



HAL
open science

Seabird Breeding Colonies in East and North Greenland: A Baseline

David Boertmann, Flemming Merkel, Olivier Gilg

► **To cite this version:**

David Boertmann, Flemming Merkel, Olivier Gilg. Seabird Breeding Colonies in East and North Greenland: A Baseline. *Arctic*, 2020, 73 (1), pp.20-39. 10.14430/arctic69885 . hal-03854021

HAL Id: hal-03854021

<https://hal.science/hal-03854021v1>

Submitted on 25 Nov 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Seabird Breeding Colonies in East and North Greenland: A Baseline

David Boertmann,¹ Flemming Merkel² and Olivier Gilg^{3,4}

(Received 25 June 2019; accepted in revised form 30 September 2019)

ABSTRACT. This paper presents the results of a number of aircraft- and boat-based surveys for seabird breeding colonies in East and North Greenland carried out in the period 2003 to 2018 and gives the first comprehensive overview of the distribution and size of the seabird breeding colonies in this remote and mainly uninhabited region. Seventeen seabird species breed in approximately 800 sites distributed very unevenly along the coasts, with high concentrations at the polynyas and long stretches with very few breeding seabirds. Climate changes are in full progress in East and North Greenland, especially affecting the sea ice regime, and seabirds are expected to respond to these changes in different ways. For example, since the 1980s, Common Eiders (*Somateria mollissima*) have extended their breeding range more than two latitudinal degrees towards the north, now reaching the northernmost land on Earth. Lesser Black-backed Gulls (*Larus fuscus*) and Great Cormorants (*Phalacrocorax carbo*) have immigrated, and Sabine's Gulls (*Xema sabini*) have increased and extended their range. Besides presenting survey results, this report may also serve as a baseline for future studies of the abundance of breeding seabirds in East and North Greenland.

Key words: colonial seabirds; distribution; Greenland; climate change

RÉSUMÉ. Cet article présente les résultats de comptages de colonies d'oiseaux marins nicheurs menés en bateau et en avion dans l'est et le nord du Groenland entre 2003 et 2018. Il s'agit de la première synthèse globale consacrée à la distribution et à la taille des colonies de reproduction d'oiseaux marins pour cette région reculée et principalement inhabitée. Dix-sept espèces d'oiseaux marins se reproduisent sur environ 800 sites répartis de façon très irrégulière le long des côtes, avec de fortes concentrations aux alentours des polynies, mais aussi de grandes régions avec très peu d'oiseaux marins nicheurs. Les changements climatiques sont déjà très perceptibles dans l'est et le nord du Groenland. Ils y impactent fortement le régime de la banquise et on s'attend à ce que les oiseaux marins y répondent de différentes façons. L'eider à duvet (*Somateria mollissima*) a par exemple étendu son aire de distribution de plus de deux degrés de latitude vers le nord depuis les années 1980, atteignant les terres les plus septentrionales au monde. Le goéland brun (*Larus fuscus*) et le grand cormoran (*Phalacrocorax carbo*) se sont installés alors que la mouette de Sabine (*Xema sabini*) a étendu son aire de distribution et a vu ses effectifs augmenter. En plus de présenter des résultats de comptages, cette étude pourra également servir d'état initial pour évaluer à l'avenir les changements d'abondance et de distribution des oiseaux marins nicheurs dans l'est et le nord du Groenland.

Mots clés : oiseaux marins coloniaux; distribution; Groenland; changements climatiques

Révisé pour la revue *Arctic* par Nicole Giguère.

INTRODUCTION

Knowledge of the distribution and population sizes of breeding seabirds is important for management and protection not only of coastal areas, but also for the adjacent open sea exploited by foraging seabirds (Thaxter et al., 2012; Gaston et al., 2013). Such knowledge of seabird distribution and population size has been widely used for the regulation of petroleum exploration in West Greenland, where the knowledge base is extensive, largely because of the efforts of Finn Salomonsen (1979a, b) and many surveys carried out in the 1990s (Boertmann et al., 1996). In East and North Greenland, similar knowledge is much

less comprehensive, mainly due to logistical constraints. Firstly, the infrastructure is very limited in this region, hosting only 6% of the Greenland population (totalling 56 000 inhabitants in 2014) in only two small areas (around Tasiilaq at 65°37' N and Ittoqqortoormiit at 70°30' N). Secondly, the coasts have been, until recently, difficult to access because of the continuous presence of drift ice, even during the short summer season.

This lack of knowledge has been addressed over the past 20 years with increased research activity. This paper presents an outline of the results obtained on the distribution and abundance of breeding colonial seabirds in the region covering East and North Greenland

¹ Department of Bioscience, Aarhus University, Frederiksborgvej 399, 4000 Roskilde, Denmark; dmb@bios.au.dk

² Greenland Institute of Natural Resources, Kivioq 2, PO Box 570, 3900 Nuuk, Greenland

³ Groupe de Recherche en Ecologie Arctique, 16 rue de Vernot, 21440 Francheville, France

⁴ UMR 6249 Chrono-environnement, Université de Bourgogne Franche-Comté, 16 route de Gray, 25000 Besançon, France

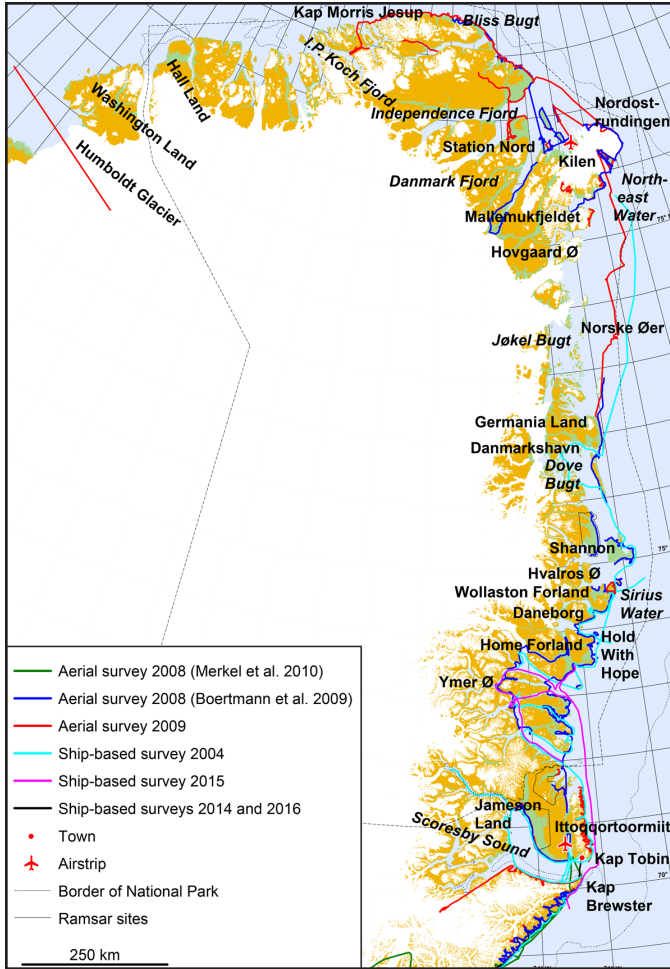


FIG. 1. Northeast Greenland with aerial and ship-based survey routes and tracks shown. Inland Ice and glaciers are shown in white; the sea is shown in pale blue; land below 200 m above sea level is shown in green; land above 200 m above sea level is shown in ochre. The dotted line in the sea indicates the 500 m depth contour. The red lines indicate the borders of the survey region.

(Figs. 1, 2). Our aim is to provide a reliable baseline that can be used to assess future changes in the seabird abundance and distribution in this region.

Before the surveys reported here, available information on breeding seabirds in East and North Greenland was limited to studies devoted to specific colonies and to opportunistic observations. Records from Southeast Greenland date back to the early 1900s (Helms, 1926; Degerbøl and Møhl-Hansen, 1935; Knudsen, 1935; Hørring, 1939; Ray, 1973; Meltofte, 1976), and observations of seabird colonies from Northeast Greenland date back to the Danmark Ekspedition in 1906–08 (Manniche, 1910). Since then, several authors have reported on seabird colonies in Northeast Greenland (Pedersen, 1930, 1942; Løppenthin, 1932; Rosenberg et al., 1970; Meltofte, 1975, 1977, 1978; Håkansson et al., 1981; Meltofte et al., 1981; Hjort et al., 1983, 1988; Forchhammer, 1990; Stemmerik, 1990; Forchhammer and Maagaard, 1990; Falk and Møller, 1995; Falk et al., 1997; Egevang and Stenhouse, 2007; Egevang et al., 2008). Information from North Greenland west of Kap Morris Jøsup is very limited (Bennike and Kelly, 1986;

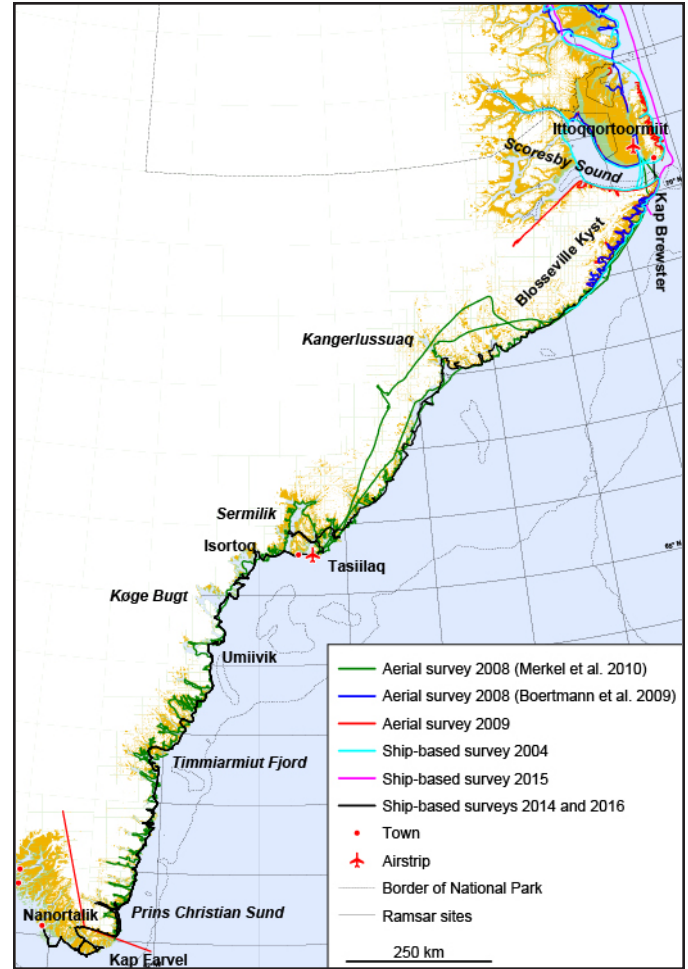


FIG. 2. Southeast Greenland with aerial and ship-based survey routes and tracks shown. Inland Ice and glaciers are shown in white; the sea is shown in pale blue; land below 200 m above sea level is shown in green; land above 200 m above sea level is shown in ochre. The dotted line in the sea indicates the 500 m depth contour. The red lines indicate the borders of the survey region.

Andreassen, 1999; Bennike and Feilberg, 2004), and earlier historical information from these remote parts is extremely scarce (Dietz and Andersen, 1984).

Regular monitoring of seabird colonies takes place only at the Thick-billed Murre (*Uria lomvia*) colonies at Kap Brewster and Raffles Ø near the town of Ittoqqortoormiit, known also as Scoresbysund (Falk and Kampp, 1998; Merkel, 2016; Egevang et al., 2017). However, the monitoring program at the Zackenberg research facility also includes occasional surveying of seabird colonies (Arctic Tern [*Sterna paradisaea*], Sabine’s Gull [*Xema sabini*], and Common Eider [*Somateria mollissima*]) near the site; that is, at the Daneborg military station and on the island of Sandøen (Hansen et al., 2007).

METHODS

This account covers the coasts of East and North Greenland from Ikerasassuaq (Prins Christian Sund) in the south (60°04' N, 43°13' W) to the Humboldt Glacier in

the northwest (79°35' N, 67°15' W). The area comprises the former municipalities of Tasiilaq and Ittoqqortoormiit (today part of the Sermersooq Municipality), the entire national park in East and North Greenland, and Washington Land. Hence, it includes the northernmost coasts in the world at 83°40' N.

In 2005, the Greenland government planned to launch a round of licensing for petroleum exploration in the waters off Northeast Greenland. This plan initiated a number of environmental background studies with the aim to provide data for the preparation of a strategic environmental impact assessment, which was carried out by the Danish Centre for Energy and Environment (DCE) at Aarhus University and the Greenland Institute of Natural Resources (Boertmann and Mosbech, 2012). These studies included two aerial surveys for seabirds in the coastal environment (Boertmann et al., 2009; Boertmann and Nielsen, 2010). In 2008, the Greenland Institute of Natural Resources also carried out an aerial survey, primarily of Common Eider colonies in Southeast Greenland, to acquire data for the management of the Greenland eider populations (Merkel et al., 2010). In addition, boat-based surveys of colonial seabirds were launched in 2014 and 2016, which covered the mainly unexplored (regarding seabirds) coast of Southeast Greenland (Boertmann and Rosing-Asvid, 2014, 2017). All data collected by DCE and the Greenland Institute of Natural Resources is compiled in the Greenland Seabird Colony Register (Boertmann et al., 2010b). Table 1 gives an overview of the surveys.

Besides these studies supported by the Greenland and Danish governments, the French non-governmental organization, Groupe de Recherche en Écologie Arctique (GREA), has since 1979 performed almost annual ecological studies, including surveys of breeding seabirds, along the coasts of East Greenland between 69° N and 77° N. Since 2003, GREA also visited and surveyed different areas between 80° N and 83°40' N (Kap Morris Jesup), including regular visits to Station Nord (81°37' N) and several visits to the Henrik Krøyer Holme islands (80°39' N) in the biologically rich Northeast Water polynya (Gilg et al., 2003, 2008, 2011). The most comprehensive colony surveys by GREA occurred in 2004 and 2015, when the schooner *Tara* (<https://oceans.taraexpeditions.org>) was used as an observation platform (Gilg et al., 2005). To date, with the exception of their specific research on Ivory Gulls (*Pagophila eburnea*) (Gilg et al., 2009, 2010, 2016; Yannic et al., 2016), none of the GREA seabird surveys has ever been published.

Data of the 17 colonial seabird species breeding in East and North Greenland from the Greenland Seabird Colony Register and GREA were combined. The selected species are all colonial breeders in the region, except for the Parasitic Jaeger (*Stercorarius parasiticus*), but we have included it here because it does breed in colonies in other areas of the North Atlantic (Cramp and Simmons, 1982). Many of the other species, such as the Glaucous Gull (*Larus hyperboreus*), Common Eider, and Arctic Tern, also breed in solitary pairs

TABLE 1. The seabird colony surveys in East and North Greenland. Survey route lengths in kilometres are rounded to the nearest hundred.

Year	Period	Platform	Area	Survey length
2004	8 July–31 August	Boat	NE Greenland	3300
2008	12–26 June	Aircraft	SE Greenland	6900
2008	19 July–18 August	Aircraft	NE Greenland	4500
2009	26 July–2 August	Aircraft	NE Greenland	3900
2015	26 July–12 August	Boat	NE Greenland	900
2015	18–28 July	Boat	SE Greenland	1700
2016	21 July–1 August	Boat	SE Greenland	1600

and have been included here. Typical non-colonial species, such as Red-breasted Merganser (*Mergus serrator*) and Long-tailed Duck (*Clangula hyemalis*), were omitted.

The survey methods used from the different observation platforms—ships and aircraft—are described in the post-survey reports (Gilg et al., 2005; Boertmann et al., 2009; Boertmann and Nielsen, 2010; Merkel et al., 2010; Boertmann and Rosing-Asvid, 2014, 2017). Coasts and potential breeding sites were surveyed by flying over or sailing parallel to the coast (“total counts,” see Laursen et al., 2008) and in some cases, specific sites were sought out and surveyed. Many colonies were also photographed for later estimation of breeding seabird numbers. Both during the aerial and ship-based surveys, at least two observers were actively searching the coasts.

Survey results for species originally recorded as individuals are converted to pairs by applying a conversion factor of 0.7 (Birkhead, 1978; Harris, 1989), as done in Canada in a comparable seabird status paper (Gaston et al., 2012). This conversion was not done for Black Guillemot (*Cepphus grylle*) (see below). Unless otherwise stated, all bird numbers in this paper refer to the most recent survey.

The estimates of the total seabird populations in East and North Greenland are based on the sum of the most recent survey results, including solitary pairs. Correction for the fraction of the unsurveyed coasts is also considered for widespread species such as the Black Guillemot and the Glaucous Gull, and expert judgement is applied to some degree. The fraction of unsurveyed coasts, excluding glacier coasts, were calculated from measurements of coastlines in GIS (MapInfo).

Since most of the colonies have only been described recently and visited once, assessing population trends is difficult for this region. Furthermore, successive surveys when available are sometimes difficult to compare because of changing observation conditions (e.g., in platform type—ship vs. aircraft). However, as mentioned above, dedicated monitoring takes place at two colonies (Merkel, 2016) for which population trends will be published separately, and a more comprehensive analysis of population trends in the region covered by the GREA surveys is planned.

Site names are usually given either in Greenlandic or Danish following toponymy of available topographic maps. For a few more significant and internationally recognized sites, English names are used.

TABLE 2. Fraction of Southeast, Northeast, and North Greenland coasts surveyed since 2003.

Area	Total coast	Surveyed coast	Unsurveyed coast	% surveyed	Delimitation
Southeast, south	9932	7342	2590	74	Prins Christian Sund to Tasiilaq
Southeast, north	4788	3590	1198	75	Tasiilaq to Kap Brewster
Scoresby Sound Fjord	2577	1242	1335	48	Kap Brewster to Kap Tobin
Northeast	14 980	12 190	2790	81	Kap Tobin to Kap Morris Jesup
North	4032	1475	2557	37	Kap Morris Jesup to Humboldt Glacier
Total	36 309	25 839	10 470	71	

RESULTS

Overall, 71% of the coastline of East and North Greenland has been surveyed since 2003, with some regional variation (Table 2). Along these coasts, 799 breeding sites for 17 seabird species are recorded (Tables 3 and 4, Figs. 1, 2). From these sites, the combined databases contain 2191 records. Depending on its original description, we sometimes define a colony as including sub-colonies on nearby islands; in other cases, nearby island colonies are defined as separate colonies. The new data collected since 2003 more than sextupled the number of known seabird breeding sites in the covered region (Table 3). Figures 3–12 present species maps with the location of all known seabird breeding colonies and sites in the covered region.

Species Accounts

Northern Fulmar (*Fulmarus glacialis*): Ten sites with breeding (or presumed breeding) Northern Fulmars are known (Fig. 3). However, at three of these sites (Dunholm, Hvalros Ø, Home Forland), Northern Fulmars have only been observed once on land despite several subsequent visits, and it is doubtful if these sites represent regular breeding sites. All the stable colonies are located on steep cliffs and at the polynyas (i.e., at the Northeast Water polynya and the mouth of Scoresby Sound). The colonies at the Northeast Water polynya are distributed over several cliffs and were discovered in 1907 during the Danmark Ekspedition (Manniche, 1910). Surveyed in 1993, the estimated number of breeding pairs at these colonies was

TABLE 3. State of knowledge regarding number of seabird breeding colonies in East and North Greenland before 2000 and today (after the surveys reported in the text). Colony numbers are distributed on the former administrative regions and the National Park. Since 2009, Tasiilaq and Ittoqqortoormiit Municipalities have been part of Sermersooq Municipality, which includes the former Nuuk and Paamiut Municipalities in West Greenland. Today, Avanersuaq Municipality is part of Avannaata Kommunia in West Greenland.

Region	Before 2000	Today
Tasiilaq Municipality	14	155
Ittoqqortoormiit Municipality	19	197
National Park in East and North Greenland	87	441
Avanersuaq Municipality (Washington Land)	6	6
Total	126	799

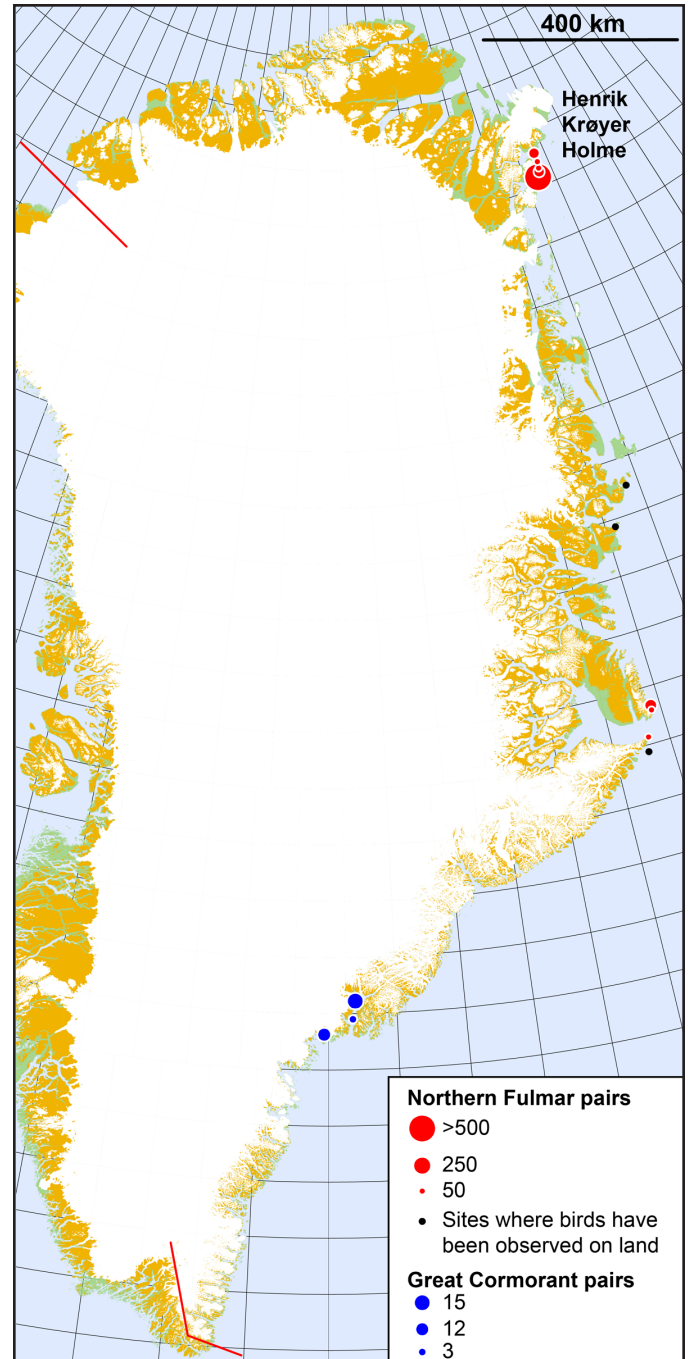


FIG. 3. Distribution and size of Northern Fulmar and Great Cormorant breeding colonies. Inland Ice and glaciers are shown in white; the sea is shown in pale blue; land below 200 m above sea level is shown in green; land above 200 m above sea level is shown in ochre. The dotted line in the sea indicates the 500 m depth contour. The red lines indicate the borders of the survey region.

then 1475 (Falk and Møller, 1995, 1997). All the other colonies are small with less than 150 pairs, and the total number in the region probably does not exceed 2000 pairs.

Great Cormorant (*Phalacrocorax carbo*): Only three breeding colonies are known, and all are from cliffs in the Sermilik (Isortoq) area west of Tasiilaq (Fig. 3). An additional possible colony was reported by a local source around 2010; however, during the 2014 survey, it was determined that the location was a roosting site without nests. Only one of the colonies has been surveyed twice, and it held 22 nests in 2005 and 12 in 2014. The total population in the region apparently numbers fewer than 50 pairs. According to local sources, the colonies were established in the period 2000–05, and there may be more colonies in the region. This small population is very isolated; the nearest breeding populations are located in Iceland (600 km) and in West Greenland (1500 km apart; if following the shortest distance over water).

Common Eider (*Somateria mollissima*): In East Greenland, Common Eiders usually breed in small colonies on low islands, but solitary nesting eiders can also be found on both islands and infrequently on mainland coasts. Scattered colonies have been located all along the coasts of the region from 61°30' N in the south to northernmost Greenland and in Washington Land in the west, where in 1999 Bennike and Feilberg (2004) observed single females with chicks, and Andreassen (1999) reported a small colony (Fig. 4). There are, however, long stretches of coastline where breeding has not yet been observed, such as the Blosseville Kyst and in most of North Greenland. In total, 116 colony sites are known; in addition to these are the solitary breeders, of which known sites are shown on Figure 4. The largest colonies are found on the mainland at two manned stations in Northeast Greenland (Danmarkshavn and Daneborg), where the birds place their nests near tethered sledge dogs (Meltotte, 1978). More than 3100 pairs have been reported at Daneborg (result of photocounts in 2012; O. Gilg, unpubl. data) and up to 400 at Danmarkshavn (U. Capito, pers. comm. 2009), while all other colonies range between 2 and 300 pairs.

In 2008, Merkel et al. (2010) estimated the population of breeding eiders in Southeast Greenland at 1600–3200 pairs. Based on an aerial survey of pre-breeding birds in Northeast Greenland in May 2008, the breeding population here was estimated to be at least 13 000 pairs (Boertmann et al., 2009). The combined most recent survey results from all the colonies report many fewer (6000 pairs), which indicates many unknown breeding sites or perhaps a large non-breeding segment of the population.

Parasitic Jaeger (*Stercorarius parasiticus*): The Parasitic Jaeger is not strictly colonial in the region covered by this paper, and many solitary breeding pairs remain unrecorded. In total, 25 sites with breeding jaegers in East Greenland and one from Washington Land in North Greenland are registered in the two databases. Two pairs were observed at two sites (one with a distance of more than 1 km between pairs) and three pairs at only one site (Fig. 5).

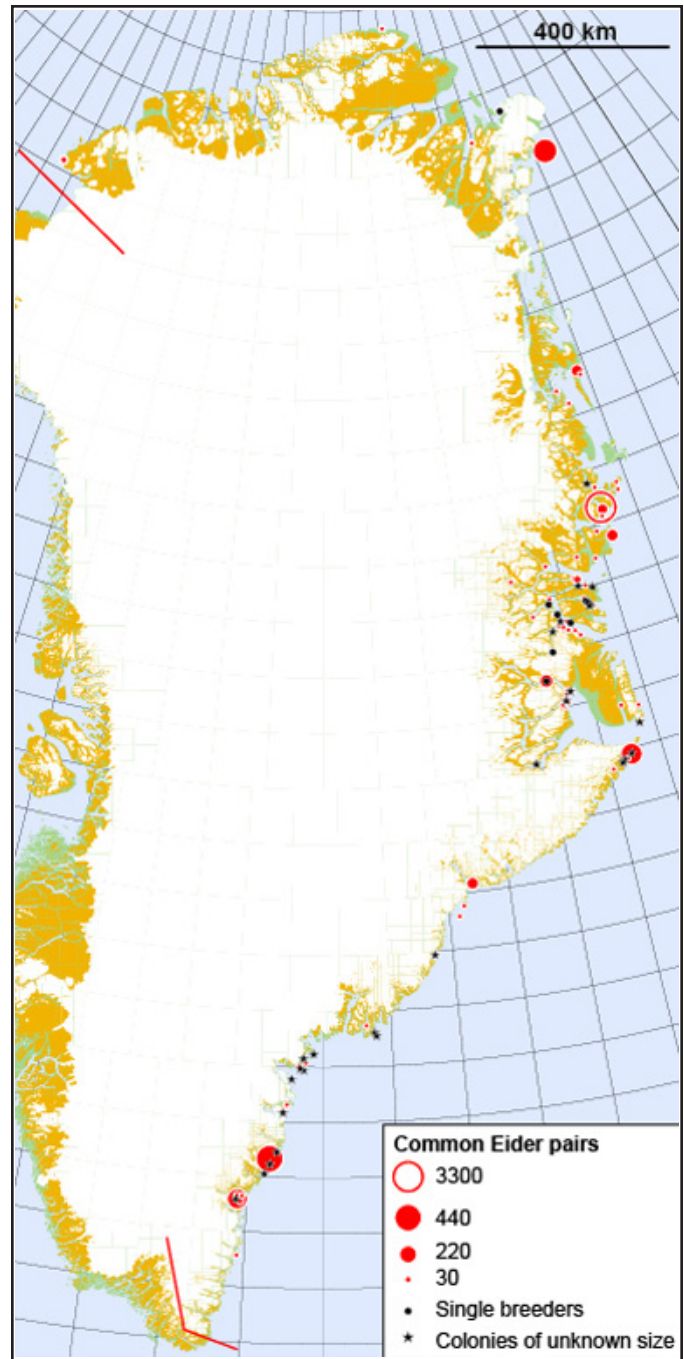


FIG. 4. Distribution and size of Common Eider breeding colonies in East and North Greenland. The black dots indicate observations of solitary nests and single females with chicks. Colonies with fewer than 30 pairs ($n = 73$) are shown with the symbol for 30 pairs, in order to be visible on the map.

In East Greenland, single birds have been observed as far north as the Northeast Water polynya (Boertmann et al., 2009). The population in East and North Greenland is very small, even considering that many breeding sites remain unrecorded, and probably does not exceed 200 pairs.

Sabine's Gull (*Xema sabini*): Sabine's Gulls are known from 34 breeding sites in the region covered by this report (Fig. 6). The southernmost site is located on the coast of Jameson Land and the northernmost site on the island north

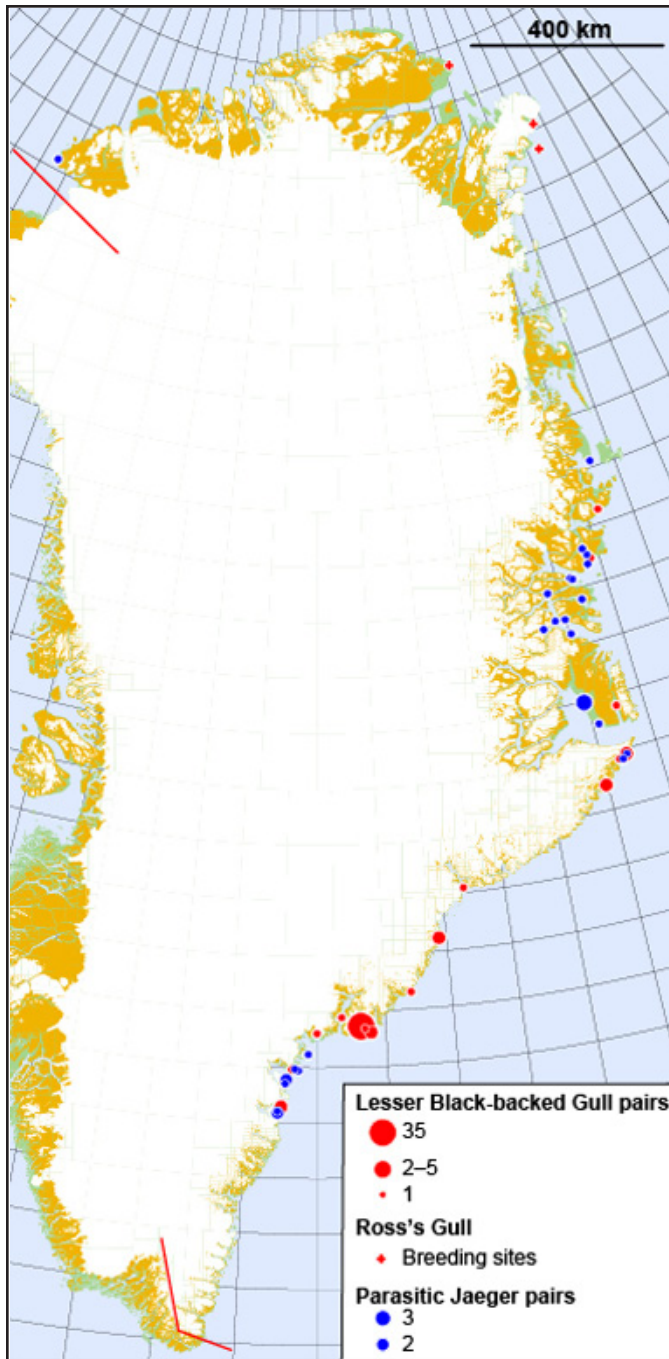


FIG. 5. Distribution and size of Parasitic Jaeger, Lesser Black-backed Gull, and Ross's Gull breeding colonies (including sites with solitary pairs).

of Bliss Bugt at 83°38' N. In contrast to the situation in Arctic Canada and Alaska (Stenhouse et al., 2001; Norment et al., 2015), Sabine's Gulls usually breed in well-defined colonies in East and North Greenland, probably because most colonies are located on small islands (Mallory et al., 2012). At the few mainland sites, the colonies seem less well defined. The sum of the most recent survey results adds up to 470 pairs, with the largest colonies at Kilen, Rensøkæret (at Danmarkshavn), and Sandøen, with a maximum of 150 pairs at all three, although not in the same season. The colony size fluctuates widely from year to year,

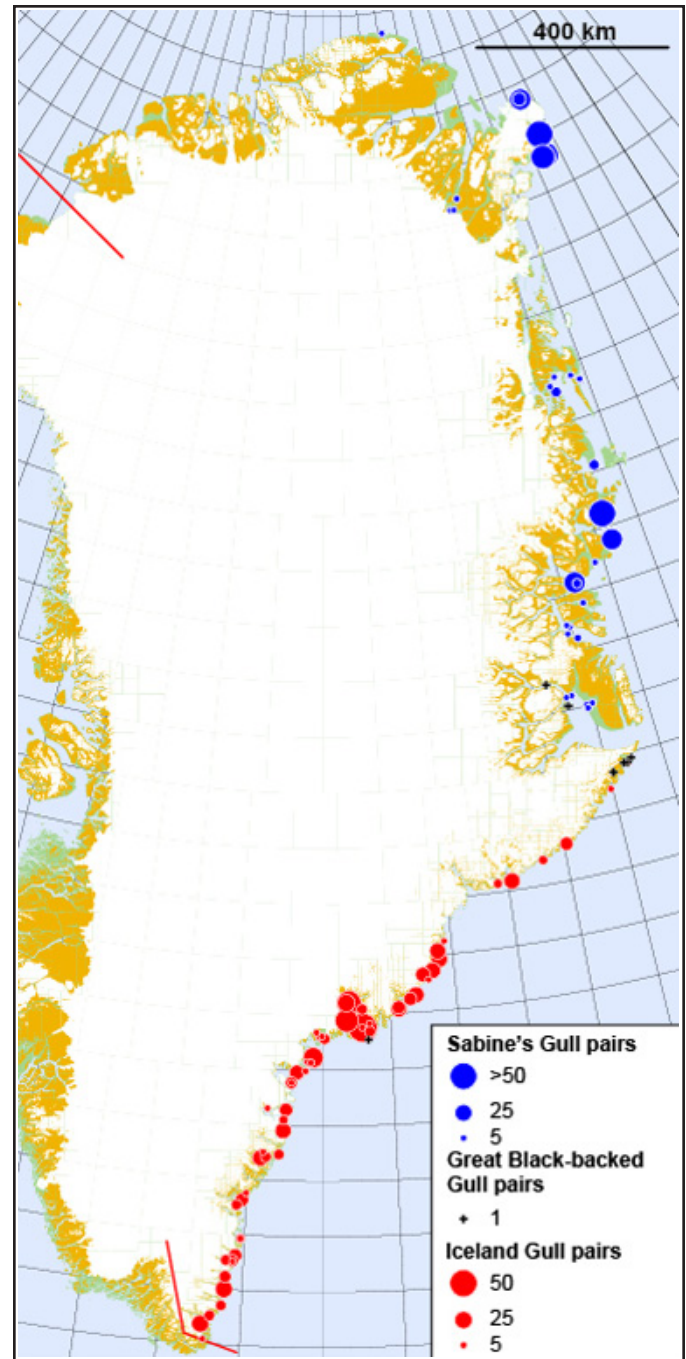


FIG. 6. Distribution and size of Sabine's Gull, Iceland Gull, and Great Black-backed Gull breeding colonies (including sites with solitary pairs).

and often many non-breeding adults attend the colonies (Forchhammer and Maagaard, 1991).

Lesser Black-backed Gull (*Larus fuscus*): This species immigrated to West Greenland in the 1990s and quickly established a large and widespread population (Boertmann, 2008; Boertmann and Frederiksen, 2016). Besides a few breeding records in Northeast Greenland at Hold With Hope in 2004, Fame Øer (near Ittoqqortoormiit) in 2005, and on Sandøen in 2003–08 (Gilg et al., 2005; Boertmann and Frederiksen, 2016), no breeding Lesser Black-backed Gulls were recorded in East Greenland before the 2014

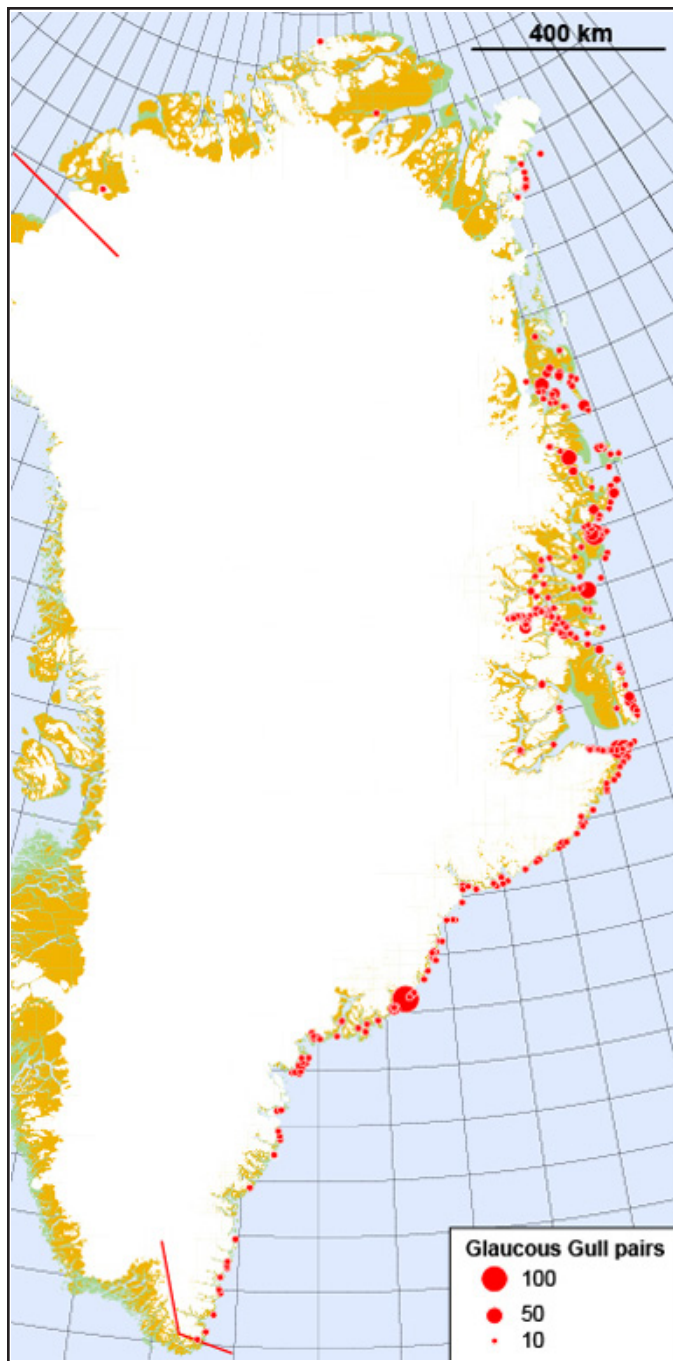


FIG. 7. Distribution and size of Glaucous Gull breeding colonies (including sites with solitary pairs). Locations with only one pair ($n = 87$) are shown with the symbol for 10 pairs in order to be visible on the map.

and 2015 surveys. These surveys revealed that the species was well-established in Southeast Greenland. Several small colonies (up to 35 pairs) and solitary pairs in colonies of other gulls were found between 64° N and 68° N and farther north on the coast, just south of the Scoresby Sound polynya, with the main part located in the Tasiilaq region (Fig. 5). Eighteen breeding sites are now known from the region, with a total of 50–60 pairs.

Iceland Gull (*Larus glaucooides*): This gull species has a low-Arctic distribution in Greenland. In East Greenland,

58 breeding colonies are known with the northernmost at $69^{\circ}30'$ N and the largest concentration in the Tasiilaq area (Fig. 6). These colonies are relatively small with up to 55 pairs. The most recent survey results for all colonies add up to 750 pairs, but there are likely many unrecorded colonies along the unsurveyed coasts in Southeast Greenland.

Glaucous Gull (*Larus hyperboreus*): In total, 403 breeding sites for Glaucous Gulls are recorded from East and North Greenland (Fig. 7). These include solitary pairs ($n = 139$), either alone or at colonies of other species ($n = 48$), and colonies with up to 100 pairs (average 8 pairs). Breeding sites are found along all coasts, as far north as $83^{\circ}30'$ N in the east and in Washington Land in the west, with concentrations at Tasiilaq in Scoresby Sound, at the Sirius Water, in Dove Bugt, and to a lesser extent at the Northeast Water polynya. Besides at the Northeast Water polynya, very few colonies have been located north of 78° N. The most recent surveys add up to 2200 pairs. As many solitary pairs are overlooked and considerable numbers may hide in the unsurveyed coasts—especially in the inner fjords, this figure represents a minimum estimate of the population size.

Great Black-backed Gull (*Larus marinus*): The range of this species, which is widespread in West Greenland, is restricted to two regions in East Greenland (the Tasiilaq area and the Scoresby Sound Fjord complex; Fig. 6), and the number of breeding pairs is very low. In Tasiilaq, only one breeding site was located during the surveys in 2008, 2014, and 2016. From the Scoresby Sound Fjord area, the Great Black-backed Gull is known from six sites (four at colony sites with other species) in the area south of Kap Brewster and inside the fjord complex (Gilg et al., 2005; Boertmann and Frederiksen, 2016). The total population hardly exceeds 20 pairs.

Ross's Gull (*Rhodostethia rosea*): This species has been found breeding, or presumed breeding, at three sites in Northeast Greenland—all at the Northeast Water polynya and its associated shore leads (Fig. 5). Two of the sites, Henrik Krøyer Holme and Kilen, can be described as seabird colonies where a single pair of Ross's Gulls was found among Arctic Terns, Sabine's Gulls, and (on Henrik Krøyer Holme) Ivory Gulls (Gilg et al., 2003; Egevang and Boertmann, 2008). The third breeding site included a solitary pair (Hjort, 1980). Their presence on the breeding sites is apparently not constant, as several researchers failed to find the species on the main site (Henrik Krøyer Holme) in recent years (Gilg et al., 2008, 2011; M. Frederiksen, pers. comm. 2018).

Black-legged Kittiwake (*Rissa tridactyla*): Thirty colony sites are known from East Greenland (Fig. 8); of these, 10 were without birds during the most recent surveys. The combined survey results add up to a total of 4800 pairs. The colony size varies from 3 to 850 pairs, with the two largest at the Scoresby Sound polynya and the Northeast Water polynya. Labansen et al. (2010) listed 16 colonies in East Greenland. This figure was increased by the 2006 and 2014 surveys, although some of the new sites (known by

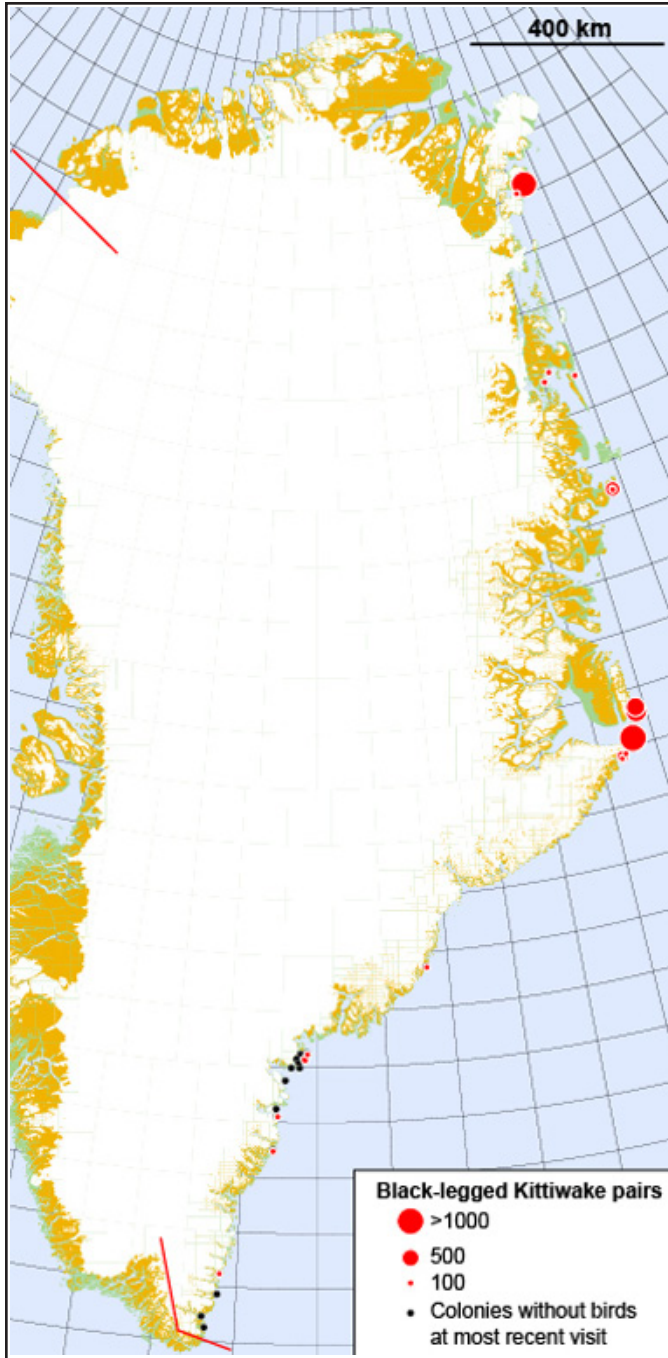


FIG. 8. Distribution and size of Black-legged Kittiwake breeding colonies. Small colonies with fewer than 100 pairs ($n = 12$) are shown with the symbol for 100 pairs in order to be visible on the map.

local people) had only empty nests and had been without birds for several years.

Ivory Gull (*Pagophila eburnea*): In total, 43 colony sites are known from East and North Greenland (Fig. 9). The majority are located on the coasts of the Northeast Water polynya and adjacent shore leads, while some are also found inland on island nunataks (isolated rocks protruding above the glacier surface). Far from this stronghold, a few colonies have been found in the region between Tasiilaq and Scoresby Sound (Wright and Matthews, 1980; Merkel

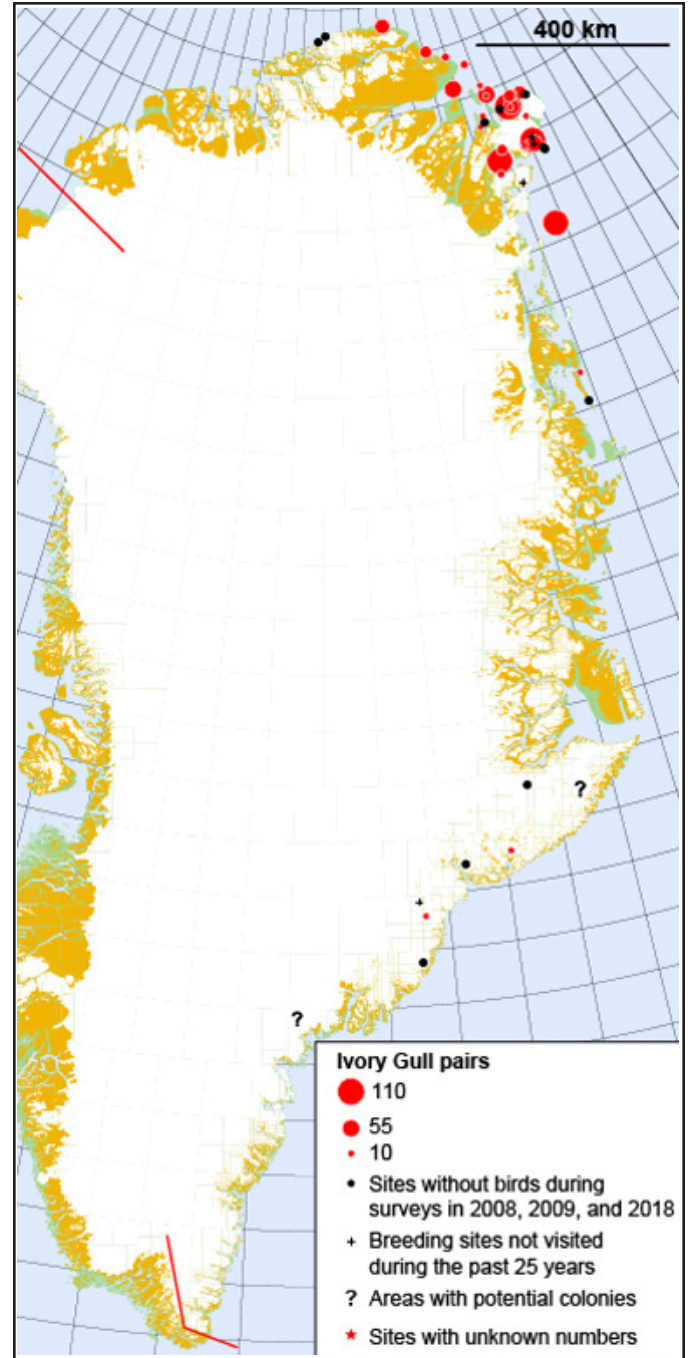


FIG. 9. Distribution and size of Ivory Gull breeding colonies. Question marks show areas where Ivory Gulls are regularly observed along the coasts in the summer.

et al., 2010) and in the Dove Bugt region (Meltøfte et al., 1981). Gilg et al. (2009) also list a number of unconfirmed breeding sites recorded in North Greenland before 1925, including two sites in Washington Land. Ivory Gull colonies were specifically sought out in 2007, 2008, and 2009, when a total of 32 colony sites (including several new ones) were surveyed (Boertmann et al., 2009; Gilg et al., 2009; Boertmann and Nielsen, 2010; Merkel et al., 2010). The size of the colonies ranges from one pair to approximately 200 pairs. The sum of the most recent surveys adds up to

1300 pairs, while Gilg et al. (2009) calculated a breeding population of ca. 1800 birds, and commented that the total Greenland population could possibly be higher than 4000 birds (2000 pairs). Thirteen colony sites in the stronghold near Station Nord were surveyed in both 2008 and 2009. Of these, six sites were occupied both years, four only in 2008, two only in 2009, and one in neither of the two years. In the southern part of the distribution range, five sites (one new) were surveyed during the same years and only two of them were occupied. In the Dove Bugt region two sites are known, one with very irregular occupation (most recently in 2004) and one probably an error (H. Meltofte, pers. comm. 2018).

On Figure 9, two areas (Køge Bugt south of Tasiilaq and part of Blosseville Kyst) are indicated by a question mark. Here, adult birds are regularly observed in coastal waters near productive glaciers and breeding colonies may exist inland.

Arctic Tern (*Sterna paradisaea*): In total, 216 breeding sites are known from East and North Greenland (Fig. 10). Of these, 25 are located in Southeast Greenland, 29 inside the Scoresby Sound Fjord, 158 in Northeast Greenland, and four in North Greenland. Besides these colonies, solitary Arctic Terns are also found breeding along coasts (on gravel beaches or in river deltas) or at inland lakes (usually on small islets). Most of the colonies were small, with fewer than 70 pairs ($n = 166$) during the most recent survey; 25 colonies were occupied by 70–700 pairs, while three other colonies were occupied by more than 700 pairs (up to 1100 pairs). The latter are primarily located in Northeast Greenland between 73° N and 75° N. Extensive coastlines of East and North Greenland are, however, without any colonies (e.g., the Blosseville Kyst, the coast between Tasiilaq and Kangerlussuaq, and between Germania Land and Hovgaard Ø). Based on the most recent survey, the total number of Arctic Terns in these colonies adds up to 12 000 pairs.

Black Guillemot (*Cephus grylle*): The Black Guillemot is widespread and numerous in the region south of 72° N, where 183 colonies are recorded and where the number of observed birds at each site varies between 1 and 300 (Fig. 11). North of this latitude, colonies are very scarce ($n = 16$) and small, with recorded maxima of 60 individuals at Hvalros Ø and 20 at Mallemukfjeldet, both sites located at polynyas. From Washington Land, only two breeding sites are known, but observations of birds close to the coast indicate that more breeding sites may exist (Andreassen, 1999; Bennike and Feilberg, 2004). The total number of individuals recorded at the most recent survey adds up to 8000. However, since the number of observed individuals in this species fluctuates through the day and season (Ewins, 1985; Andersen et al., 2009), this figure may only reflect an order of magnitude. Moreover, it is certainly below the actual numbers in the region, as many colonies may hide along unsurveyed coasts, especially in Southeast Greenland.

Thick-billed Murre (*Uria lomvia*): There are only two large Thick-billed Murre colonies in East Greenland, both of which are located at the Scoresby Sound polynya

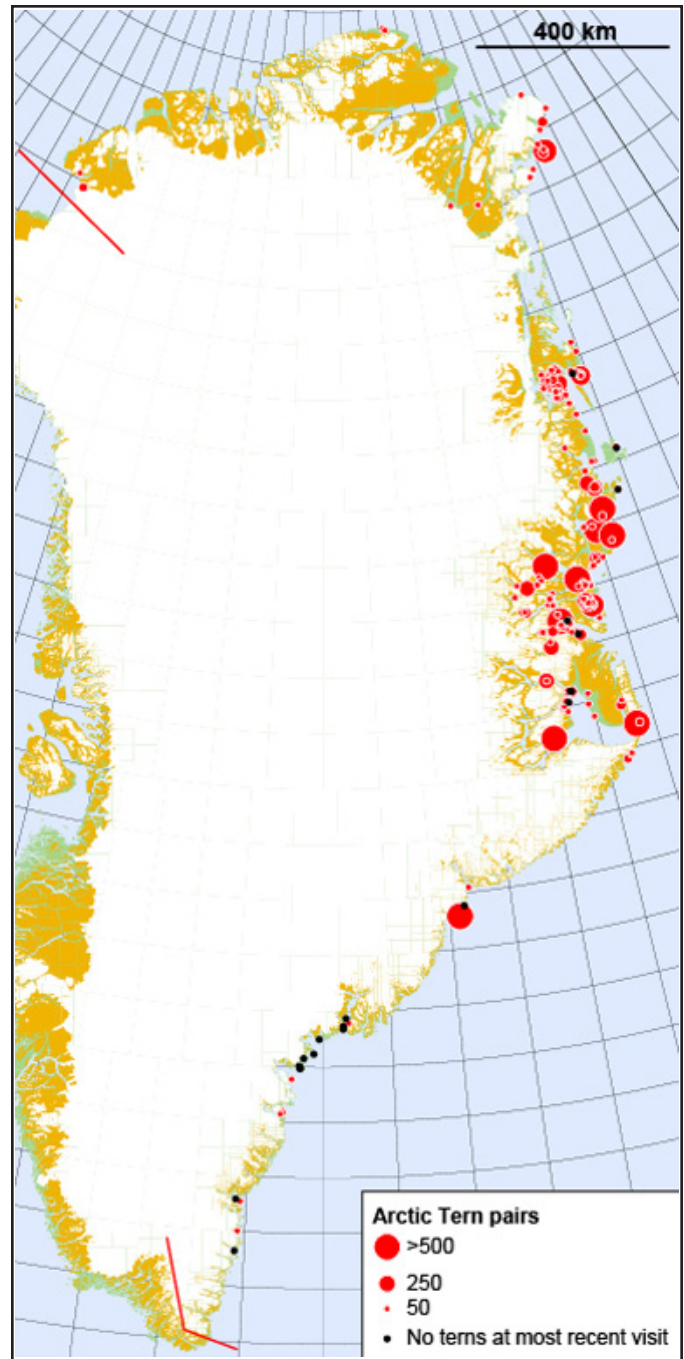


FIG. 10. Distribution and size of Arctic Tern breeding colonies. Small colonies with fewer than 50 individuals ($n = 43$) are shown with the symbol for 50 birds in order to be visible on the map.

(Fig. 12). They are monitored by the Greenland Institute of Natural Resources and both show steady declines. At the latest survey in 2018, the colony at Raffles Ø numbered 1600 pairs and the colony on Kap Brewster numbered 2700 pairs (Greenland Institute of Natural Resources, unpubl. data). In 2004, Gilg et al. (2005) observed two Thick-billed Murres on the bird cliff on Rathbone Ø (8 km north of Raffles Ø) and suspected breeding. This suspicion was again expressed in 2018 by local sources in Ittoqqortoormiit (J. Flora, pers. comm. 2018). Meltofte (1976) also mentioned

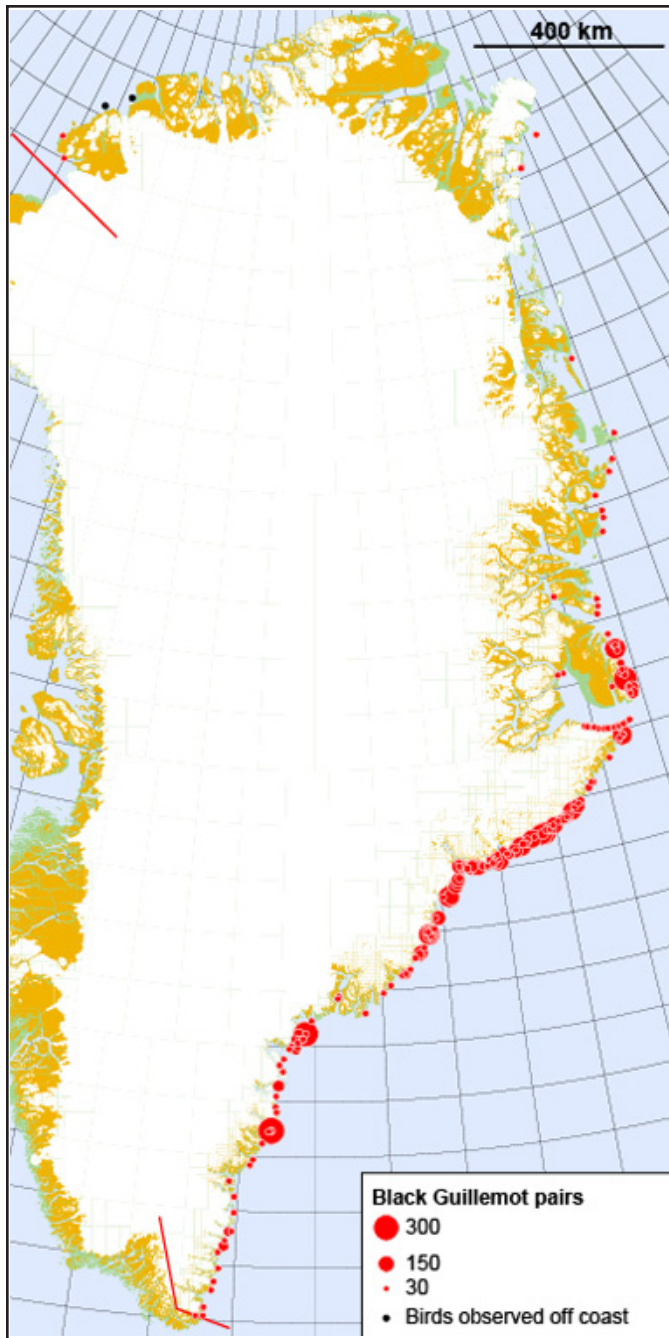


FIG. 11. Distribution and size of Black Guillemot breeding colonies. Small colonies with fewer than 30 individuals ($n = 124$) are shown with the symbol for 30 birds in order to be visible on the map.

a breeding site on Steward Ø south of Kap Brewster, but no murres have been observed at this site during subsequent surveys reported in this paper.

Little Auk (*Alle alle*): This species breeds in huge colonies at coasts bordering the Scoresby Sound polynya (Fig. 12). The total number of breeding birds was roughly estimated at 3.5 million pairs in 1985 (Kampp et al., 1986, 1987). Figure 12 only gives an overview of the positions of colonies, as their population size is practically unknown. Observations of Little Auks at Kap Dalton in 1933 and Hvalros Ø in 1987 were then considered as an indication of

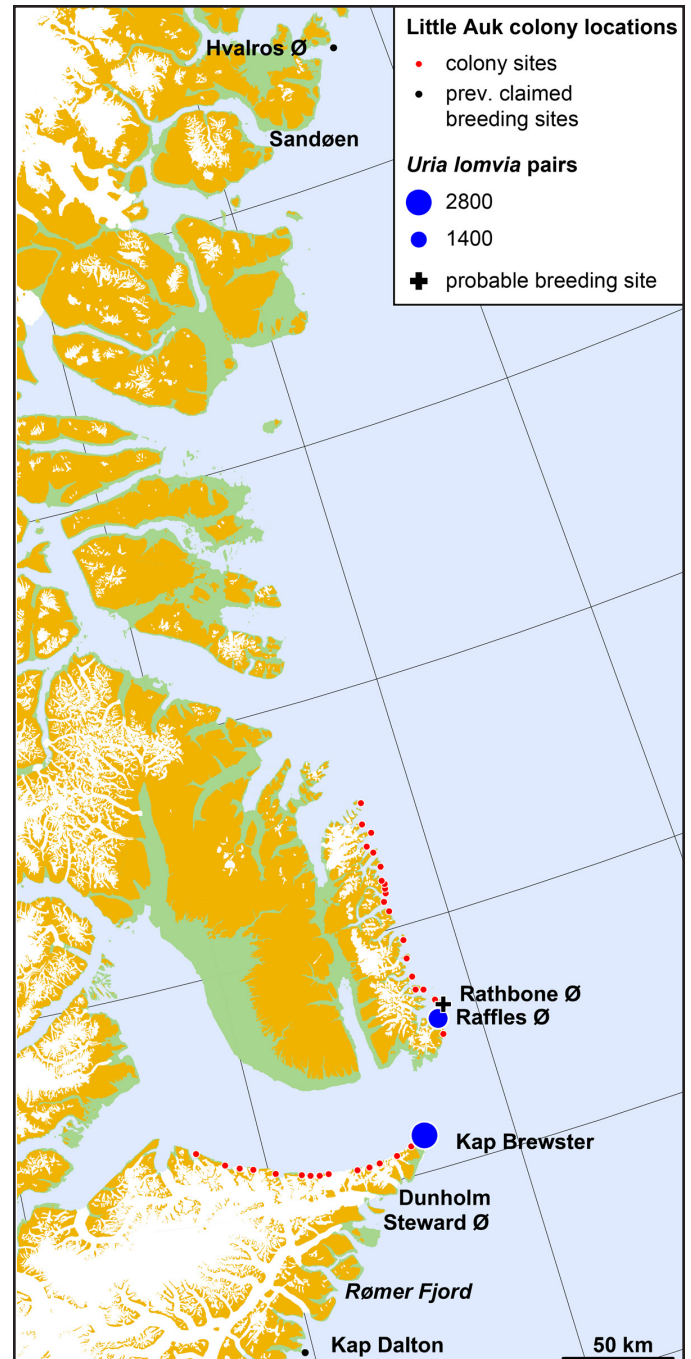


FIG. 12. Distribution and size of Thick-billed Murre and Little Auk breeding colonies.

breeding (Degerbøl and Møhl-Hansen, 1935; Stemmerik, 1990), but we failed to find evidence of breeding in recent years (and only saw non-breeding birds at sea) despite several visits at both sites. Breeding has also been suspected on Shannon and nearby islands (Meltofte et al., 1981), but we did not find any trace of breeding birds here in 2004 and 2008 (Gilg et al., 2005; Boertmann et al., 2009).

Atlantic Puffin (*Fratercula arctica*): Meltofte (1976) mentioned Atlantic Puffins breeding on Raffles Ø and observations of birds at Kap Brewster, both sites at the Scoresby Sound polynya. Since then, one puffin was

TABLE 4. Estimates of population size of breeding colonial seabirds in East and North Greenland compared to recent estimates in West Greenland.

Species	East and North	West	Year of West estimates	Sources of West estimates
Northern Fulmar	2000	78 000	1996	Boertmann et al., 1996
Great Cormorant	30	5000	1997	Boertmann and Mosbech, 1997
Common Eider	16 000	65 000	2010	Meltofte, 2013
Parasitic Jaeger	200	1000	2019	this study
Sabine's Gull	500	500	2013	Boertmann and Huffeldt, 2013
Lesser Black-backed Gull	60	2000	2016	Boertmann and Frederiksen, 2016
Herring Gull	0	10	2016	Boertmann and Frederiksen, 2016
Iceland Gull	1000	100 000	2010	Boertmann et al., 2010b
Glaucous Gull	2900	60 000 ²	2015	Petersen et al., 2015
Great Black-backed Gull	20	5000	2016	Boertmann and Frederiksen, 2016
Ross's Gull	0–1	0–1	2008	Egevang and Boertmann, 2008
Black-legged Kittiwake	4800	100 000	2010	Labansen et al., 2010
Ivory Gull	2000	0	2009	Gilg et al., 2009
Arctic Tern	12 000	90 000	2003	Egevang and Boertmann, 2003
Common Murre	0	2000	1996	Boertmann et al., 1996
Thick-billed Murre	4300	325 000	2016	Merkel, 2016
Razorbill	0	5000	2008	Boertmann, 2008
Black Guillemot	10 000	180 000	2010	Boertmann et al., 2010b
Little Auk	3 500 000 ¹	33 000 000	2003	Kampp et al., 1987; Egevang et al., 2003
Atlantic Puffin	0–5	5000	2010	Boertmann, 2008
Total number	3 555 936	34 023 511		
Total number without Little Auk	55 816	1 023 511		

¹ 1985 estimate in Kampp et al. (1987).

² Middle of range given by Petersen et al. (2015).

observed flying off the cliff at Raffles Ø in 2004 (Gilg et al., 2005), and a few birds were seen on (and below) the cliffs of Kap Brewster in 2004 and 2015. Farther north, one individual was observed on Hvalros Ø flying from the cliff in 2004. It is therefore likely that a few pairs breed at these sites located at the two southern polynyas in East Greenland. There is, moreover, an observation that indicates breeding in the southern part of the region: Glahder (1993) observed an adult carrying fish towards the coast just to the south of the region covered by this account.

Total Numbers

In Table 4, the breeding populations of colonial seabirds in East and North Greenland are estimated and compared to previously published estimates from West Greenland, which span almost the same latitudinal range. The number of breeding sites and the number of breeding birds are both much lower in East and North Greenland, where fewer species breed. A simple calculation of colony density in the region results in two colonies per 100 km of coast (excluding glacier coasts) compared to four colonies per 100 km in West Greenland. A rough estimate of the total number of seabirds breeding in East and North Greenland suggests that they are nearly 10 times less abundant than in West Greenland (20 times less when excluding the Little Auks; Table 4).

DISCUSSION

Although the survey effort has been intensive since 2003, large parts of the study region remain unsurveyed

for breeding seabirds (Table 2). These parts include most of North Greenland between Washington Land and I.P. Koch Fjord and the region between Germania Land and Hovgaard Ø. The probability of finding significant colonies of Black-legged Kittiwake, Thick-billed Murre, and Little Auk in these parts is, however, low because the sea off these regions is mainly ice covered during the breeding season. Another gap in our survey effort is the interior part of many fjord systems (except between 72° N and 73°30' N where the GREA expeditions have surveyed). Commuting (between nests and foraging areas) murre and Black-legged Kittiwakes would have been noticed when passing by the fjord mouths if large colonies were located in the inner fjord systems; however, many gulls—especially Glaucous and Iceland Gulls—Common Eiders, and Arctic Terns may hide in these unsurveyed parts.

There may also be more Ivory Gull colonies than reported here, as the extensive nunatak areas where a few colonies have been located, have only been surveyed sporadically. The observations of Ivory Gulls along some coasts with calving glaciers, such as Køge Bugt and Blosseville Kyst (Boertmann and Rosing-Asvid, 2014, 2017) could indicate such overlooked breeding sites (Fig. 9).

Range Changes

There is no doubt that the Common Eider has expanded its range towards the north in recent decades. Nesting or paired eiders have been located at Station Nord (solitary) and on an island as far north as 83°38' N; further, females with chicks were observed in 2008 in outer Independence Fjord (82°30' N). These sites were visited by keen

ornithologists in the 1970s and 1980s (Håkansson et al., 1981; Hjort, 1986; Hjort et al., 1983, 1988, Bennike and Kelly, 1986) and they did not report Common Eiders. The northernmost breeding record until then was at the coasts of the Northeast Water polynya at 81° N (Hjort et al., 1983, 1988).

The Sabine's Gull population has definitely increased in Northeast Greenland during recent decades; new colonies have been found at many sites where ornithologists in the 1960s and 1970s did not report them (e.g., Meltofte et al., 1981), and many "old" colonies now hold much higher numbers than previously recorded (e.g., Meltofte, 1975). It is also noteworthy that small colonies (2–3 pairs) were found far inland (up to 40 km) in the Danmark Fjord area and on the island at 83°38'N, in 2008.

Salomonsen (1967) indicated the northern limit for breeding Iceland Gulls in East Greenland at 68° N, and understandably, given the great distance from the gull's known range, disregarded the record of a colony in Northeast Greenland at 75° N (Pedersen, 1934; Boertmann, 1994). Whether the colonies found north of 68° N in 2008 and 2016 are the result of a range expansion or just of increased observation effort is not known.

Historical sources mention the Great Black-backed Gull as a scarce breeder in the Tasiilaq area (Helms, 1926; Salomonsen, 1967) where its status has not changed during recent decades. The other breeding region, south of Kap Brewster, seems to be a recent colonization, first recorded in 2004 (Gilg et al., 2005). Previous surveys in 1974 did not mention this easily recognizable species (Meltofte, 1976). Both this species and the Lesser Black-backed Gull are expected to increase and extend their ranges in East Greenland in the future.

It is well known that Ivory Gulls have low site fidelity, moving among colony sites from year to year (de Korte and Volkov, 1993), and that they can establish colonies at temporary substrates such as gravel-covered ice floes or icebergs (Boertmann et al., 2010a; Nachtsheim et al., 2016) or at new sites. For example, in 2018 three new sites were located 18, 21, and 24 km from the historical colony at Station Nord (M. Frederiksen, pers. comm. 2018). Well-known colony sites can also be without breeding birds for years, such as the largest colony in Greenland (Henrik Krøyer Holme), which was empty in 2009, 2017, and 2018, or can be occupied but totally unproductive in some years due to unsuitable weather conditions, such as rain storms (Yannic et al., 2014).

During the most recent surveys, 22 colonies of Arctic Tern had no breeding birds (Fig. 10). Arctic Terns can skip breeding in some years, for example, because of bad weather conditions in the spring or the threat of predation from foxes stuck on the islands after breakup of the sea ice (Levermann and Tøttrup, 2007; Egevang and Frederiksen, 2011). Hence, at least in Northeast Greenland, these empty colonies cannot be taken as an indication of a population decline. In Southeast Greenland in 2014 on the other hand, local people argued that predation from landlocked polar

bears was the main reason for non-breeding and that this had occurred for several years. In this region, a polar bear-induced decline of Arctic Terns cannot be excluded (see also Prop et al., 2015).

The East Greenland Ecosystem

The marked discrepancy in density and abundance of breeding seabirds in East and North Greenland compared to West Greenland is assumed to be linked to the different oceanographic conditions. The continental shelf off West Greenland has many local upwelling events, permanent open water in the southern part, and earlier breakup of sea ice farther north, all factors contributing to high primary production (Buch, 2002; Laidre et al., 2008). Off East Greenland, a strong current conveys nutrient-poor and cold water (including large quantities of drift ice) from the Polar Basin over the continental shelf—an outflow shelf, *sensu* Carmack and Wassmann (2006). This largely inhibits primary production and planktonic blooms, except in the few polynyas and probably along the shelf break. The summer sea ice off East and North Greenland is, however, retreating (Laidre et al., 2015; Stroeve and Notz, 2018), and seabirds have already responded, as exemplified by the recent breeding range extension of gulls, Arctic Terns, and Common Eiders to the northernmost land on Earth.

When looking at the distribution of all the seabird breeding colonies in East and North Greenland, one region stands out, both in terms of diversity and in bird numbers: the coasts of the Scoresby Sound polynya. This is the only region where huge colonies of Little Auks, roughly estimated at 3.5 million pairs in 1985 (Kampp et al., 1987), are found. The only colonies of Thick-billed Murre and the largest of Black-legged Kittiwake are also found there. The coast just south of Kap Brewster (to Rømer Fjord) also hosts Arctic Terns, Common Eiders, and several gull colonies. In total, 11 colonial seabird species breed here. The only other area in Greenland that can match this richness in seabirds is the Avanersuaq area of Northwest Greenland, which holds even more breeding seabirds (Boertmann and Mosbech, 1998; Egevang et al., 2003; Burnham et al., 2012; Merkel et al., 2014) and which also borders the North Water polynya (Hastrup et al., 2018).

The two other major polynyas of East and North Greenland, the Northeast Water polynya (with breeding Northern Fulmar, Common Eider, Sabine's Gull, Black-legged Kittiwake, Ivory Gull, Arctic Tern, and Black Guillemot) and the Sirius Water (with Black-legged Kittiwake, Arctic Tern, Sabine's Gull, and Common Eider) support many fewer species and breeding pairs, although still high in diversity and density compared to the general coastlines of the region.

Why these two polynyas are less rich in seabird abundance is unknown. Since the coastal morphology is optimal for breeding seabirds at both polynyas, the explanation probably comes from different oceanographic features. At least in the Northeast Water, a strong

benthic-pelagic coupling and low densities of copepods (Hobson et al., 1995; Hirsche and Kwasniewski, 1997; Karnovsky et al., 2007) apparently limit the availability of food for most of the colonial seabirds (Falk et al., 1997). This is certainly not the case in the Scoresby Sound polynya, but biological and physical oceanographic data are lacking from this important polynya (and from the Sirius Water), except for some recent studies on copepod abundance carried out in relation to studies on Little Auk foraging strategies (Fort et al., 2013; Amélineau et al., 2016).

Locally, small areas with early sea ice breakup, for example created by tidal currents, also hold seabird colonies, although much smaller than at the large polynyas. Such areas include the northern outlet of Dove Bugt (with breeding Common Eider, Sabine's Gull, Black-legged Kittiwake, and Arctic Tern), the mouth of Kangerlussuaq (Common Eider, Arctic Tern, and Black Guillemot), Timmiarmiut Fjord (Common Eider, and Arctic Tern) and the archipelago of Umiivik (Common Eider).

The sea ice condition in spring and summer is another significant factor determining the distribution of seabird colonies in East and North Greenland; in contrast to the polynyas, the ice here both prevents access to foraging waters and delays the primary production in the water column. But the summer sea ice off East Greenland is currently decreasing, both in duration and extent (Laidre et al., 2015; Stroeve and Notz, 2018; Box et al., 2019). This decrease is illustrated by the ship-based surveys off the Blossville Kyst in 2004 and 2016, which were performed in completely ice-free waters, whereas expeditions in 1899, 1900, 1932, and 1980 struggled with dense sea ice on exactly the same dates in July (Amdrup, 1902; Mikkelsen, 1933; Andersen, 1981).

Other coastlines stand out for their lack of seabird colonies. The most significant are the coast between Germania Land and Hovgaard Ø, where no colonies are located. Their absence can of course be partly attributed to the low survey effort there. However, ice conditions certainly play a role: the Norske Øer Ice Barrier, which is a wide (up to 100 km), semi-permanent ice shelf, covers all waters east of the islands throughout the year (Schneider and Budeus, 1997); the Jøkel Bugt between the mainland and the islands is also permanently covered by large, stationary, tabular icebergs. The ice shelf has, however, proven less stable in recent years (Sneed and Hamilton, 2016), and the potential for establishing new seabird colonies here is high.

Very few colonies are known from the western part of North Greenland, between I.P. Koch Fjord and Humboldt Glacier, and all are located in Washington Land where archaeologists, botanists, and geologists (with ornithology as a hobby) recorded birds in 1999 (Andreassen, 1999; Bennike and Feilberg, 2004). The surveys reported in the present account did not cover this area, but previous ornithological activity did not record any colonies between I.P. Koch Fjord and Washington Land (Håkansson et

al., 1981; Bennike and Kelly, 1986). A few historical observations indicate that Black Guillemot may occur in Hall Land (Dietz and Andersen, 1984), and there may be additional colonies of Common Eider and Arctic Tern, especially along the coasts of Washington Land.

Climate Change

The ongoing decline in ice cover is expected to continue, and depending on which greenhouse gas emission scenarios will prevail, the summer sea ice at the North Pole may disappear within less than two decades (Overland and Wang, 2013). The world's northernmost seabird colony with Arctic Tern, Ivory Gull, Sabine's Gull, and Common Eider was located at 83°38' N in 2008, in an area where no colonial seabirds were breeding in the 1970s and 1980s. The eiders have moved more than two latitudinal degrees north to reach this site since the 1980s, and the potential for establishment of new colonies of these species along the coasts of North Greenland is high.

All but a few of the seabird species breeding in East and North Greenland will probably benefit from these changes—more open water and hence more, easier, and earlier feeding opportunities. The Ivory Gull, however, will lose its primary feeding habitat, the summer sea ice, and is expected to decline in Greenland and elsewhere. It is currently red listed globally as Near Threatened (NT) (BirdLife International, 2018a). It is also red listed on a national level in Greenland (Vulnerable, VU) and Norway (Vulnerable, VU) (Boertmann and Bay, 2018; Henriksen and Hilmo, 2015). Russia and Canada have not adopted the IUCN (International Union of Nature Conservation) red list system, but maintain similar lists on which the species is listed as “rare” and “endangered,” respectively (Iliashenko and Iliashenko, 2000; COSEWIC, 2006).

Comprehensive surveys of Ivory Gull colonies have only been achieved twice in Greenland in recent decades. The small survey effort, in combination with the species ability to shift between breeding sites (de Korte and Volkov, 1993; and results reported above), makes it difficult to assess population trends for Greenland. However, the observation that three out of five colony sites in Southeast Greenland were empty in 2008 and 2009 is concerning (see also Gilg et al., 2009). This observation, and the information from Canada where the breeding population has declined by more than 70% within just 20 years (Gilchrist and Mallory, 2005), calls for a survey of all the breeding sites in Greenland. Such a survey was conducted in 2019, alongside similar surveys throughout the species breeding range (cf. the International Ivory Gull Conservation Strategy and Action Plan; Gilchrist et al., 2008).

Another species dependent on sea ice and ice edges for feeding during the breeding season is the Little Auk (e.g., Bradstreet, 1982; Lønne and Gabrielsen, 1992; Jakubas et al., 2013). Studies in East Greenland indicate that Little Auks are more flexible in their foraging behavior than previously assumed and can also fledge their chicks on

a diet based on open-water prey (Gremillet et al., 2012; Amélineau et al., 2016). In the long run, however, there may be concerns for the species' status in the Scoresby Sound polynya. A northwards range shift could be likely if feeding conditions in the nearby sea allow, since nesting habitats are at least abundant there.

Thick-billed Murres are also dependent on the timing of sea ice breakup and the occurrence of ice edges (Laidre et al., 2008). Since their numbers in the two breeding colonies are rapidly declining, partly because of harvest (Merkel et al., 2014) and likely also because of other overall oceanographic processes affecting birds in the wintering area (Descamps et al., 2013, Frederiksen et al., 2019), there is strong concern for their future.

Finally, new species may become established in the region. The most likely candidate is the Great Skua (*Stercorarius skua*). The species has since 2003 repeatedly been observed under conditions that strongly suggest breeding at several sites in East Greenland: Kilen (up to three supposed pairs), Nordostrundingen, and Henrik Krøyer Holme in the Northeast Water polynya area (Gilg et al., 2003; P. Clausen, pers. comm. 2006; Boertmann and Nielsen, 2010; M. Frederiksen, pers. comm. 2018) and at the northern Blossville Kyst (Gilg et al., 2003; Boertmann et al., 2009; Boertmann and Nielsen, 2010; Boertmann and Rosing-Asvid, 2017). But breeding has so far not been confirmed.

The Northern Gannet (*Morus bassanus*) is another potential new breeder. The mackerel (*Scomber scombrus*) has recently moved into Southeast Greenland waters where a large fishery has developed (Jansen et al., 2016). As mackerel is an important food item for gannets (Cramp and Simmons, 1977), they may follow this prey and establish breeding colonies in Southeast Greenland or perhaps in Southwest Greenland first, matching the situation from the Barents Sea (Barrett et al., 2017). Whether Atlantic Puffin establish a larger and more stable breeding population is questionable as the population in the North Atlantic is, in general, not thriving (BirdLife International, 2017), although the Svalbard population appears to be doing well (Henriksen and Hilmo, 2015). Other likely candidates from neighbouring areas—Iceland and West Greenland—include Razorbill (*Alca torda*) and Herring Gull (*Larus argentatus*), both rare visitors to East Greenland. In a longer perspective, the Leach's Storm Petrel (*Hydrobates leucorhous*) may also be a candidate as a new breeding bird in Southeast (or Southwest) Greenland, although the population of this species is also currently declining (BirdLife International, 2018b).

Conservation

A very large part of the region described in the present study is included in the Northeast Greenland National Park (Figs. 1, 2), where the seabird colonies are protected and traffic-related disturbance regulated. Moreover, two areas inside the national park and two just south of the park are designated as Ramsar sites, which are wetlands

of international importance and protected from habitat changes under the Ramsar Convention on Wetlands (Fig. 2). The remaining colonies, including the important Little Auk and Thick-billed Murre colonies, as well as other seabird colonies in Southeast Greenland, are only protected by the national nature protection law, which regulates traffic in and near colony sites. All species are also protected from hunting in the breeding season, a regulation relevant only in the two inhabited regions of East Greenland.

In recent years, there has been focus on vulnerable and important marine areas in the Arctic, both on a national level and internationally. The Arctic Council has designated Arctic marine areas of heightened ecological and cultural significance, which may lead to protection from the impacts of shipping (AMAP/CAFF/SDWG, 2013). In 2010, the Danish and Greenlandic ministers of environment requested an identification of ecologically valuable and sensitive marine areas in relation to shipping in Greenlandic waters (Christensen et al., 2012). These two initiatives resulted in the designation of a number of marine areas as candidates for protection, including the Northeast Water polynya, the Sirius Water, and the Scoresby Sound polynya, all areas of importance for breeding seabirds. In addition, the IUCN has designated the Northeast Water polynya and the Scoresby Sound polynya as sites of potential outstanding universal value (Speer et al., 2017).

The formal protection of seabird colonies in East and North Greenland can therefore be regarded as adequate, but regulation should be reinforced in a better way, especially for the rapidly declining Thick-billed Murre colonies, which have suffered (and perhaps still do) from illegal overharvesting.

Besides presenting the first comprehensive analysis of all available survey results, this status paper hopefully will help to assess future climate-induced changes on the breeding seabird populations in East and North Greenland, including indirect impacts resulting from human activities (e.g., tourism, onshore mining, offshore oil exploitation, shipping) facilitated by these ongoing rapid changes (e.g., warmer climate and less sea ice).

ACKNOWLEDGEMENTS

The aerial surveys in 2008 and 2009 were funded by the Bureau of Minerals and Petroleum (Greenland Government) and the ship-based surveys in 2014 and 2016 by the Danish Environment Protection Agency (DANCEA), the Environment Agency for Mineral Resource Activities (Greenland Government), the Greenland Institute of Natural Resources, and Aarhus University. The 2008 aerial survey in Southeast Greenland was financed by the Greenland Institute of Natural Resources. Local information on seabirds was obtained from the skilled boatmen who navigated the vessels in 2015 and 2016: Sigurður Pettursson (Kuummiit), Ole Isakson (Nanortalik), Vitus Michealsen (Tasiilaq) and Anders Sanimiunaaq (Tasiilaq).

The GREA surveys (1979–2018) were funded by a large

number of private and public grants over the past 40 years. We cannot list them all, but the Tara Ocean Foundation (especially Etienne Bourgois, Agnès Bourgois and Romain Troublé), Columbia Sportswear, Post Greenland (Allan Pertti Frandsen), Frederik Paulsen, l'Agence Nationale de la Recherche (grant ILETOP ANR-16-CE34-0005) and, since 2011, the French Polar Institute IPEV (program Interactions 1036) deserve special mention for their long-term and invaluable support. Among the many ornithologists and naturalists who joined these private expeditions, a few also deserve special thanks for their significant help in the field or for sharing their data: Eric Bushel, Christian Drone, Corinne Eckert, Vladimir Gilg, Christian Hag, Vadim Heuacker, Jacques Inset, Johannes Lang, Pierre Leguesdron, Freddy Marivaux, Brigitte Sabari, Raphaël Sané, Renaud Scheiffler, Benoît Sittler, Jean-Pierre Wiest, and Glenn Yannic.

Finally, we wish to thank all the scientists and travellers who provided data to the Greenland Seabird Colony Register, the Danish Environment Protection Agency, which partly funded the preparation of this paper, and three anonymous reviewers, who commented on and improved the manuscript.

REFERENCES

- AMAP/CAFF/SDWG. 2013. Identification of Arctic marine areas of heightened ecological and cultural significance: Arctic Marine Shipping Assessment (AMSA) IIc. Oslo: Arctic Monitoring and Assessment Programme (AMAP).
- Amdrup, G. 1902. Carlsbergfondets Expedition til Østgrønland ud ført i Aarene 1898–1900 [The Carlsberg Foundation expedition to East Greenland 1898–1900]. Meddelelser om Grønland 27. 372 p.
- Amélineau, F., Grémillet, D., Bonnet, D., Le Bot, T., and Fort, J. 2016. Where to forage in the absence of sea ice? Bathymetry as a key factor for an Arctic seabird. PLoS ONE 11(7): e0157764. <https://doi.org/10.1371/journal.pone.0157764>
- Andersen, A.-M.H., Rahe, K., Sveegaard, S., and Forchhammer, M.C. 2009. Colony attendance in a Black Guillemot colony in West Greenland. Dansk Ornitologisk Forenings Tidsskrift 103:22–27.
- Andersen, J. 1981. Kaptajn Ejnar Mikkelsens Mindeekspedition 1980 [Captain Ejnar Mikkelsen memorial expedition 1980]. Scoresbysund-Angmagssalik. Field report. Ørholm Stationsvej 22, DK 2800 Lyngby, Denmark.
- Andreassen, C. 1999. Foreløbig feltrapport vedr: Arkæologiske undersøgelser på Washington Land [Preliminary field report regarding archaeological studies in Washington Land]. Greenland National Museum and Archives, Hans Egedesvej 8, Boks 145, 3900 Nuuk, Greenland.
- Barrett, R.T., Strøm, H., and Melnikov, M. 2017. On the polar edge: The status of the Northern Gannet (*Morus bassanus*) in the Barents Sea in 2015–16. Polar Research 36: 1390384. <https://doi.org/10.1080/17518369.2017.1390384>
- Bennike, O., and Feilberg, J. 2004. Bird observations in Washington Land, North Greenland, in 1999. Dansk Ornitologisk Forenings Tidsskrift 98:192–195.
- Bennike, O., and Kelly, M. 1986. Bird observations in central North Greenland. Dansk Ornitologisk Forenings Tidsskrift 80:29–34.
- BirdLife International. 2017. Atlantic Puffin *Fratercula arctica*. The IUCN Red List of Threatened Species 2017. <https://www.iucnredlist.org/species/22694927/132581443>
- . 2018a. Ivory Gull *Pagophila eburnea*. The IUCN Red List of Threatened Species 2018. <https://www.iucnredlist.org/species/22694473/132555020>
- . 2018b. Leach's Storm-petrel *Hydrobates leucorhous*. The IUCN Red List of Threatened Species 2018. <https://www.iucnredlist.org/species/132438298/132438484>
- Birkhead, T.R. 1978. Attendance patterns of guillemots *Uria aalge* at breeding colonies on Skomer Island. Ibis 120(2):219–229. <https://doi.org/10.1111/j.1474-919X.1978.tb06779.x>
- Boertmann, D. 1994. An annotated checklist to the birds of Greenland. Meddelelser om Grønland. Bioscience 38:1–64.
- . 2008. The Lesser Black-backed Gull, *Larus fuscus*, in Greenland. Arctic 61(2):129–133. <https://doi.org/10.14430/arctic17>
- Boertmann, D., and Bay, C. 2018. Grønlands Rødliste 2018: Fortegnelse over grønlandske dyr og planter trusselstatus [Greenland red list 2018: List of threatened Greenland animals and plants]. Aarhus: Nationalt Center for Energi og Miljø (DCE) og Grønlands Naturinstitut. <http://www.natur.gl/roedliste/>
- Boertmann, D., and Frederiksen, M. 2016. Status of Greenland populations of Great Black-backed Gull (*Larus marinus*), Lesser Black-backed Gull (*Larus fuscus*) and Herring Gull (*Larus argentatus*). Waterbirds 39 (Special Publication 1):29–35. <https://doi.org/10.1675/063.039.sp109>
- Boertmann, D., and Huffeldt, N.P. 2013. Seabird colonies in the Melville Bay, Northwest Greenland. Scientific Report No. 45. Aarhus: Aarhus University, Danish Centre for Environment and Energy.
- Boertmann, D., and Mosbech, A. 1997. Breeding distribution and abundance of the Great Cormorant *Phalacrocorax carbo carbo* in Greenland. Polar Research 16(2):93–100. <https://doi.org/10.3402/polar.v16i2.6628>
- . 1998. Distribution of Little Auk (*Alle alle*) breeding colonies in Thule District, Northwest Greenland. Polar Biology 19(3):206–210. <https://doi.org/10.1007/s003000050236>
- . 2012. The western Greenland Sea: A strategic environmental impact assessment of hydrocarbon activities. Scientific Report No. 22. Aarhus: Aarhus University, Danish Centre for Environment and Energy.
- Boertmann, D., and Nielsen, R.D. 2010. Geese, seabirds and mammals in North and Northeast Greenland: Aerial surveys in summer 2009. NERI Technical Report No. 773. Aarhus: Aarhus University, National Environmental Research Institute.
- Boertmann, D., and Rosing-Asvid, A. 2014. Seabirds and seals in Southeast Greenland: Results from a survey in July 2014. Scientific Report No. 117. Aarhus: Aarhus University, Danish Centre for Environment and Energy.

- . 2017. Seabirds and marine mammals in Southeast Greenland II: Results from a survey between Scoresby Sound and Tasiilaq in July and August 2016. Scientific Report No. 215. Aarhus: Aarhus University, Danish Centre for Environment and Energy.
- Boertmann, D., Mosbech, A., Falk, K., and Kampp, K. 1996. Seabird colonies in western Greenland (60°–79°30' N. lat.). NERI Technical Report No. 170. Roskilde: National Environmental Research Institute.
- Boertmann, D., Olsen, K., and Nielsen, R.D. 2009. Seabirds and marine mammals in Northeast Greenland: Aerial surveys in spring and summer 2008. NERI Technical Report No. 721. Aarhus: Aarhus University, National Environmental Research Institute.
- Boertmann, D., Olsen, K., and Gilg, O. 2010a. Ivory gulls breeding on ice. *Polar Record* 46(1):86–88.
<https://doi.org/10.1017/S0032247409008626>
- Boertmann, D., Mosbech, A., Bjerrum, M., Merkel, F., and Labansen, A.L. 2010b. The Greenland seabird colony register. Poster at the 1st World Seabird Conference, 7–11 September 2010, Victoria, British Columbia.
- Box, J.E., Colgan, W.T., Christensen, T.R., Schmidt, N.M., Lund, M., Parmentier, F.-J.W., Brown, R., et al. 2019. Key indicators of Arctic climate change: 1971–2017. *Environmental Research Letters* 14(4): 045010.
<https://doi.org/10.1088/1748-9326/aafc1b>
- Bradstreet, M.S.W. 1982. Pelagic feeding ecology of Dovekies, *Alle alle*, in Lancaster Sound and western Baffin Bay. *Arctic* 35(1):126–140.
<https://doi.org/10.14430/arctic2313>
- Buch, E. 2002. Present oceanographic conditions in Greenland Waters. Scientific Report 02-02. Copenhagen: Danish Meteorological Institute.
- Burnham, K.K., Johnson, J.A., Konkel, B., and Burnham, J.L. 2012. Nesting Common Eider (*Somateria mollissima*) population quintuples in Northwest Greenland. *Arctic* 65(4):456–464.
<https://doi.org/10.14430/arctic4243>
- Carmack, E., and Wassmann, P. 2006. Food webs and physical-biological coupling on pan-Arctic shelves: Unifying concepts and comprehensive perspectives. *Progress in Oceanography* 71(2-4):446–477.
<https://doi.org/10.1016/j.pocean.2006.10.004>
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2006. COSEWIC assessment and update status report on the Ivory Gull *Pagophila eburnea* in Canada. Ottawa: COSEWIC. vi + 42 p.
https://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_ivory_gull_e.pdf
- Cramp, S., and Simmons, K.E.L., eds. 1977. The birds of the Western Palearctic, Vol. 1. London: Oxford University Press.
- , eds. 1982. The birds of the Western Palearctic, Vol. 3. London: Oxford University Press.
- Christensen, T., Falk, K., Boye, T., Ugarte, F., Boertmann, D., and Mosbech, A. 2012. Identifikation af sårbare marine områder i den grønlandske/danske del af Arktis [Identification of vulnerable marine areas in the Greenlandic/Danish Arctic]. Scientific Report No. 43. Aarhus: Aarhus University, Danish Centre for Environment and Energy.
- Degerbøl, M., and Möhl-Hansen, U. 1935. Birds (Aves): The Scoresby Sound Committee's East Greenland Expedition in 1932 to King Christian IX's Land. *Meddelelser om Grønland* 104 (18):1–30.
- de Korte, J., and Volkov, A.E. 1993. Large colony of Ivory Gulls *Pagophila eburnea* at Domashniy Island, Severnaya Zemlya. *Sula* 7(3):107–110.
- Descamps, S., Strøm, H., and Steen, H. 2013. Decline of an Arctic top predator: Synchrony in colony size fluctuations, risk of extinction and the subpolar gyre. *Oecologia* 173(4):1271–1282.
<https://doi.org/10.1007/s00442-013-2701-0>
- Dietz, R., and Andersen, O.G.N. 1984. Status over dyre- og plantelivet i Nordgrønland. Del 1: Patterdyr og fugle [Status of animal and plant life in North Greenland. Part 1: Mammals and birds]. København: Danbiu Aps, Grønlands Fiskeri- og Miljøundersøgelser.
- Egevang, C., and Boertmann, D. 2003. Havternen i Grønland [The Arctic Tern in Greenland]. Danmarks Miljøundersøgelser, Faglig Rapport nr. 438.
- . 2008. Ross's Gulls (*Rhodostethia rosea*) breeding in Greenland: A review, with special emphasis on records from 1979 to 2007. *Arctic* 61(3):322–328.
<https://doi.org/10.14430/arctic28>
- Egevang, C., and Frederiksen, M. 2011. Fluctuating breeding of Arctic Terns (*Sterna paradisaea*) in Arctic and high-Arctic colonies in Greenland. *Waterbirds* 34(1):107–111.
<https://doi.org/10.1675/063.034.0114>
- Egevang, C., and Stenhouse, I.J. 2007. Field report from Sand Island, Northeast Greenland – 2007. Nuuk: Pingortitaleriffik, Grønlands Naturinstitut.
- Egevang, C., Boertmann, D., Mosbech, A., and Tamstorf, M.P. 2003. Estimating colony area and population size of Little Auks *Alle alle* at Northumberland Island using aerial images. *Polar Biology* 26(1):8–13.
<https://doi.org/10.1007/s00300-002-0448-x>
- Egevang, C., Stenhouse, I.J., Rasmussen, L.M., Willemoes, M., and Ugarte, F. 2008. Field report from Sand Island, Northeast Greenland—2008. Nuuk: Pingortitaleriffik, Grønlands Naturinstitut.
- Egevang, C., Merkel, F., and Labansen, A. 2017. Grønlands Lomvie-kolonier—en opsummering af polarlomvieoptællinger [Greenland's guillemot colonies—a summary of the surveys]. Pingortitaleriffik. Greenland Institute of Natural Resources.
http://www.natur.gl/fileadmin/user_files/Dokumenter/PAFU/Poster_Lomvietal_juni2017_dk.pdf
- Ewins, P.J. 1985. Colony attendance and censusing of Black Guillemots *Cephus grylle* in Shetland. *Bird Study* 32(3):176–185.
<https://doi.org/10.1080/00063658509476876>

- Falk, K., and Kampp, K. 1998. Langsigtet monitoringsplan for lomvier i Grønland [Long-term monitoring plan for guillemots in Greenland]. Teknisk Rapport Nr. 18. Nuuk: Pingortitaleriffik, Grønlands Naturinstitut.
- Falk, K., and Møller, S. 1995. Colonies of Northern Fulmars and Black-legged Kittiwakes associated with the Northeast Water polynya, Northeast Greenland. *Arctic* 48(2):186–195.
<https://doi.org/10.14430/arctic1241>
- . 1997. Breeding ecology of the Fulmar *Fulmarus glacialis* and the Kittiwake *Rissa tridactyla* in high-Arctic northeastern Greenland, 1993. *Ibis* 139(2):270–281.
<https://doi.org/10.1111/j.1474-919X.1997.tb04625.x>
- Falk, K., Hjort, C., Andreasen, C., Christensen, K.D., Elander, M., Ericson, M., Kampp, K., et al. 1997. Seabirds utilizing the Northeast Water polynya. *Journal of Marine Systems* 10 (1-4):47–65.
[https://doi.org/10.1016/S0924-7963\(96\)00066-8](https://doi.org/10.1016/S0924-7963(96)00066-8)
- Forchhammer, M. 1990. Ornithological observations in Germania Land and Dove Bugt, Northeast Greenland, 1986–1988. Technical Report No. 12. Nuuk: Greenland Home Rule, Department for Wildlife Management.
- Forchhammer, M., and Maagaard, L. 1990. Distribution of breeding Sabine's Gulls in Greenland. *Dansk Ornitologisk Forenings Tidsskrift* 84:162–164. (Danish, with English summary.)
- . 1991. Breeding biology of Sabine's Gull *Larus sabini* in Northeast Greenland. *Dansk Ornitologisk Forenings Tidsskrift* 85:53–62.
- Fort, J., Moe, B., Strøm, H., Grémillet, D., Welcker, J., Schultner, J., Jerstad, K., Johansen, K.L., Phillips, R.A., and Mosbech, A. 2013. Multicolony tracking reveals potential threats to Little Auks wintering in the North Atlantic from marine pollution and shrinking sea ice cover. *Diversity and Distributions* 19(10):1322–1332.
<https://doi.org/10.1111/ddi.12105>
- Frederiksen, M., Linnebjerg, J.F., Merkel, F.R., Wilhelm, S.I., and Robertson, G.J. 2019. Quantifying the relative impact of hunting and oiling on Brünnich's Guillemots in the North-west Atlantic. *Polar Research* 38: 3378.
<https://doi.org/10.33265/polar.v38.3378>
- Gaston, A.J., Mallory, M.L., and Gilchrist, H.G. 2012. Populations and trends of Canadian Arctic seabirds. *Polar Biology* 35(8):1221–1232.
<https://doi.org/10.1007/s00300-012-1168-5>
- Gaston, A.J., Elliott, K.H., Ropert-Coudert, Y., Kato, A., Macdonald, C.A., Mallory, M.L., and Gilchrist, H.G., 2013. Modelling foraging range for breeding colonies of Thick-billed Murres *Uria lomvia* in the eastern Canadian Arctic and potential overlap with industrial development. *Biological Conservation* 168:134–143.
<https://doi.org/10.1016/j.biocon.2013.09.018>
- Gilchrist, G., and Mallory, M.L. 2005. Declines in abundance and distribution of the Ivory Gull (*Pagophila eburnea*) in Arctic Canada. *Biological Conservation* 121(2):303–309.
<https://doi.org/10.1016/j.biocon.2004.04.021>
- Gilchrist, G., Strøm, H., Gavriilo, M.V., and Mosbech, A. 2008. International Ivory Gull conservation strategy and action plan. CAFF Technical Report No. 18. Akureyri, Iceland: CAFF International Secretariat, Circumpolar Seabird Group (CBird).
- Gilg, O., Sabard, B., Sittler, B., Mariaux, F., Leguesdron, P., and Gilg, V. 2003. *Ecopolaris 2003*. Ecological expedition to North Greenland and Dove Bugt: North-East Greenland National Park. Field report. Francheville: GREA.
- Gilg, O., Sabard, B., Kampp, K., Andreasen, C., Scheifler, R., Ioset, J., Schwoehrer, C., et al. 2005. *Ecopolaris Tara 5 expedition to NE Greenland 2004*. Francheville: GREA.
- Gilg, O., Sabard, B., Aebischer, A., Hardy, L., and Bernard, F. 2008. *Ecopolaris and Sagax expeditions to E and N Greenland 2007*. Preliminary field report. Francheville: GREA.
- Gilg, O., Boertmann, D., Merkel, F., Aebischer, A., and Sabard, B. 2009. Status of the endangered Ivory Gull, *Pagophila eburnea*, in Greenland. *Polar Biology* 32(9):1275–1286.
<https://doi.org/10.1007/s00300-009-0623-4>
- Gilg, O., Strøm, H., Aebischer, A., Gavriilo, M.V., Volkov, A., Miljeteig, C., and Sabard, B. 2010. Post-breeding movements of the Northeast Atlantic Ivory Gull *Pagophila eburnea* populations. *Journal of Avian Biology* 41(5):532–542.
<https://doi.org/10.1111/j.1600-048X.2010.05125.x>
- Gilg, O., Sabard, B., Aebischer, A., Yannic, G., Pouivé, E., Mosimann, P., and Gilg, V. 2011. *Ecopolaris expeditions to North Greenland 2008–10: Summary field report*. Francheville: GREA.
- Gilg, O., Istomina, L., Heygster, G., Strøm, H., Gavriilo, M.V., Mallory, M.L., Gilchrist, G., et al. 2016. Living on the edge of a shrinking habitat: The Ivory Gull, *Pagophila eburnea*, an endangered sea-ice specialist. *Biology Letters* 12(11): 20160277.
<https://doi.org/10.1098/rsbl.2016.0277>
- Glahder, C. 1993. Havfugle langs Syd- og Sydøstgrønland, August 1990 [Seabirds along South and South Greenland, August 1990]. *Dansk Ornitologisk Forenings Tidsskrift* 87:252–255.
- Grémillet, D., Welcker, J., Karnovsky, N.J., Walkusz, W., Hall, M.E., Fort, J., Brown, Z.W., Speakman, J.R., and Harding, A.M.A. 2012. Little Auks buffer the impact of current Arctic climate change. *Marine Ecology Progress Series* 454:197–206.
<https://doi.org/10.3354/meps09590>
- Håkansson, E., Bennike, O., Mølgaard, P., and Frykman, P. 1981. Nordgrønlandske fugleobservationer—Somrene 1976 og 1978 [Bird observations from northern Greenland in the summers of 1976 and 1978]. *Dansk Ornitologisk Forenings Tidsskrift* 75:51–67. (Danish, with English summary.)
- Hansen, J., Tøttrup, A.P., and Levermann, N. 2007. Birds. In: Klitgaard, A.B., Rasch, M., and Caning, K., eds. *Zackenbergs Ecological Research Operations, 12th Annual Report, 2006*. Copenhagen: Danish Polar Center. 44–58.
- Harris, M.P. 1989. Variation in the correction factor used for converting counts of individual guillemots *Uria aalge* into breeding pairs. *Ibis* 131(1):85–93.
<https://doi.org/10.1111/j.1474-919X.1989.tb02747.x>

- Hastrup, K., Mosbech, A., and Grønnow, B. 2018. Introducing the North Water: Histories of exploration, ice dynamics, living resources, and human settlement in the Thule region. *Ambio* 47(Suppl. 2):S162–S174.
<https://doi.org/10.1007/s13280-018-1030-2>
- Helms, O. 1926. The birds of Angmagssalik. *Meddelelser om Grønland* 58(4):205–274.
- Henriksen, S., and Hilmo, O., eds. 2015. Norsk rødliste for arter 2015 [Norwegian red list for species 2015]. Trondheim, Norway: Artsdatabanken.
[https://www.artsdatabanken.no/Files/13973/Norsk_r_dliste_for_arter_2015_\(PDF\)](https://www.artsdatabanken.no/Files/13973/Norsk_r_dliste_for_arter_2015_(PDF))
- Hirsche, H.-J., and Kwasniewski, S. 1997. Distribution, reproduction and development of *Calanus* species in the Northeast Water in relation to environmental conditions. *Journal of Marine Systems* 10(1-4):299–317.
[https://doi.org/10.1016/S0924-7963\(96\)00057-7](https://doi.org/10.1016/S0924-7963(96)00057-7)
- Hjort, C. 1980. Ross's Gull *Rhodostethia rosea* breeding in Peary Land, North Greenland, 1979. *Dansk Ornitologisk Forenings Tidsskrift* 74:75–76.
- . 1986. Fåglar och landskab i Johannes V. Jensen Land – världens nordligsta landområde [Birds and landscape in Johannes V. Jensen Land—the world's northernmost land area]. *Vår Fågelvärld* 45:476–482.
- Hjort, C., Håkansson, E., and Stemmerik, L. 1983. Bird observations around the Nordøstvandet polynya, Northeast Greenland, 1980. *Dansk Ornitologisk Forenings Tidsskrift* 77:107–114.
- Hjort, C., Håkansson, E., and Mølgaard, P. 1988. Bird observations on Kilen, northeasternmost Greenland, 1985. *Dansk Ornitologisk Forenings Tidsskrift* 82:19–24.
- Hobson, K.A., Ambrose, W.G., Jr., and Renaud, P.E. 1995. Sources of primary production, benthic-pelagic coupling, and trophic relationships within the Northeast Water polynya: Insights from $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis. *Marine Ecology Progress Series* 28:1–10.
<https://doi.org/10.3354/meps128001>
- Hørring, R. 1939. Birds. In: 6. og 7. Thule expeditions til Sydøstgrønland 1931–33 [Sixth and Seventh Thule expedition to Southeast Greenland 1931–33]. *Meddelelser om Grønland* 108(6):1–44.
- Iliashenko, V.Yu., and Iliashenko, E.I. 2000. *Krasnaya kniga Rossii: Pravovye akty* [Red data book of Russia: Legislative acts]. Moscow: State Committee of the Russian Federation for Environmental Protection.
- Jakubas, D., Trudnowska, E., Wojczulanis-Jakubas, K., Iliszko, L., Kidawa, D., Darecki, M., Blachowiak-Samolyk, K., and Stempniewicz, L. 2013. Foraging closer to the colony leads to faster growth in Little Auks. *Marine Ecology Progress Series* 489:263–278.
<https://doi.org/10.3354/meps10414>
- Jansen, T., Post, S., Kristiansen, T., Óskarsson, G.J., Boje, J., MacKenzie, B.R., Broberg, M., and Siegstad, H. 2016. Ocean warming expands habitat of a rich natural resource and benefits a national economy. *Ecological Applications* 26(7):2021–2032.
<https://doi.org/10.1002/eap.1384>
- Kampp, K., Meltofte, H., and Mortensen, C.E. 1986. Little Auks in Scoresby Sund. Copenhagen: Zoological Museum and Greenland Environmental Research Institute. 60 p. (Danish, with English summary.)
- . 1987. Population size of the Little Auk *Alle alle* in East Greenland. *Dansk Ornitologisk Forenings Tidsskrift* 81:129–136.
- Karnovsky, N., Ainley, D.G., and Lee, P. 2007. The impact and importance of production in polynyas to top-trophic predators: Three case histories. Chapter 12 in: Smith, W.O., and Barber, D.G., eds. *Polynyas: Windows to the world*. Elsevier Oceanography Series 74:391–410.
[https://doi.org/10.1016/S0422-9894\(06\)74012-0](https://doi.org/10.1016/S0422-9894(06)74012-0)
- Knudsen, K. 1935. Noter om Lindenowfjords fuglefauna [Notes on Lindenow Fjord's bird fauna]. *Dansk Ornitologisk Forenings Tidsskrift* 29:37–41.
- Labansen, A.L., Merkel, F., Boertmann, D., and Nyeland, J. 2010. Status of the Black-legged Kittiwake (*Rissa tridactyla*) breeding population in Greenland, 2008. *Polar Research* 29(3):391–403.
<https://doi.org/10.1111/j.1751-8369.2010.00169.x>
- Laidre, K.L., Heide-Jørgensen, M.P., Nyeland, J., Mosbech, A., and Boertmann, D. 2008. Latitudinal gradients in sea ice and primary production determine Arctic seabird colony size in Greenland. *Proceedings of the Royal Society B* 275(1652):2695–2702.
<https://doi.org/10.1098/rspb.2008.0874>
- Laidre, K.L., Born, E.W., Heagerty, P., Wiig, Ø., Stern, H., Dietz, R., Aars, J., and Andersen, M. 2015. Shifts in female polar bear (*Ursus maritimus*) habitat use in East Greenland. *Polar Biology* 38(6):879–893.
<https://doi.org/10.1007/s00300-015-1648-5>
- Laursen, K., Frikke, J., and Kahlert, J. 2008. Accuracy of 'total counts' of waterbirds from aircraft in coastal waters. *Wildlife Biology* 14(2):165–175.
[https://doi.org/10.2981/0909-6396\(2008\)14\[165:AOTCOW\]2.0.CO;2](https://doi.org/10.2981/0909-6396(2008)14[165:AOTCOW]2.0.CO;2)
- Levermann, N., and Tøttrup, A.P. 2007. Predator effect and behavioral patterns in Arctic Terns (*Sterna paradisaea*) and Sabine's Gulls (*Xema sabini*) during a failed breeding year. *Waterbirds* 30(3):417–420.
[https://doi.org/10.1675/1524-4695\(2007\)030\[0417:PEABPI\]2.0.CO;2](https://doi.org/10.1675/1524-4695(2007)030[0417:PEABPI]2.0.CO;2)
- Lønne, O.J., and Gabrielsen, G.W. 1992. Summer diet of seabirds feeding in sea-ice-covered waters near Svalbard. *Polar Biology* 12(8):685–692.
<https://doi.org/10.1007/BF00238868>
- Løppenthin, B. 1932. Die vögel Nordöstgrönlands zwischen 73°00' und 75°30' N. Br. [The birds of Northeast Greenland between 73°00' and 75°30' N]. *Meddelelser om Grønland* 91(6). 127 p.
- Mallory, M.L., Boadway, K.A., Davis, S.E., and Maftai, M. 2012. Breeding biology of Sabine's gull (*Xema sabini*) in the Canadian high Arctic. *Polar Biology* 35(3):335–344.
<https://doi.org/10.1007/s00300-011-1079-x>

- Manniche, A.L.V. 1910. The terrestrial mammals and birds of North-East Greenland: Biological observations. *Meddelelser om Grønland* 45(1):1–200.
- Meltofte, H. 1975. Ornithological observations in Northeast Greenland between 76° 00' and 78° 00' N. lat. 1969–71. *Meddelelser om Grønland* 191(9). 72 p.
- . 1976. Ornithological observations from the Scoresby Sund area, East Greenland, 1974. *Dansk Ornitologisk Forenings Tidsskrift* 70:107–122. (Danish, with English summary.)
- . 1977. Ornithological observations in Germania Land, Northeast Greenland, 1975. *Dansk Ornitologisk Forenings Tidsskrift* 71:81–94. (Danish, with English summary.)
- . 1978. A breeding association between eiders and tethered huskies in North-east Greenland. *Wildfowl* 29:45–54.
- , ed. 2013. Arctic biodiversity assessment: Status and trends in Arctic biodiversity. Akureyri: Conservation of Arctic Flora and Fauna.
- Meltofte, H., Elander, M., and Hjort, C. 1981. Ornithological observations in Northeast Greenland between 74°30' and 76°00' N. lat., 1976. *Meddelelser om Grønland, Bioscience* 3. 53 p.
- Merkel, F. 2016. Status for lomvien i Grønland, 2016 [Status of Guillemots in Greenland, 2016]. Nuuk: Pingortitaleriffik, Grønlands Naturinstitut.
http://www.natur.gl/fileadmin/user_files/Dokumenter/Overblik/Lomviestatus_2016_05_31.pdf
- Merkel, F.R., Rasmussen, L.M., and Rosing-Asvid, A. 2010. Seabirds and marine mammals in South and Southeast Greenland, June 2008. Technical Report No. 81. Nuuk: Pingortitaleriffik, Grønlands Naturinstitut.
- Merkel, F.R., Labansen, A.L., Boertmann, D.M., Mosbech, A., Egevang, C., Falk, K., Linnebjerg, J.F., Frederiksen, M., and Kampp, K. 2014. Declining trends in the majority of Greenland's Thick-billed Murre (*Uria lomvia*) colonies 1981–2011. *Polar Biology* 37(8):1061–1071.
<https://doi.org/10.1007/s00300-014-1500-3>
- Mikkelsen, E. 1933. Report on the Expedition. The Scoresby Sound Committee's 2nd East Greenland Expedition in 1932 to King Christian IX's Land. *Meddelelser om Grønland* 104(1):10–71.
- Nachtsheim, D.A., Joiris, C.R., and D'hert, D. 2016. A gravel-covered iceberg provides an offshore breeding site for Ivory Gulls *Pagophila eburnea* off Northeast Greenland. *Polar Biology* 39(4):755–758.
<https://doi.org/10.1007/s00300-015-1824-7>
- Norment, C.J., Stehn, R.A., Fischer, J.B., and Moser, T. 2015. Sabine's Gull (*Xema sabini*) nesting aggregations in western Alaska. *Northwestern Naturalist* 96(2):101–106.
<https://doi.org/10.1898/1051-1733-96.2.101>
- Overland, J.E., and Wang, M. 2013. When will the summer Arctic be nearly sea ice free? *Geophysical Research Letters* 40(10):2097–2101.
<https://doi.org/10.1002/grl.50316>
- Pedersen, A. 1930. Forgesetztte beitrage zur kenntnis der säugetiere- und vogelfauna der ostküste Grönlands [Further contribution to the knowledge of the mammal and bird fauna of the east coast of Greenland]. *Meddelelser om Grønland* 77(5):343–507.
- . 1934. Die Ornis des Mittleren Teiles der Nordostküste Grönlands [The birds of the middle parts of the north coast of Greenland]. *Meddelelser om Grønland* 100(11):1–35.
- . 1942. Säugetiere und vögel [Mammals and birds]. *Meddelelser om Grønland* 128(2):1–119.
- Petersen, A., Irons, D.B., Gilchrist, H.G., Robertson, G.J., Boertmann, D., Strøm, H., Gavrilov, M., et al. 2015. The status of Glaucous Gulls *Larus hyperboreus* in the circumpolar Arctic. *Arctic* 68(1):107–120.
<https://doi.org/10.14430/arctic4462>
- Prop, J., Aars, J., Bårdsen, B.-J., Hanssen, S.A., Bech, C., Bourgeon, S., de Fouw, J., et al. 2015. Climate change and the increasing impact of polar bears on bird populations. *Frontiers in Ecology and Evolution* 3: Article 33.
- Ray, H.P.C. 1973. Some notes on the birds observed in the Kungmiut and Tuglulik areas of East Greenland during the summer of 1967. *Dansk Ornitologisk Forenings Tidsskrift* 67:43–52.
- Rosenberg, N.Th., Christensen, N.H., and Gensbøl, B. 1970. Bird observations in Northeast Greenland. *Meddelelser om Grønland* 191(1):1–87.
- Salomonsen, F. 1967. Fuglene på Grønland [The birds in Greenland]. København: Rhodos.
- . 1979a. Ornithological and ecological studies in S.W. Greenland (59°46' – 62°27' N. Lat.). *Meddelelser om Grønland* 204(6):1–214.
- . 1979b. Marine birds in the Danish monarchy and their conservation. In: Bartonek, J.C., and Nettleship, D.N., eds. *Conservation of marine birds of northern North America: Papers from the International Symposium, 13–15 May 1975, Seattle, Washington*. Wildlife Research Report 11. Washington, D.C.: United States Department of the Interior, Fish and Wildlife Service. 267–287.
- Schneider, W., and Budéus, G. 1997. A note on Norske Ø Ice Barrier (Northeast Greenland), viewed by Landsat 5 TM. *Journal of Marine Systems* 10(1-4):99–106.
[https://doi.org/10.1016/S0924-7963\(96\)00076-0](https://doi.org/10.1016/S0924-7963(96)00076-0)
- Sneed, W.A., and Hamilton, G.S. 2016. Recent changes in the Norske Øer Ice Barrier, coastal Northeast Greenland. *Annals of Glaciology* 57(73):47–55.
<https://doi.org/10.1017/aog.2016.21>
- Speer, L., Nelson, R., Casier, R., Gavrilov, M., von Quillfeldt, C., Cleary, J., Halpin, P., and Hooper, P. 2017. Natural marine world heritage in the Arctic Ocean: Report of an expert workshop and review process. Gland, Switzerland: IUCN.
- Stemmerik, L. 1990. Hvalros Ø—a new breeding site for Fulmar *Fulmarus glacialis* and possibly for Little Auk *Alle alle* in East Greenland. *Dansk Ornitologisk Forenings Tidsskrift* 84:161. (Danish, with English summary.)

- Stenhouse, I.J., Gilchrist, H.G., and Montevecchi, W.A. 2001. Reproductive biology of Sabine's Gull in the Canadian Arctic. *Condor* 103(1):98–107.
<https://doi.org/10.1093/condor/103.1.98>
- Stroeve, J., and Notz, D. 2018 Changing state of Arctic sea ice across all seasons. *Environmental Research Letters* 13(1): 103001.
<https://doi.org/10.1088/1748-9326/aade56>
- Thaxter, C.B., Lascelles, B., Sugar, K., Cook, A.S.C.P., Roos, S., Bolton, M., Langston, R.H.W., and Burton, N.H. 2012. Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation* 156:53–61.
<https://doi.org/10.1016/j.biocon.2011.12.009>
- Wright, N.J.R., and Matthews, D.W. 1980. New nesting colonies of the Ivory Gull *Pagophila eburnea* in southern East Greenland. *Dansk Ornitologisk Forenings Tidsskrift* 74:59–64.
- Yannic, G., Aebischer, A., Sabard, B., and Gilg, O. 2014. Complete breeding failures in Ivory Gull following unusual rainy storms in North Greenland. *Polar Research* 33: 22749.
<https://doi.org/10.3402/polar.v33.22749>
- Yannic, G., Yearsley, J.M., Sermier, R., Dufresnes, C., Gilg, O., Aebischer, A., Gavrilov, M.V., et al. 2016. High connectivity in a long-lived high-Arctic seabird, the Ivory Gull *Pagophila eburnea*. *Polar Biology* 39(2):221–236.
<https://doi.org/10.1007/s00300-015-1775-z>