips to the open-water area north of the colonies were more direct (Fig. 6, examples in the appendix), perhaps indicating that the birds targeted more predictable, but less profitable, food sources. The exact nature of these food sources is unknown, but ivory gulls are known to feed on both fish and various marine invertebrates.

Coastal trips were highly variable, but a large proportion of the observed trips targeted one specific area about 25 km south-southwest of Station Nord (Fig. 7). This area is the inner part of the bay Hvidebugt, at the marine terminus of the calving glacier Marsk Stig Bræ. The glacier front and the area immediately offshore was heavily used by three individuals, which made respectively 15, 38 and 7 trips to the area. At the glacier front, gulls presumably target marine invertebrates such as amphipods, euphausiids or pteropods, which are stunned or killed by exposure to fresh meltwater. Ivory gulls have also been observed to feed extensively at glacier fronts in Svalbard (Lydersen et al. 2014).

All 9 individuals originally tagged at Station Nord made several subsequent visits to the station (mean 11.6, range 2-28 per individual excluding the tagging occasion), where they remained for 10-270 minutes (mean 54 minutes).

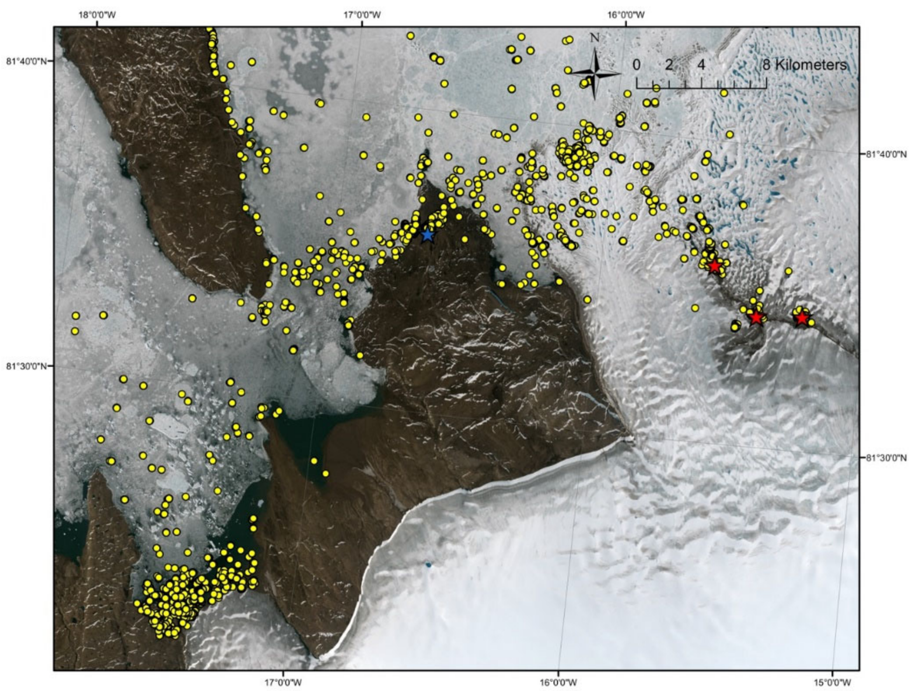


Figure 7. Inferred foraging locations (speed < 0.5 m/s) of ivory gulls in the area around Station Nord (blue asterisk), focusing on the glacier front at Marsk Stig Bræ (bottom left). The background image is a high-resolution, true-colour satellite photo (Sentinel-2) from 14 August 2018.

Trip characteristics

We recorded a total of 292 foraging trips (range 2-59 per bird) made by the 10 tracked individuals. Overall mean trip length was 214 km and mean duration 18.5 h, with substantial variation among individuals (Fig. 8). The longest trip recorded was 1850 km and lasted 182 h, with a maximum distance from the colony of 502 km (Fig. 6). Birds spent on average 65% of the time away from the colony (range 52-90% per bird). Over the course of the study period, trips became progressively longer (Fig. 9). This may reflect that chicks became older and were left alone for longer periods (or eventually became independent), or that breeding attempts failed. On each trip, birds spent on average 37% of the time (range 6-50% per bird) more or less stationary (speed < 0.5 m/s), presumably either resting or actively foraging.

Preliminary conclusions

The information collected in 2018 adds substantial new knowledge about ivory gull distribution and ecology in Greenland. The newly discovered colonies are, put together, one of the largest known breeding concentrations. The information obtained about foraging areas is entirely new, and can be used in management of this vulnerable species in relation to human use of areas. Both the new colonies and most of the foraging areas used by the tracked birds fall within 'fauna and flora area' no. 16, defined by Aastrup & Boertmann (2009).

With minor exceptions, the tracked birds unfortunately did not use the North East Water polynya or other areas of the Greenland Sea, instead foraging to the north in the Wandel Sea. We have thus not obtained specific new knowledge about important areas for ivory gulls in or near the license areas in the Greenland Sea. However, some general conclusions on important foraging areas for breeding ivory gulls can be made:

- When present and active, calving glaciers are very important foraging areas.
- Marginal ice zones within 50-100 km of the colony are important.
- Areas of offshore pack ice up to 500 km from the colony are also used, although it is unclear how important these areas are to actively breeding birds.

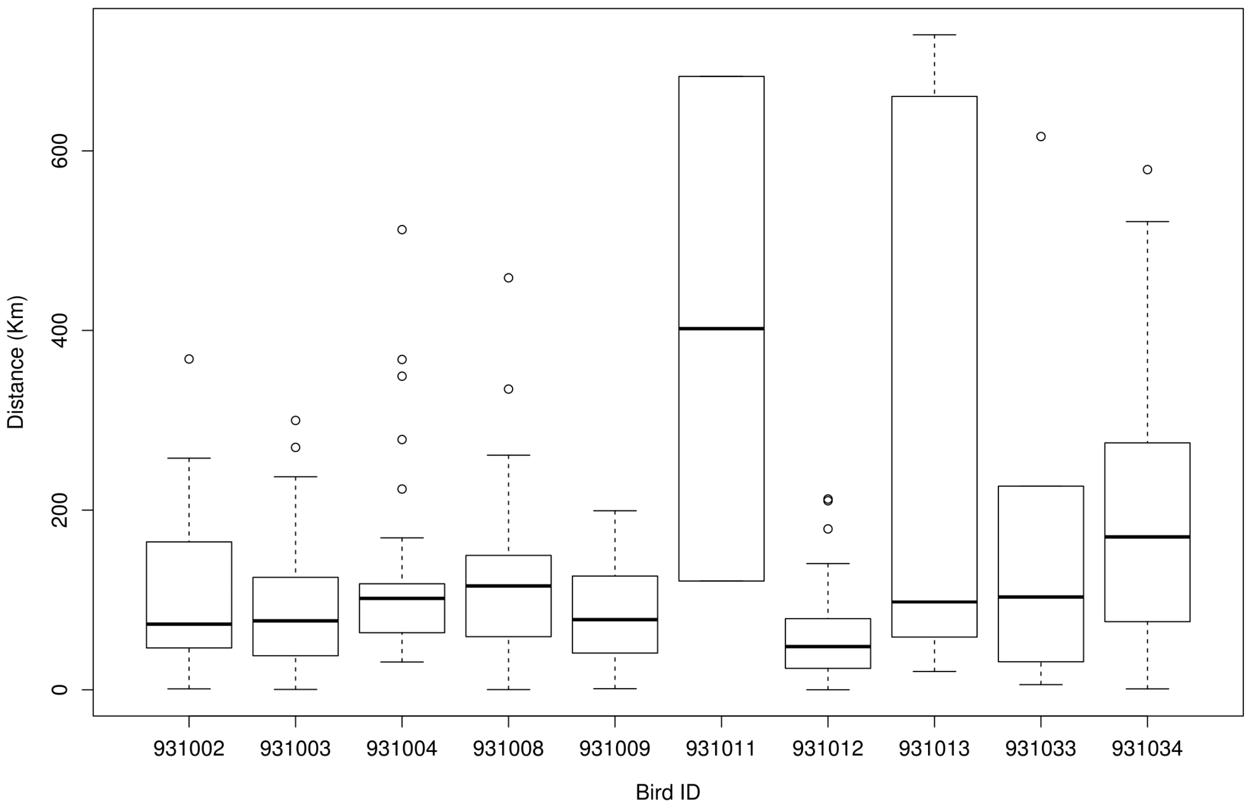


Figure 8a. Box plot showing the distribution of trip length of each tracked individual. The bold horizontal line indicates median trip length, while the box indicates the 25th and 75th percentiles. One extremely long trip for bird 931033 has been left out.

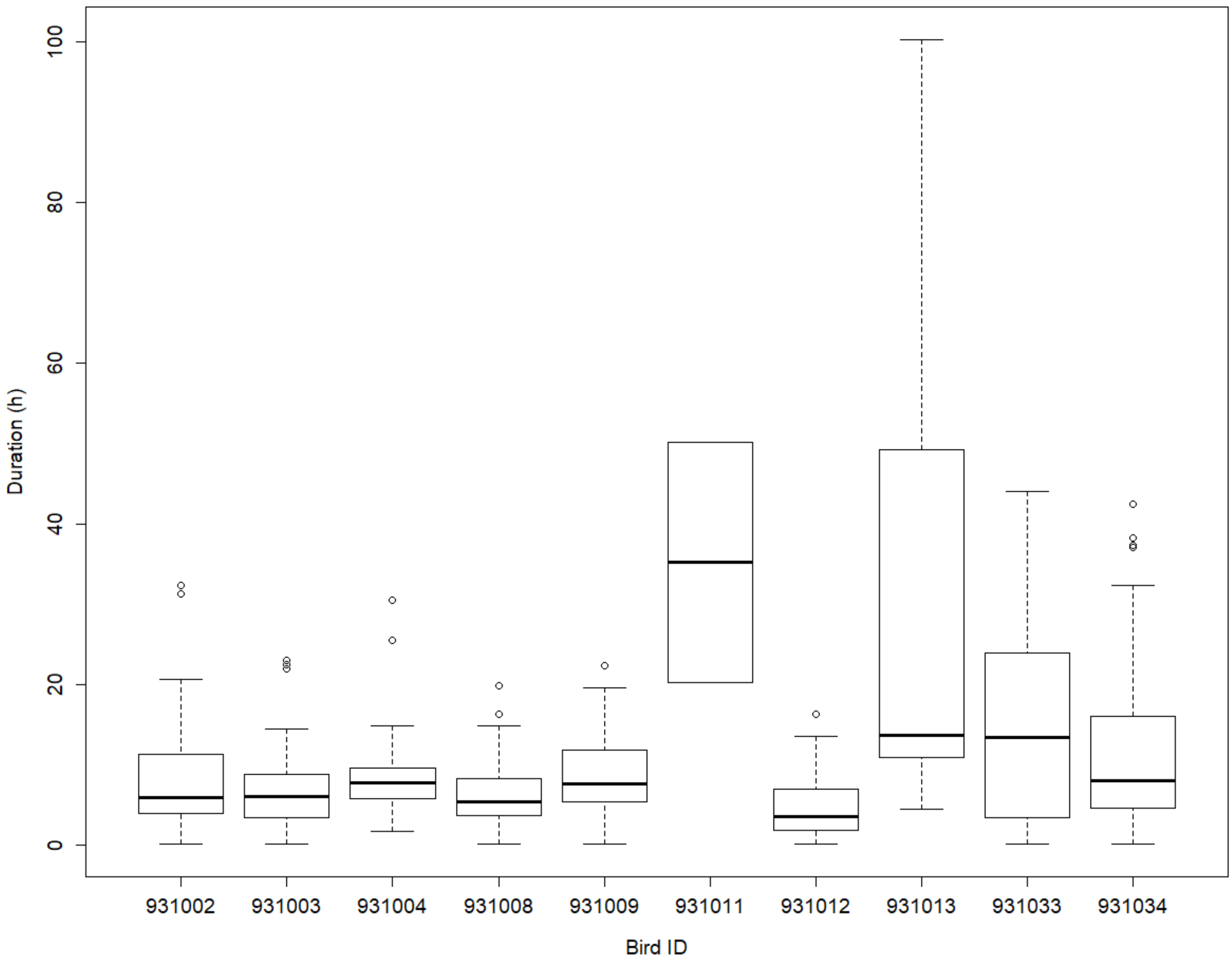


Figure 8b. Box plot showing the distribution of trip duration of each tracked individual. The bold horizontal line indicates median trip length, while the box indicates the 25th and 75th percentiles. One extremely long trip for bird 931033 has been left out.

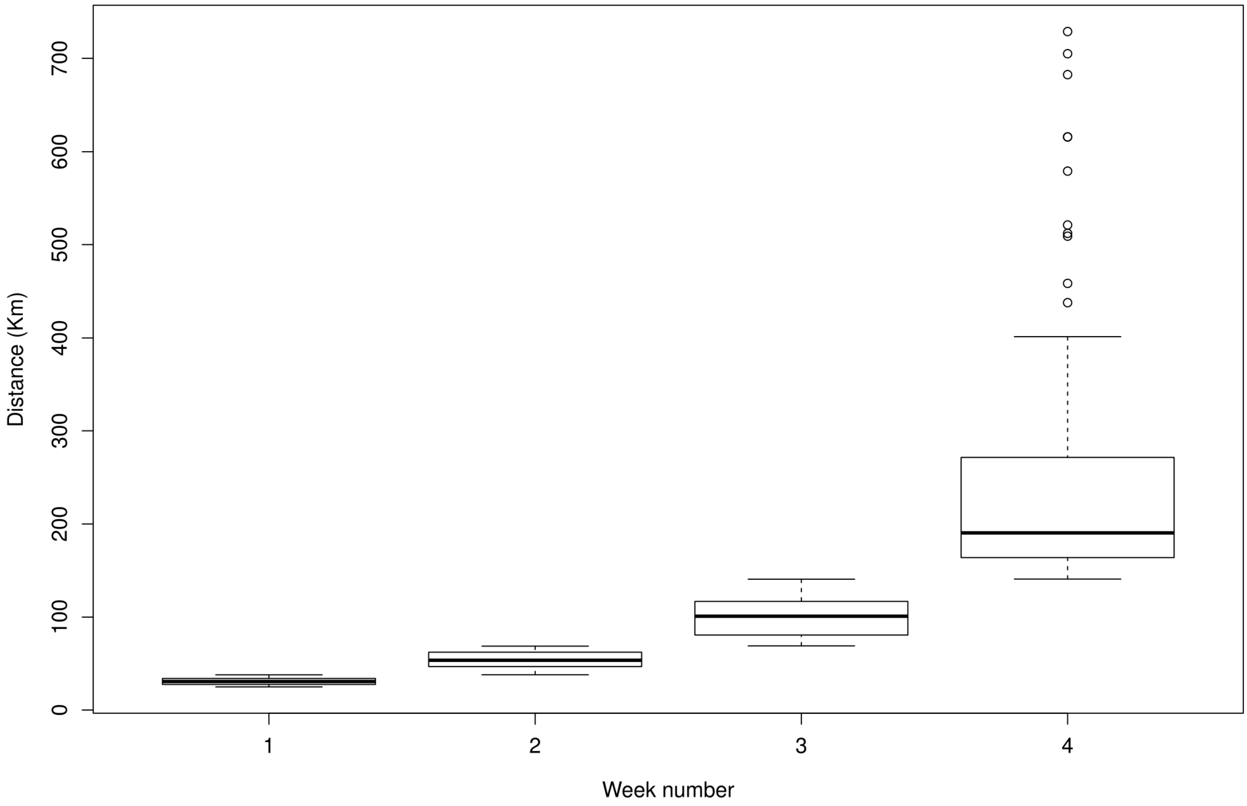


Figure 9a. Distribution of trip length over the four weeks of the study period, pooled for all birds. One extremely long trip in week 4 has been left out.

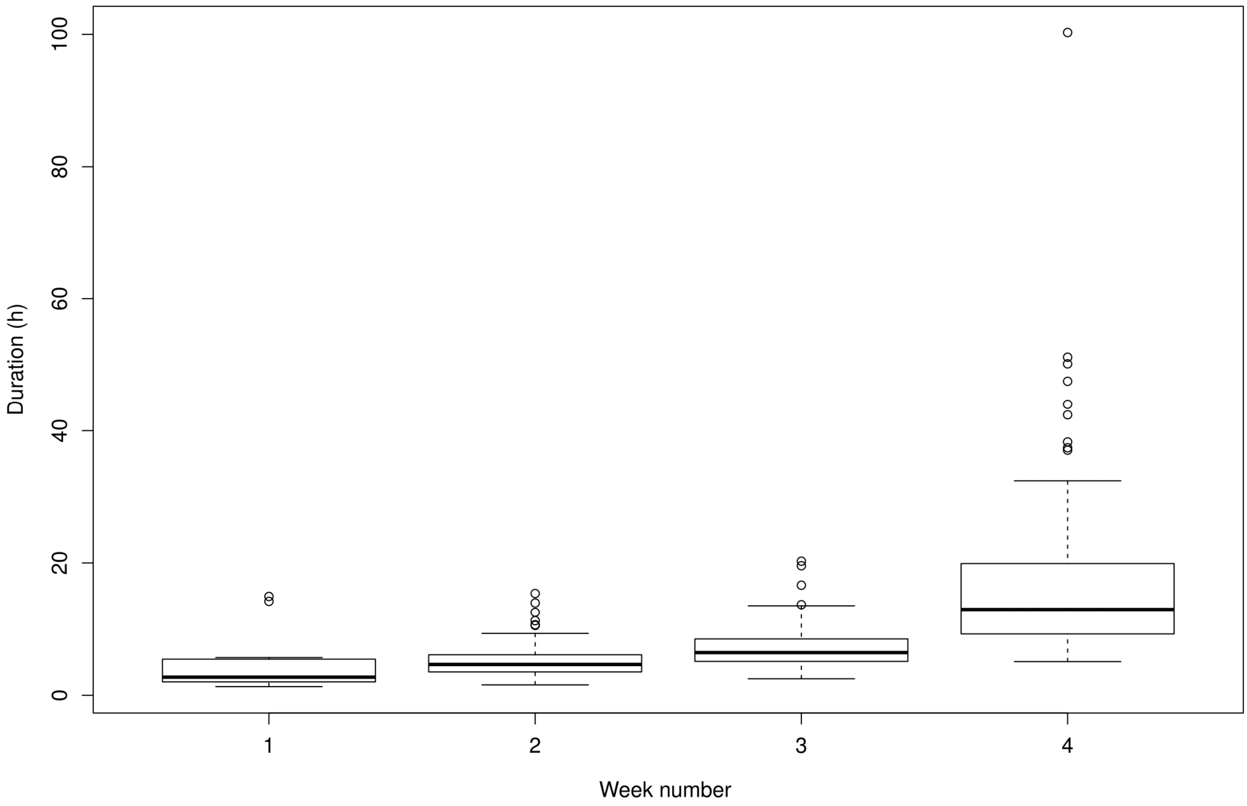


Figure 9b. Distribution of trip duration over the four weeks of the study period, pooled for all birds. One extremely long trip in week 4 has been left out.

3. Photographic survey of thick-billed murre colonies

Only two colonies of thick-billed murres exist in East Greenland, both in the Scoresby Sound area near Ittoqqortoormiit. These two colonies were surveyed from a boat on 21 July 2018. High-resolution digital photographs were taken at Raffles Island (Appalik, 70.60 °N, 21.51 °W) from 17:48 to 17:56, and at Kap Brewster (Kangikajek, 70.15 °N, 22.07 °W) from 19:15 to 20:33, all times East Greenland Summer Time (i.e. UTC). Individual photographs were stitched into composite images using the Microsoft ICE software, and subsequently all murres present were counted.

The numbers of birds present in a murre colony varies over the day, often in a colony-specific pattern, and counts should ideally be standardised to a specific time of day to account for this. However, we have no information on the diel variation in attendance at the two East Greenland colonies. Furthermore the images taken in 2018 were affected by strong sunlight, making counting difficult in some sections. For these reasons, count results should be regarded as of intermediate quality.

The number of murres counted was 2300 at Raffles Island and 3900 at Kap Brewster. For Raffles Island, this is the highest number recorded since 1995 (2500), and follows two lower counts in 2004 (2200) and 2010 (1700) (Merkel et al. 2014). For Kap Brewster, the new count continues a declining trend, with the two previous counts being 7900 in 2004 and 4800 in 2010 (Merkel et al. 2014).

4. Little auk studies at the Kap Høegh colony

4.1 Study species

The little auk is a small (~160 g) diving alcid foraging on zooplankton (Mosbech et al. 2018). In Northeast Greenland, it is present in the colony from early May to late August. The nest is hidden below the surface between boulders on the talus slope. It breeds often in high densities in large colonies, in Northwest Greenland the little auk is reported to breed in densities of more than 1 pair / m2 (Mosbech et al. 2017). Site fidelity is high, each pair returning to the same nest year after year. It lays a single egg, which both sexes take share in incubating. The chick is fed up to ten meals per day, each consisting of many hundreds of copepods (Welcker et al. 2009, Frandsen et al. 2014, Mosbech et al. 2017). The parents collect the zooplankton up to ~100 km from the colony (Amélineau et al. 2016).

4.2 The long-term study at Kap Høegh

The little auk field studies at Kap Høegh (70.72 °N, 21.55 °W) took place in the breeding season 2018 in collaboration with a research program conducted by a French team conducting a long-term study in the colony. This collaboration allows us to integrate our results in a larger pool of information, and to draw on the larger pool of information on the little auk ecology for the Strategic Environmental Impact Assessment. The French little auk research program is called ADACLIM: *Responses of Arctic marine birds to environmental constraints in the context of climate change*. Climate change profoundly affects Arctic marine ecosystems. These changes have direct and indirect impacts upon Arctic marine organisms. Direct effects are due to temperature increase which lead to a reorganization of oceanic food webs as well as to effects on animal physiology. Indirect effects are linked to shrinking sea ice and the opening of new areas for human industries, which both contribute to enhanced pollutions. In this context, the long-term ADACLIM research programme led by Jérôme Fort and David Grémillet and funded by the French Polar Institute (IPEV) aims to (1) understand the ecological functioning of little auks, a key sentinel species of a warming Arctic and (2) use little auks as biological indicators of Arctic pollutants and investigate ecological impacts of an exposure to a cocktail of pollutants. In order to achieve these research objectives, annual scientific expeditions to Kap Høegh at a major little auk breeding site have been conducted since 2005.

One of the major tasks of ADACLIM is the monitoring of several biological parameters every year, concerning both the breeding and non-breeding ecologies of little auks. This long-term monitoring makes it possible to define baselines for the species under current environmental conditions, and also to test the hypothesis that Arctic climate change and increasing pollution are impacting the trophic status, the foraging ecology, the reproductive output, the body condition, the multi-annual survival and the migratory ecophysiology of little auks. For instance, it allowed to demonstrate that the decrease of sea-ice extent in the little auk foraging environment has modified bird behaviour and diet over the last decade. Hence, adults tend to spend more time searching for their prey, dive deeper and provide their chick with less ice-associated amphipods. Nevertheless, these changes did not show impact on bird survival. Another example is the recent increase of little auk exposure to mercury

(+3.4% per year over the last decade) which is associated to a decrease of adult body condition as well as to a decrease of chick growth rates. During the 2018 field campaign, we continued this monitoring effort with the aim to further investigate little auk population responses to environmental change. In that context, the new photo monitoring study which started in 2018 as part of the NEG project package will be important. The use of video cameras during the 2018 field campaign will help to accurately estimate, for the first time at Kap Høegh, bird density and breeding success at the population level. Combined with baseline information for this little auk colony, these video camera data from the NEG project will thus provide essential data for a better understanding of the impacts of environmental modifications on little auks, not only at the individual, but at the population level. In addition, the set-up of a time-lapse camera that will continuously record bird densities at a specific plot over the coming years will provide new information about the phenology of this population (arrival time at the colony in spring, departure to migration after the breeding season). This information will thus complement our dataset by providing new baseline information for this little auk population that could be confronted to environmental conditions. It will also be compared to similar data acquired at another major breeding site in Northwest Greenland to enlarge our knowledge of little auks facing environmental modifications.

Beyond this specific comparison between Greenland little auk breeding sites, ADACLIM is part of a large international collaboration on little auks with researchers studying other major breeding sites in Northwest Greenland (Aarhus University), Spitsbergen and Bear Island (Norwegian Polar Institute and Gdánsk University) and Russia (Russian Arctic National Park). More specifically, this collaborative effort allows 1) to investigate differences in the responses of populations to climate change and environmental modifications, 2) to evaluate large scale non-breeding distribution and migratory strategies of little auks at a meta-population scale. This collaboration for instance allowed to identify several hotspots for this species, including two key areas located in the Greenland Sea and off Newfoundland.

ADACLIM also participates in an international, pan-Arctic network (ARCTOX), aiming to map and monitor the large scale contamination of Arctic marine food webs and to further understand the sources and impacts of mercury contamination on the little auk and Arctic biota.

4.3 Deployment of a solar powered time-lapse monitoring camera

A solar powered time-lapse camera was deployed in July 2018 to monitor little auk attendance in a study plot in the colony in the coming years. Throughout the breeding season, photos will be taken with 1 h intervals. Data will be downloaded each year by the ADACLIM team.

When not at sea or in the nest, the adult breeders spend time on top of the boulders resting and socializing with other birds. Here they are visible and will be recorded on photos in the monitoring plot. Many factors influence the attendance pattern recorded by the time-lapse camera, however most importantly the attendance reflect the foraging conditions as well as weather conditions, phenology of the breeding cycle, and frequency of disturbance by predators. When food is scarce the birds spend more time at sea and less in the monitoring plot.

We selected a plot in the central part of the colony (Fig. 10) and installed a solar powered time-lapse monitoring camera. We used a monitoring camera set-up which has been developed and used with success in West Greenland (Merkel et al. 2016). A Canon DSLR camera with a custom-made programmable timer was mounted in a weatherproof box equipped with a battery pack connected to an external solar power unit (Fig. 11 and 12). For details on the camera setup, see Merkel et al. (2016). The camera is programmed to take a single photo every hour throughout the breeding season (1 April – 1 September) for 4 years. However, it is planned to download the photos from the camera each year. The first download was done in 2019, but photos have not yet been analysed.

Figure 10. The time-lapse camera is deployed centrally in the colony (red arrow).

Figure 11. The weather-proof box with time-lapse camera and solar power unit.

Figure 12. The box is bolted to a boulder.

4.4 Video surveillance of little auks

A video surveillance plot was established to get detailed information on attendance pattern, chick feeding rates and breeding density using the methods described in Mosbech et al. (2017). A plot with good overview was selected in the central part of the colony (70° 43.648 min N, 21° 35.571 min W). The plot was an approximate square (side lengths: 420, 395, 310, 380 cm) with an area of 13.7 m^2. Two video cameras were set up overlooking the area from different angles, both downslope to protect the lens from precipitation. One camera was used as backup for the main camera. The custom designed (M. Garbus) video camera setup was weatherproof and solar powered, designed to run continuously for 2-3 weeks. Each setup consisted of a camera (HIK Vision Exir DS-7604NI-K1) mounted on a tripod fixed to boulders, a 120 W portable solar power unit and a hard disk (5 Tb) in a weatherproof box.

The video surveillance was started 22 July and ran for 12 days until 4 August. Of the 288 h possible, surveillance data was missing for 77 h (27%) due to bad weather. The main camera was restarted 4 August and recorded further 22 days until 26 August. This setup missed about 100 h (19%) of 528 possible h of recording, mainly due to darkness during nights.

An analysis of the attendance pattern using counts of birds in the plot at 30 min. intervals shows how attendance was reduced during a bad weather event 30 July – 3 August, and how attendance declined quickly from 6 August and onwards (Fig. 13). There was a clear diurnal rhythm until 8 August, with peak numbers attending around noon (Fig. 14). There was a significant change in behavior from 7-8 August and from this time, birds were observed circling most of the day with only brief landings (2-25 seconds) and even though circling birds could be observed on the videos, 3 h could pass without any bird attending the plot. This significant shift in attendance pattern has not been observed in previous studies, and it is speculated that it is related to a poor breeding performance in the colony in 2018. It is preliminarily estimated that there were 8-10 pairs with a chick in the plot (0.6 – 0.7 chicks / m^2), which is somewhat lower than what has been found in high density areas in North-west Greenland (1.1 – 1.6 chicks / m^2, Mosbech et al 2017). The latest fledging chick was observed as late as 25 August. It was apparent form the videos that Ravens were predating little auk chicks in the plot in the latter part of the period. This analysis is not finished.

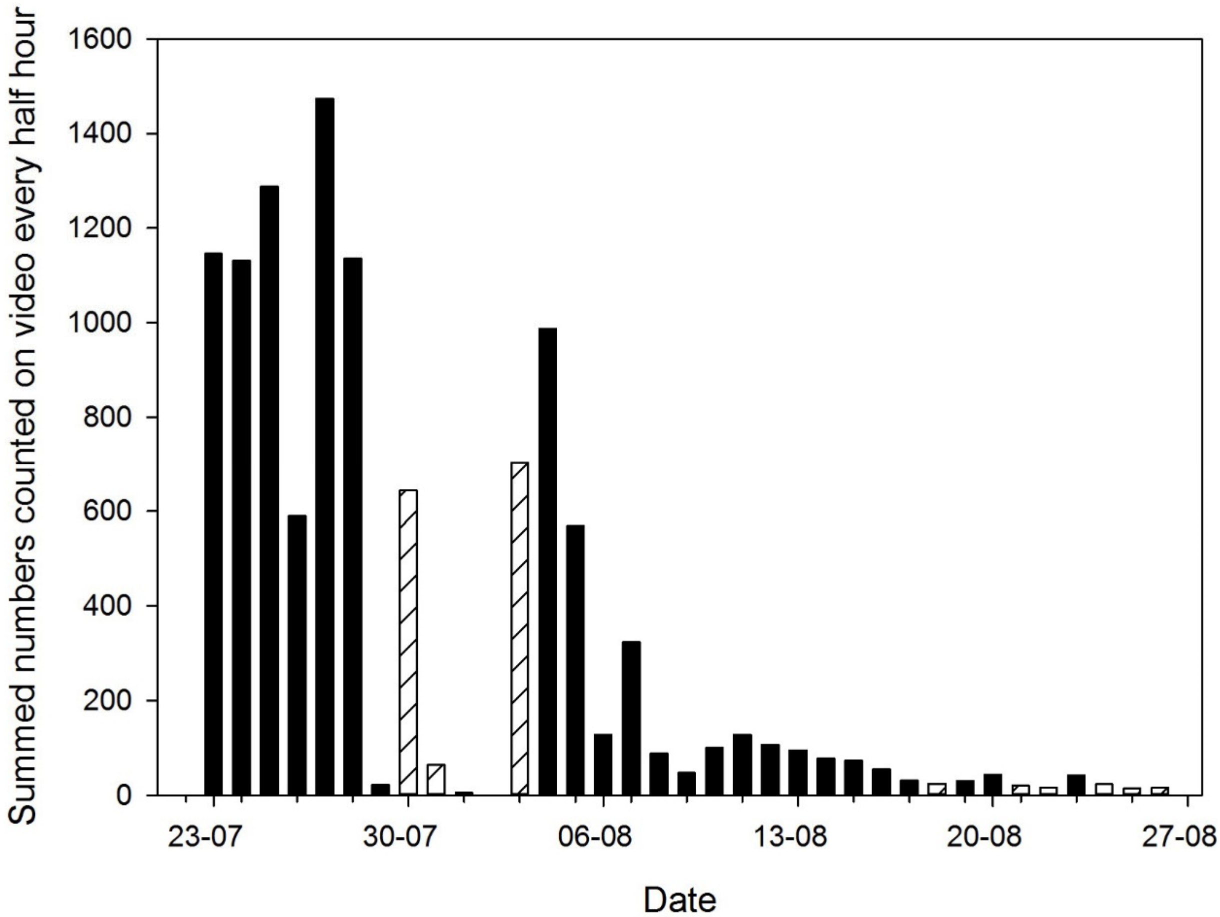


Figure 13. The daily sum of half-hourly counts of little auks, as a proxy for the daily attendance in the plot. Due to weather conditions, the camera did not record in the period 2-3 August and only recorded part of the days 30 July-1 August and 4 August (hatched bars).

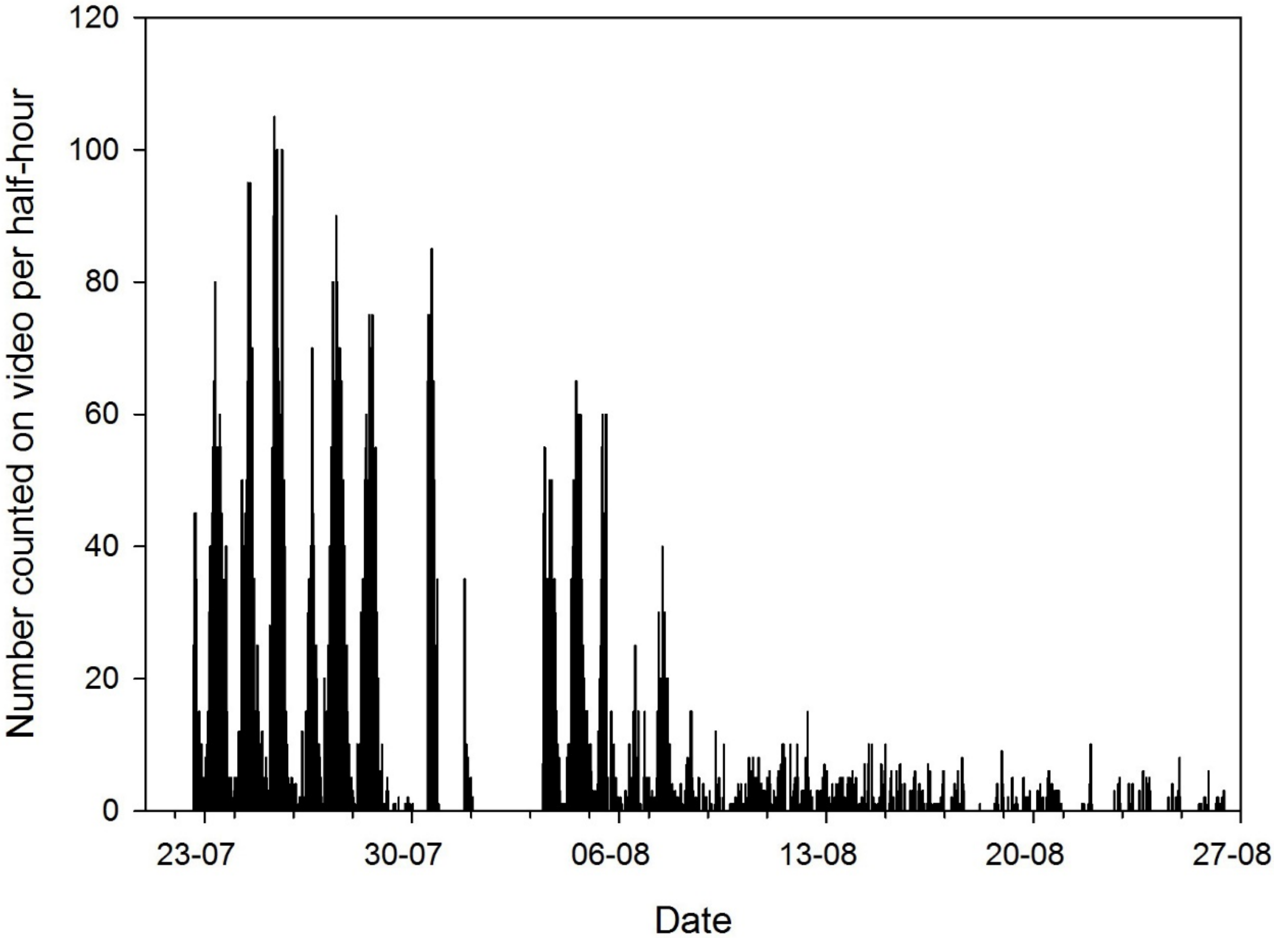


Figure 14. Counts of attending little auks every half hour in the period 23 July to 27 August. Due to weather conditions the camera did not record in the period 2-3 August and only recorded part of the days 30 July-1 August and 4 August. Starting 14 August where 2 hours recording were lost due to night darkness, some hours were lost each night due to darkness.

5. Conclusions

The tracking data collected in 2017 and 2018 have provided new information about potential foraging areas of Sabine's and ivory gulls in the Greenland Sea. Sabine's gulls appear to use mainly areas along the ice edge, at least during egg laying and early incubation. Although the tracked ivory gulls mainly used foraging sites in the Wandel Sea, areas used by the Greenland Sea population are likely to be similar, i.e. pack ice, productive ice-free areas, calving glaciers and human settlements.

Once data have been processed and reported, the aerial survey of ivory gull colonies in 2019 will provide an important update on the status and distribution of this high-priority species in East Greenland. In combination with the tracking data, and the ship-based at-sea survey carried out in 2017 as part of project 2.1, this will allow preliminary identification of likely important foraging areas. The survey of thick-billed murre colonies in 2018 was the first since 2010, and provided an important update on the status of this threatened and declining species.

Tracking of 21 little auks from the Kap Høegh colony was successfully completed in 2019. However, analyses of most data collected in the little auk study have not yet been finalized. Once more complete results are available, they will provide a much improved picture of important foraging areas and their links to specific oceanographic conditions, as well as on attendance patterns, chick feeding rates and breeding density.

Overall, the project has improved our understanding of the importance of the Greenland Sea for breeding seabirds. However, it is also clear that large gaps in knowledge remain, and the logistical challenges involved in seabird fieldwork in this remote area mean that these gaps will only be filled gradually.

6. References

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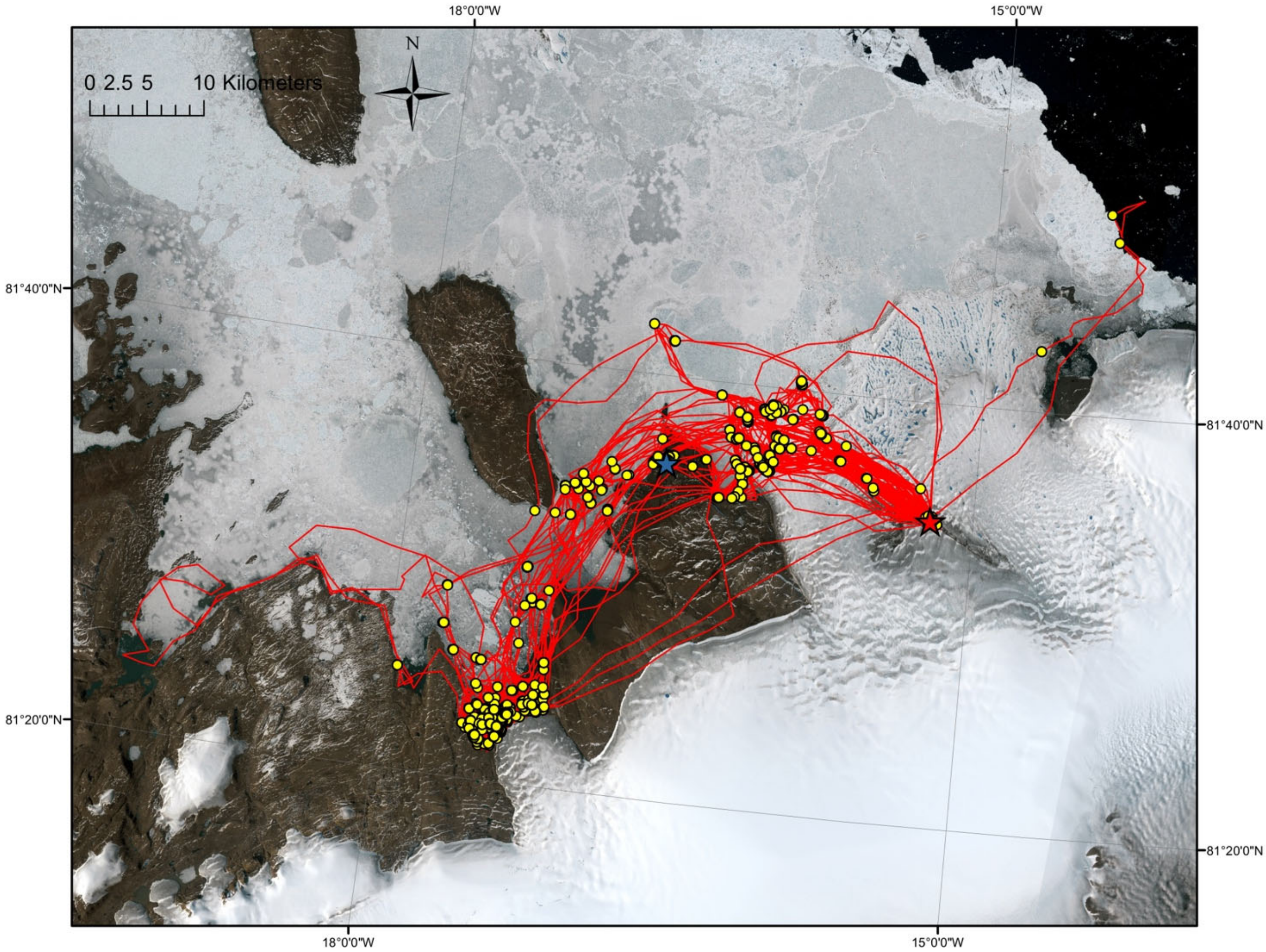
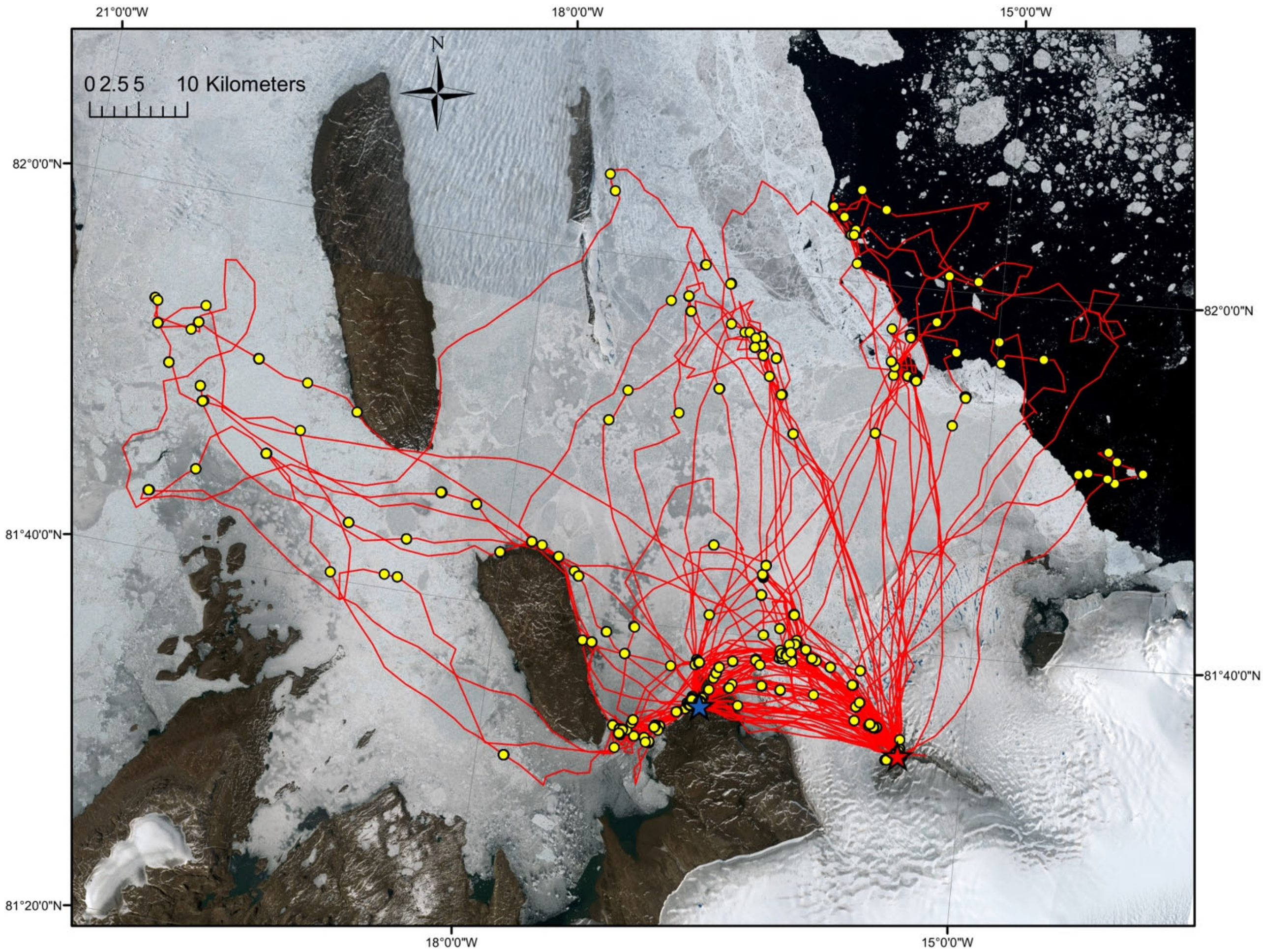
7. Appendix

7.1 Detailed tracking data for ivory gulls

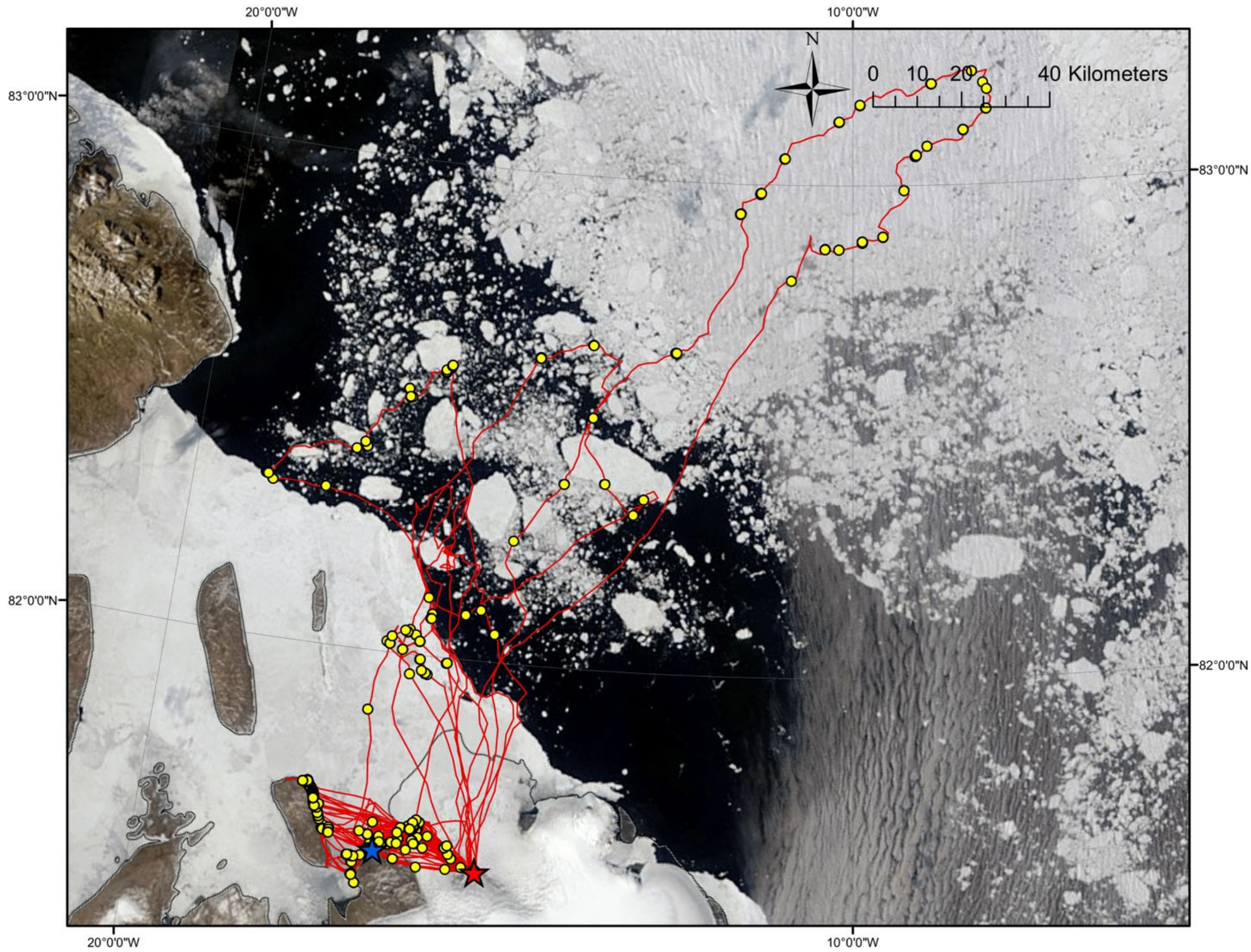
The following set of maps show all tracks recorded for each individual. Potential foraging locations, where speed was less than 0.5 m / s, are highlighted.



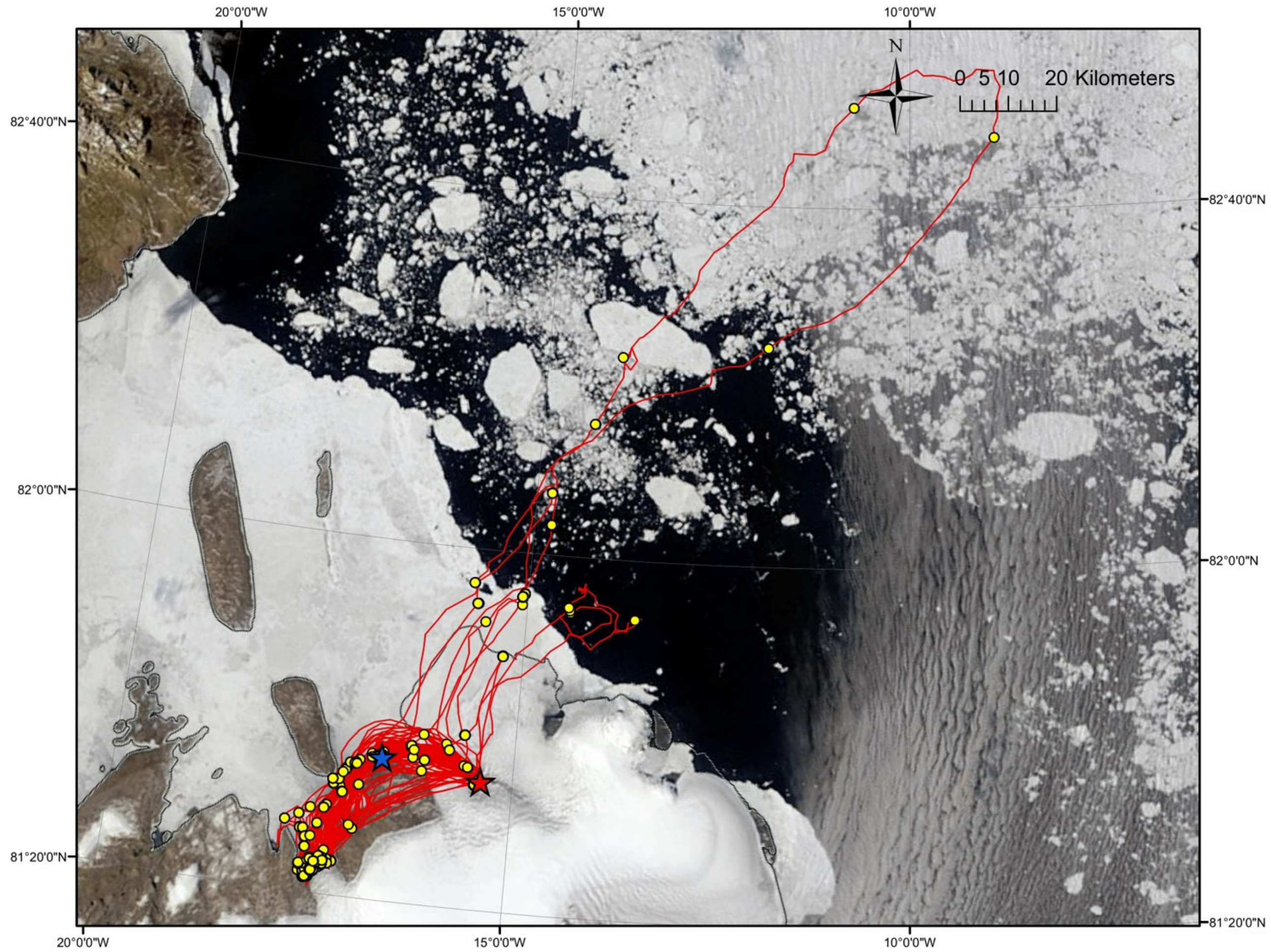
All trips recorded for individual 931002. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 41, total trip length = 4830 km, total trip duration = 403 h.



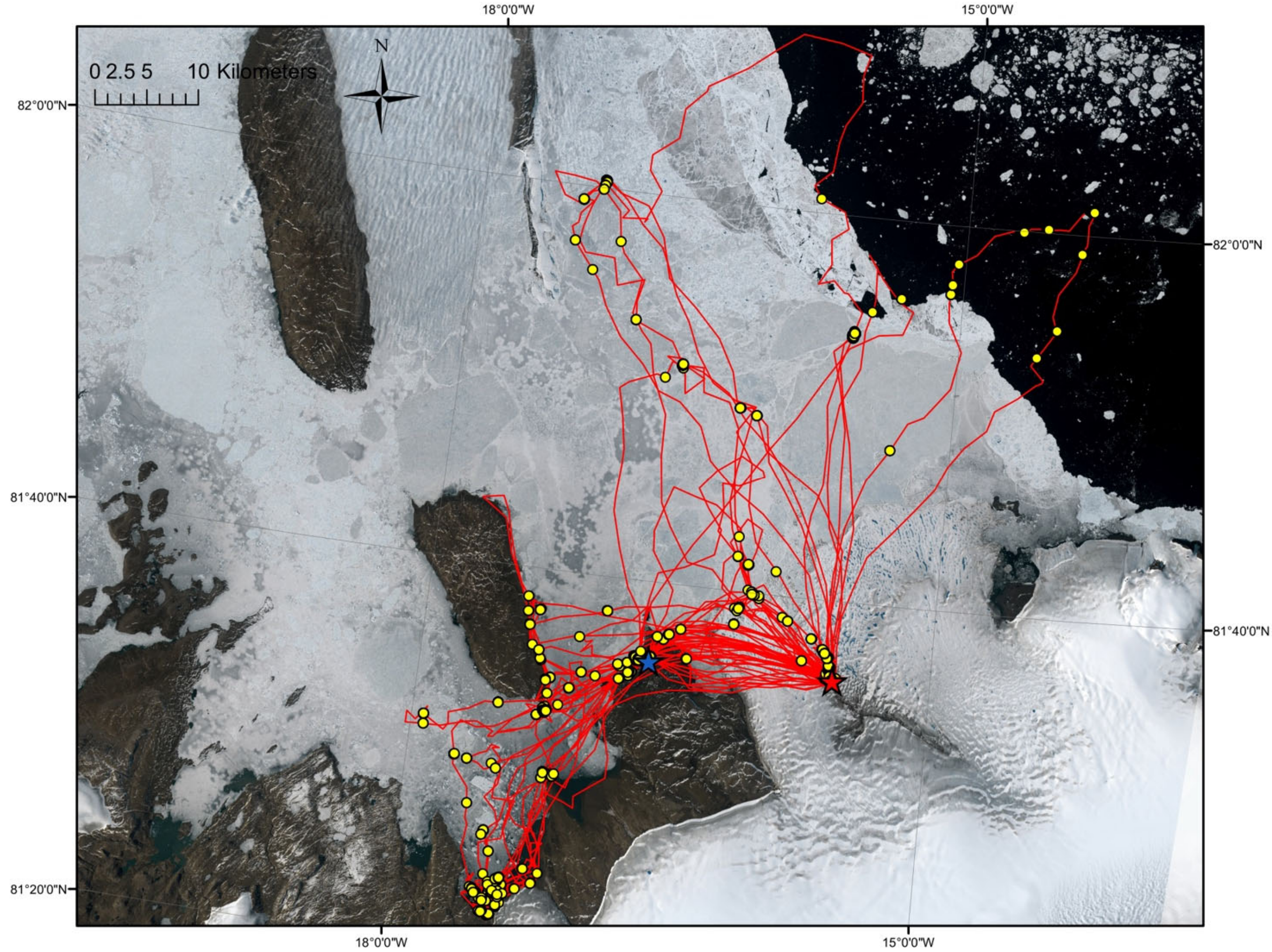
All trips recorded for individual 931003. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 42, total trip length = 4840 km, total trip duration = 354 h.



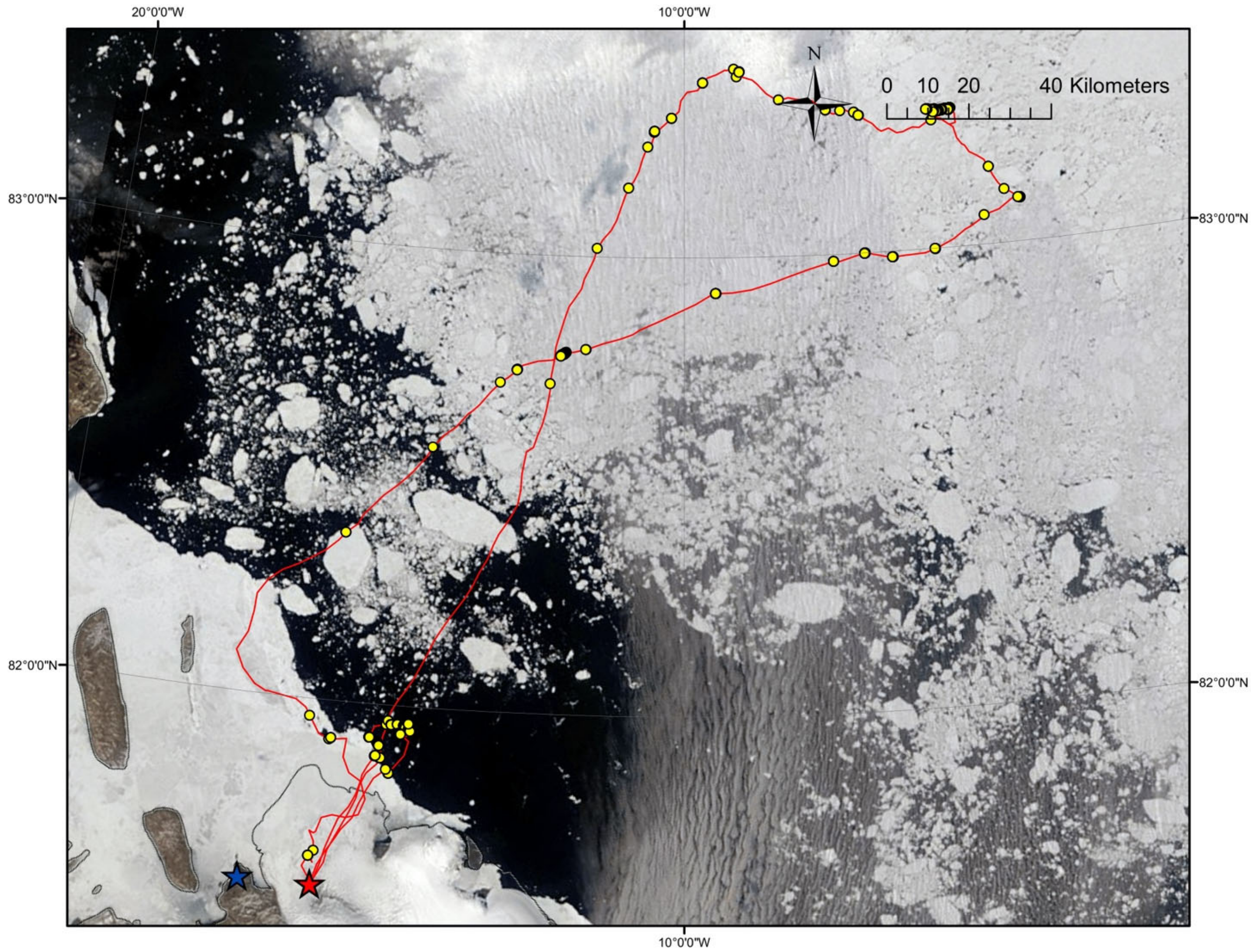
All trips recorded for individual 931004. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 37, total trip length = 4572 km, total trip duration = 323 h.



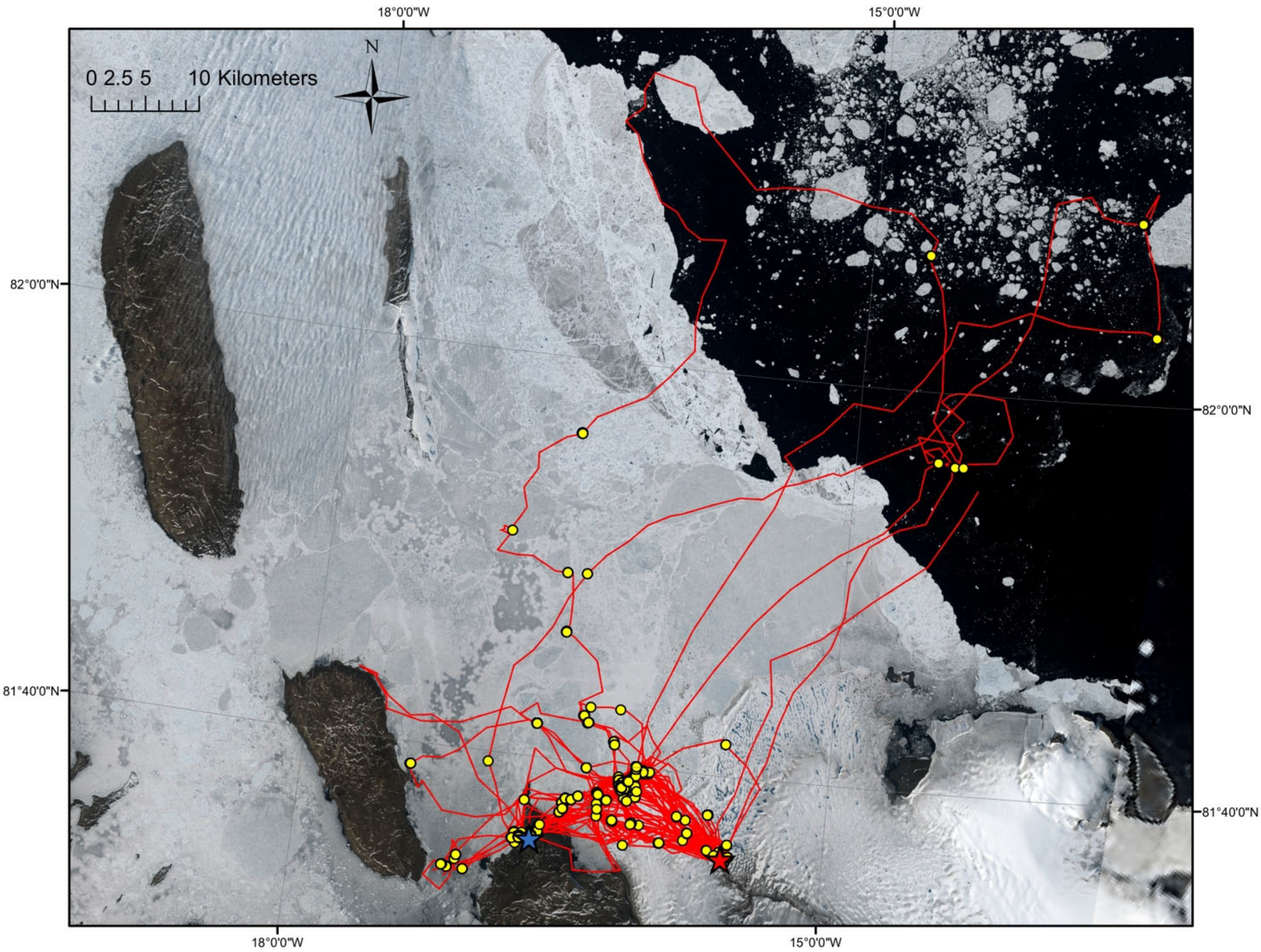
All trips recorded for individual 931008. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 59, total trip length = 7388 km, total trip duration = 407 h.



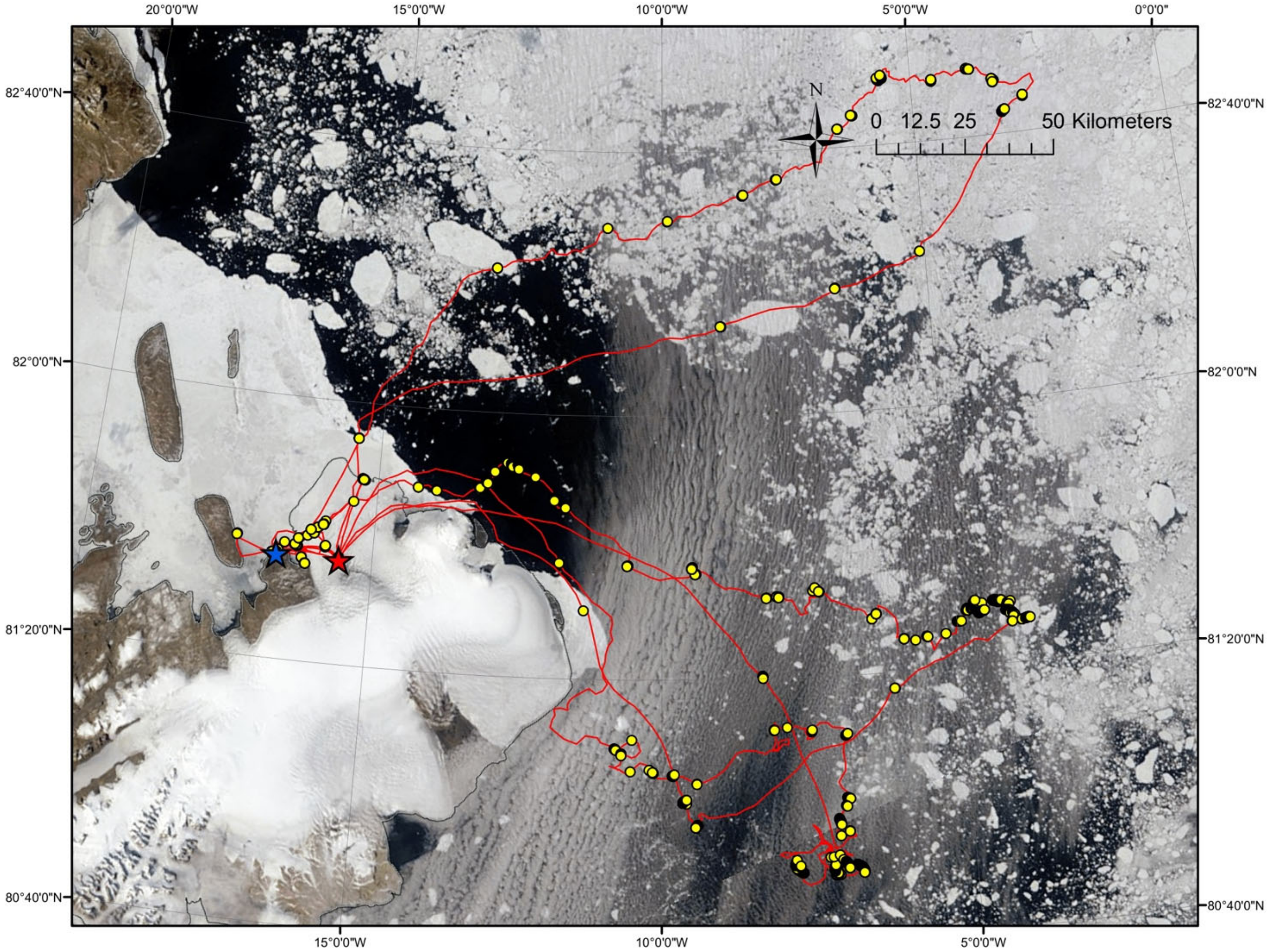
All trips recorded for individual 931009. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 31, total trip length = 3019 km, total trip duration = 309 h.



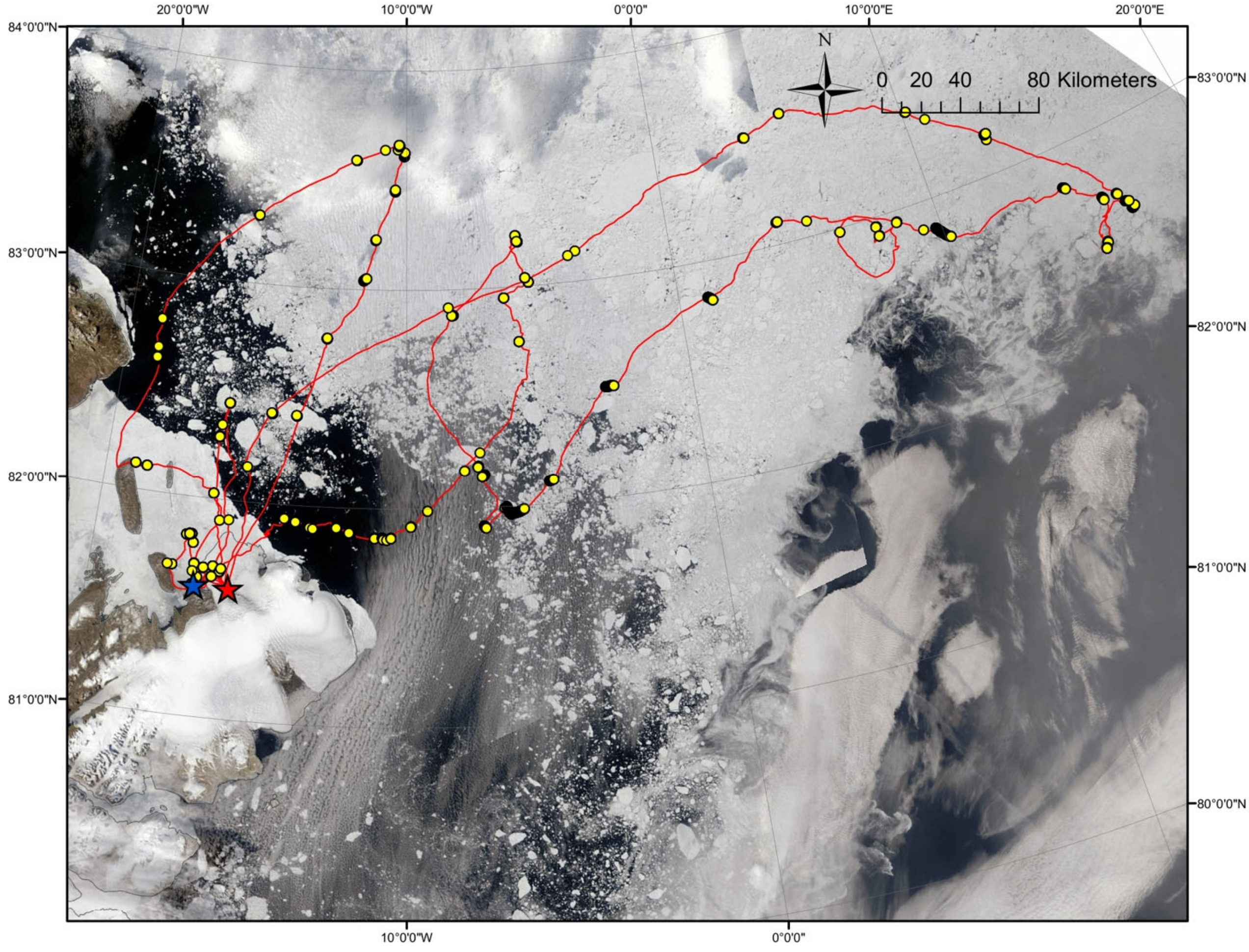
All trips recorded for individual 931011. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 2, total trip length = 804 km, total trip duration = 70 h.



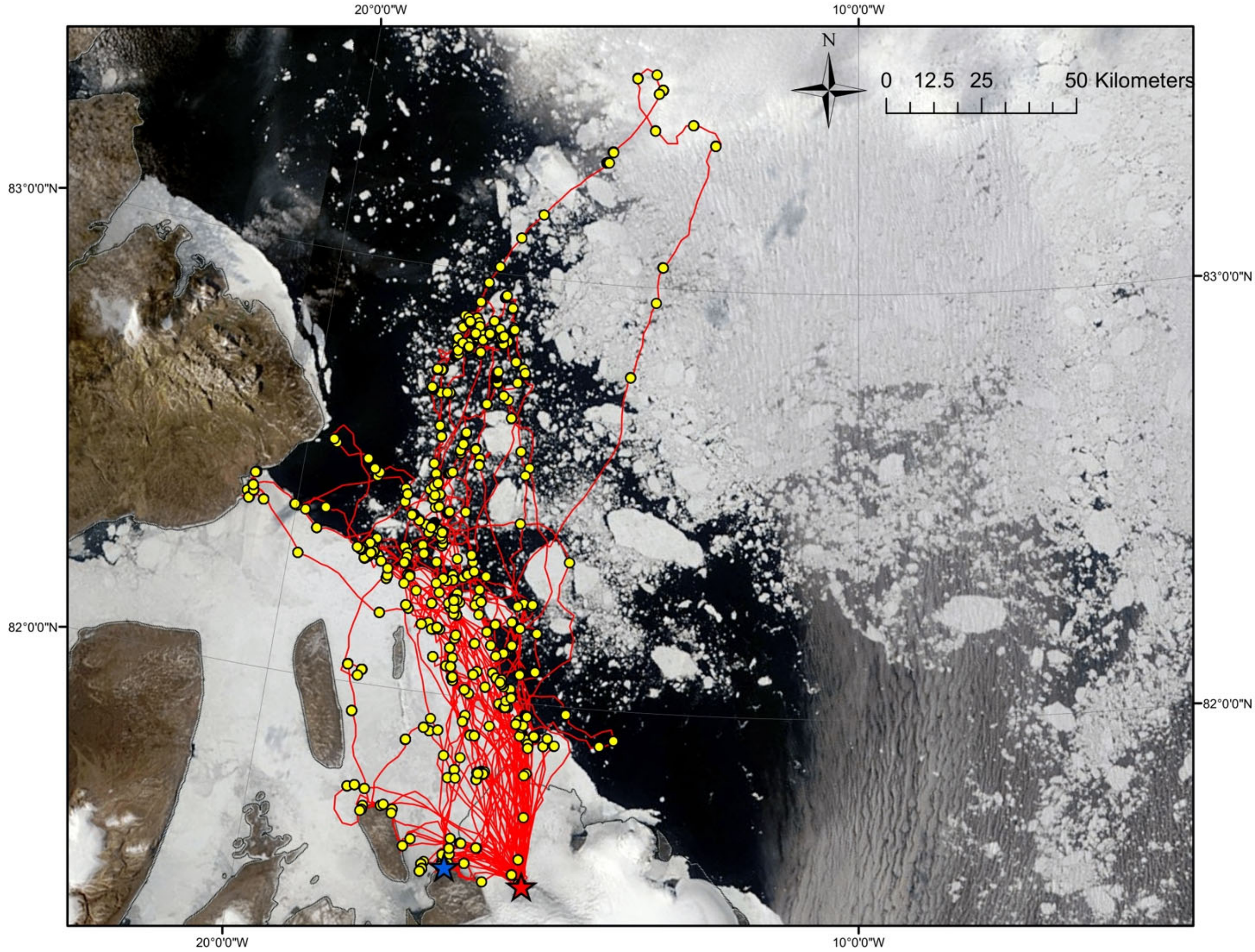
All trips recorded for individual 931012. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 28, total trip length = 2242 km, total trip duration = 168 h.



All trips recorded for individual 931013. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 6, total trip length = 2265 km, total trip duration = 234 h.



All trips recorded for individual 931033. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 6, total trip length = 2931 km, total trip duration = 280 h.



All trips recorded for individual 931034. Dots show potential foraging locations, and lines show recorded tracks. Number of foraging trips = 40, total trip length = 8376 km, total trip duration = 547 h.

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POPULATION SIZE AND HABITAT USE OF BREEDING SEABIRDS IN NORTHEAST GREENLAND

Field studies 2017-18

This study is part of the Northeast Greenland Environmental Study Program. The Northeast Greenland Environmental Study Program is a collaboration between DCE – Danish Centre for Environment and Energy at Aarhus University, the Greenland Institute of Natural Resources, and the Environmental Agency for Mineral Resource Activities of the Government of Greenland. Oil companies operating in Greenland are obliged to contribute to knowledge regarding environmental matters. The Strategic Environmental Impact Assessment and the background study program is funded under these commitments administered by the Mineral Licence and Safety Authority and the Environmental Agency for Mineral Resource Activities.

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