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New species records and changes in abundance of waterfowl in northwest Greenland

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New species records and changes in abundance of waterfowl in northwest Greenland

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Abstract Breeding populations of Nearctic and Palearctic waterfowl have undergone significant changes in abundance and distribution over the past 50 years. The Avanersuaq District in northwest Greenland is home to an assemblage of waterfowl from both geographic areas; however, minimal historic or current information is available on species abundance. In 2008 and 2009, we conducted field surveys in Greenland from 76.00° to 77.35°N for breeding and non-breeding waterfowl and have collected anecdotal field notes of avian observations over a 20-year period (1993–2012). During these periods, we documented the first observation of a Ross's goose (*Chen rossii*) and the first confirmed breeding by lesser snow geese (*Chen caerulescens caerulescens*) in Greenland. Northern pintails (*Anas acuta*) were observed for the first time in northwest Greenland, and a previously unknown breeding location for brent geese (*Branta bernicla hrota*) was also identified. Local populations of greater snow (*C. c.*) and Canada geese (*B. canadensis*) have increased in size. The Booth Sound and Drown Bay wetland areas and many islands throughout the Avanersuaq District were identified as critical habitat for both breeding and non-breeding waterfowl. Further increases in waterfowl abundance, including more frequent rare and new visitors, are likely in the study area as breeding populations further south continue to increase and an ameliorating climate allows for a longer breeding season. These results will prove useful as a baseline for comparisons with future surveys.

Keywords Waterfowl · Ross's goose · Snow goose · Range expansion · Abundance

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Introduction

Waterfowl populations in the Nearctic and Western Palearctic have undergone significant demographic changes over the past half-century with many species rapidly increasing or decreasing in abundance (for review see Fox et al. 2010; Johnsgard 2010; USFWS 2012; Wetlands International 2013). In particular, changes in agricultural practices in the temperate Nearctic and Palearctic have provided wintering Arctic nesting geese with abundant and nutritious food, resulting in significant increases in abundance and expanded breeding ranges (Ankney 1996; Abraham and Jefferies 1997; Moser 2001; Jefferies et al. 2003; Abraham et al. 2005; Fox et al. 2005; Gauthier et al. 2005). It is unclear what combined effect agricultural changes and climate change will have on waterfowl, but

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studies indicate a poleward shift in range due to warming global temperatures (Boyd and Madsen 1997; Thomas and Lennon 1999; Hickling et al. 2006; Zuckerberg et al. 2009; Brommer et al. 2012).

Greenland is home to a diverse mix of waterfowl species that winter in either continental North America or Northern Europe (Salomonsen 1950; Boertmann 1994; Lyngs 2003). Few surveys of breeding waterfowl populations within Greenland have been conducted, and those that do exist are focused on a few geographic areas and a relatively small number of species (e.g., Røen 1960; Malecki et al. 2000; Christensen and Falk 2001; Merkel 2010). Most published studies documenting changes in waterfowl numbers in north Greenland, for example, are based only on singular observations or anecdotal field notes collected during expeditions, most likely due to the area's remoteness and extreme weather. Thus, detecting accurate long-term changes in species composition and abundance can be difficult.

The Avanersuaq District in northwest Greenland (Fig. 1) is home to tens-of-millions of seabirds and the largest population of common eiders (*Somateria mollissima*) and snow geese (*Chen caerulescens*) in Greenland (Boertmann 1994, 1996; Burnham et al. 2012a). Six waterfowl species are known to breed in the area: common eiders, king eiders (*Somateria spectabilis*), long-tailed ducks (*Clangula hyemalis*), snow geese, Canada geese (*Branta canadensis*), and brent geese (*Branta bernicla*) (Salomonsen 1950; Boertmann 1994). Of these, the common eider occurs in the greatest numbers, with an estimated 25,000–30,000 breeding pairs based on a survey conducted in 2009 (Burnham et al. 2012a). Information on the other five species is limited to Salomonsen's (1950) *Birds of Greenland*, a 1959 snow goose survey by Røen (1960), and general species observations collected during both historical and contemporary expeditions and brief visits to the area or anecdotal field notes (e.g., Chapman 1899; Gibson 1922; Thing 1976; Vaughan 1988; Best and Higgs 1990).

Here we present results from field surveys specifically focused on waterfowl in the Avanersuaq District during the 2008 and 2009 breeding seasons. Additionally, anecdotal data collected on waterfowl from 1993 to 2012 (while conducting research on other bird species; e.g., Burnham and Burnham 2005, 2011; Burnham et al. 2009, 2012b) are included. Results are compared with historical data to determine what changes, if any, have occurred in the local waterfowl population from the mid-twentieth century onward.

Materials and methods

The Avanersuaq District is considered a High Arctic ecosystem. Ice-free land, bordered to the east by the Greenland Ice Sheet, consist primarily of narrow coastline and offshore islands. The Booth Sound and Thule Air Base (TAB) regions (Fig. 1) are dotted by numerous ponds and comprise the most expansive ice-free land in the region. The coastline is fragmented by glaciers and dominated largely by tall cliffs and talus slopes. For additional information on the area, see Burnham et al. (2012b).

Waterfowl were documented during annual gyrfalcon (*Falco rusticolus*) and peregrine falcon (*F. peregrinus*) surveys conducted between 1993 and 2007 along approximately 750 km of coastline from 76.00° to 77.35°N (Fig. 1). Using information collected during these surveys and what little information was available in the literature (e.g., Salomonsen 1950; Røen 1960; Thing 1976; Vaughan 1988), we identified 24 locations (islands, islets, small lakes, and ponds) where nesting pairs or colonies and non-breeding flocks of geese and ducks had been documented or were probable based on habitat characteristics. Two major wetland areas were also identified: a wide river valley surrounding TAB and an area that extended from Cape Parry south to Granville Fjord (Fig. 2).

The wetland area from Cape Parry to Granville Fjord was surveyed on July 22, 2008 (Fig. 2). Due to the area's size (30 km long and up to 6 km wide) and the difficulty of traversing numerous ponds, lakes, and streams, the survey was primarily conducted by helicopter (Fig. 2 area A, C and D), with only the Booth Sound wetland area (Fig. 2 area B) surveyed on foot. For areas surveyed by helicopter, high-resolution photographs were taken of all observed snow geese pairs and flocks, but no information was collected on other waterfowl species, such as Canada geese, due to their cryptic nature. At TAB, local ponds and lakes were surveyed by vehicle and foot from 11 to 15 of July 2008 and all observed ducks and geese were counted.

Surveys in 2008 at Booth Sound and TAB were in conjunction with the National Wildlife Disease Program of the United States Department of Agriculture. Geese were captured using drive net enclosures and banded with Copenhagen ZMUC metal bands. Head length and total tarsus measurements were taken (following Dzubin and Cooch 1992) along with cloacal swabs and blood samples for most individuals that were banded.

In 2009, surveys for ducks and geese occurred at 24 sites from 8 July to 2 August. Surveys were done primarily by foot, with approximately 750 km of coastline surveyed by boat to ensure complete coverage of the entire study area. Wolstenholme and Saunders Islands are generally unsuitable for nesting waterfowl (i.e., cliffs and talus slopes) and were surveyed by boat with the exception of the large flat on the southwest side of Saunders Island, which was surveyed by foot. For information on specific island survey methodology, see Burnham et al. (2012a). When applicable, five digit codes from the *Greenland seabird colony database* (Boertmann et al. 1996) were used to identify

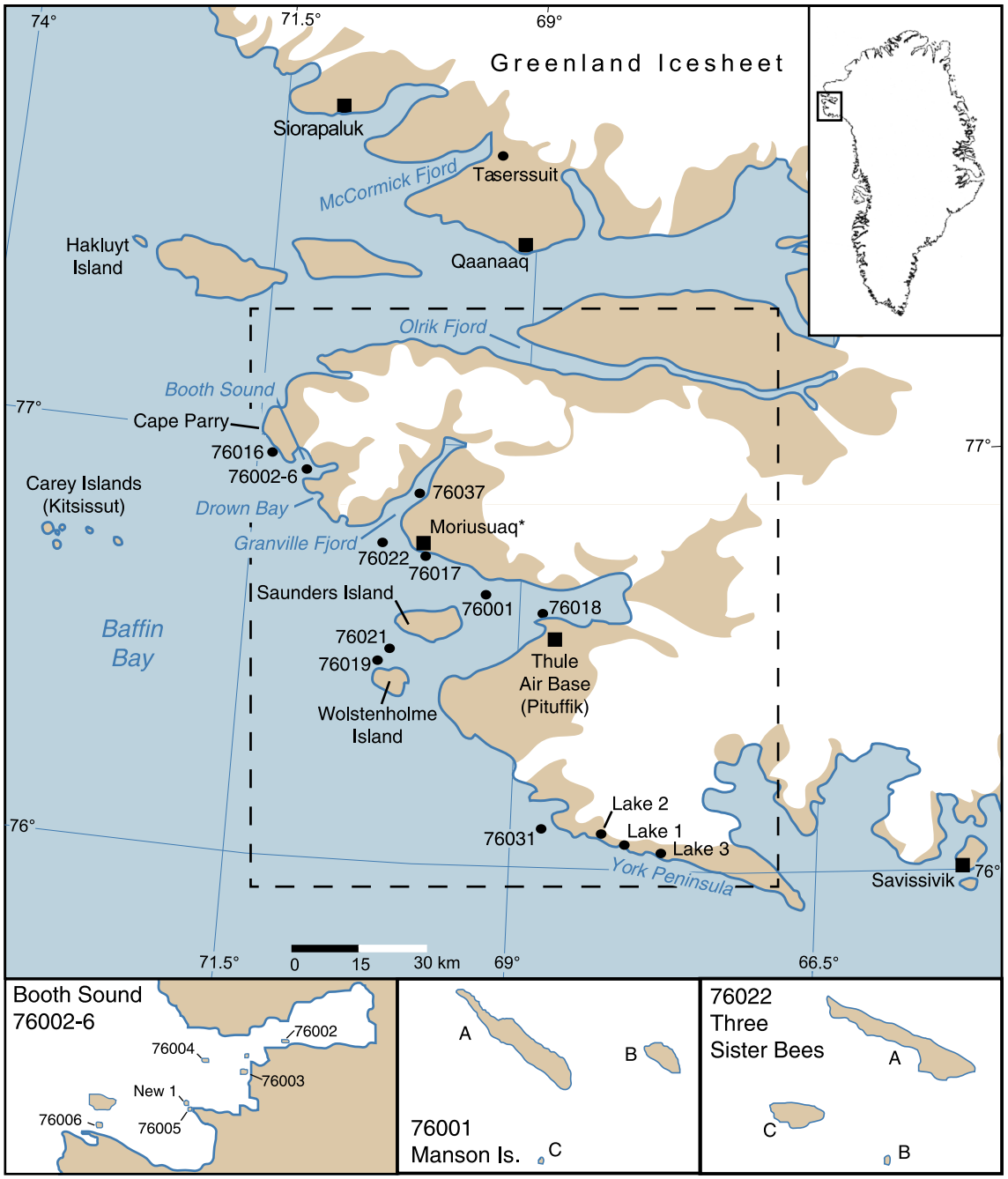

Fig. 1 Place names and locations surveyed for nesting waterfowl in the Avanersuaq District, northwest Greenland, during 2008 and 2009. *Five digit location numbers* are from the Greenland seabird database (Boertmann et al. 1996). The study area outlined by *black dashed line*. Modified from Burnham et al. 2012a

specific islands. Results of waterfowl surveys of the Carey Islands (Fig. 1; 50 km off the coast) and common eider nest counts have been published elsewhere (Burnham and Burnham 2010; Burnham et al. 2012a). Islands and coastlines were visited in years other than 2009, and while systematic surveys were not done, data were recorded, which provide useful information and have been included here.

Results

Data collected in the Avanersuaq District between 1993 and 2012 provide the first detailed inventory of waterfowl populations for this area. Primary breeding locations for waterfowl species were identified as well as areas where large numbers of subadults, failed breeders, and non-breeders reside during the breeding season.

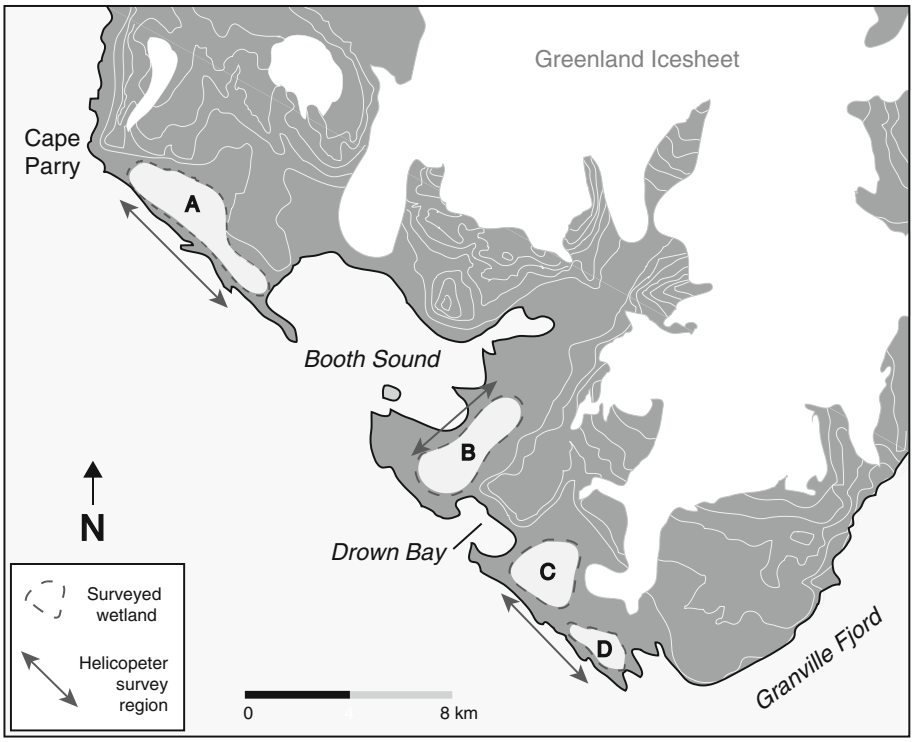

Fig. 2 Location of wetland areas that were surveyed for snow geese by helicopter from Cape Parry to the entrance of Granville Fjord. *A* Cape Parry wetland, *B* Booth Sound wetland, *C* Drown Bay wetland, *D* Drown Bay south wetland. No snow geese documented in area *A* or *D*

Snow goose

From 1993 to 2012, snow geese were documented nesting on ten islands, near small ponds and lakes in the Booth Sound and Drown Bay wetland areas, and at Lake 2 along the York Peninsula (Figs. 1, 2, areas B and C, and Table 1).

In the Booth Sound and Drown Bay wetland areas in 2008, 69 adult breeding snow geese with 77 goslings were counted along with approximately 850 flightless, or molting, non-breeders (Table 2; Fig. 2). Breeding pairs with goslings were separate from non-breeding flocks, although in some instances, multiple pairs with goslings were observed together. In the Booth Sound wetland area, 647 non-breeders were captured, including 636 mostly greater, white color morphs (270 were banded, measured, and swabbed, and blood samples were collected from 21), and 11 mostly lesser, blue color morphs (11 were banded, measured, swabbed, and blood samples were collected from nine). White morphs ($n = 270$) had significantly longer heads ($t = 3.72$, $df = 10$, $p = 0.004$,) and tarsi ($t = 3.99$, $df = 11$, $p = 0.002$) when compared to blue morphs ($n = 11$); however, overlapping distributions existed between groups, and it is likely that both greater and lesser white and blue morphs were present (Table 3). The presence of white morph lesser snow geese is further supported by our late summer observation of a few noticeably smaller individuals with more rapid wing beats in flocks of flying snow geese in the south Booth Sound area.

In 2008 on island 76001(A), a pair of blue morph lesser snow geese was observed with four goslings (all dark colored). Photos of the pair among a larger group of white morph pairs with goslings were reviewed by R. Alisauskas, K. Drake, and J. Leafloor (pers. comm.). Based on differences in size between the two color morphs, all agreed the blue morph individuals were "most likely" lesser snow geese. A blue morph pair with dark goslings was also observed in 2012 in addition to a blue morph snow goose paired with a white morph.

From islands surveyed in 2009, a total of 79 nests were counted on seven islands, nearly half (38) of which were on island 76022(C) (Table 1). Egg shell fragments from hatched eggs were found in 79 % of nests, incubating adults at 17 %, and small goslings at 5 %. Mean clutch size at the 13 nests with incubating adults was 3.6 ± 1.5 eggs (range = 1–6), and based on gosling size, chick hatching primarily occurred during the first 2 weeks of July.

Although Saunders Island was surveyed annually, snow geese were only observed on the large plain on the southwest corner of the island in 1999 when two separate groups of $\sim$20 snow geese were observed. Both groups consisted of non-breeding flightless adults and multiple adult pairs with goslings. Island 76031 was surveyed almost yearly starting in 1998 with snow geese first observed in 2009, and reproduction documented in 2012 (two goslings). Island 76001(C) was first observed with nesting snow geese in 2012 and had three pairs with goslings. At Lake 2 along the York Peninsula, a single pair of

Table 1 Results of island surveys for nesting waterfowl in the Avanersuaq District, northwest Greenland (76.00–77.25°N), which took place from July 8 to August 2, 2009. Locations 76001(B) and (C), 76002, 76004–06, 76018, 76022(B) and Saunders Island were also surveyed, and no nesting waterfowl were found (Fig. 1)

Colony number [a,b]	Site name	Survey dates	Species	Avg. eggs per nest ± SD (range)	Nests with eggs (pipped)	Nests with fragments	Nests with goslings[c]	Total nests	Adults and goslings observed[d]
76001(A)	Paattorfiarsuk (Manson Islands)	9–11 Jul	*C. c. atlanticus*	3.2 ± 1.0 (2–4)	6 (1)	9	3	18	16/6
		9–11 Jul	*Clangula hyemalis*	5.2 ± 2.6 (2–9)	11	0	0	11	None
New 1	Booth Sound	12 Jul	*Clangula hyemalis*	5	1	0	0	1	None
76003	Booth Sound	14 Jul	*C. c. atlanticus*	2.5 ± 2.1 (1–4)	2	1	0	3	None
		14 Jul	*Clangula hyemalis*	4.6 ± 3.3 (1–13)	45	0	0	45	None
		14 Jul	*Clangula hyemalis* in *somateria mollissima*	2.1 ± 1.2 (1–6)	38	0	0	34	None
76016	Qeqertaaraq	13 Jul	*Branta canadensis*	4	1	0	0	1	None
		13 Jul	*C. c. atlanticus*	–	0	5	1	6	None
76019	Igannaq (Dalrymple Rock)	15, 18, 28 Jul	*Branta bernicla*	–	0	0	1	1	4/7
		15, 18, 28 Jul	*C. c. atlanticus*	–	0	3	0	3	2/4
76021	Qeqertaarsuit (Eider Duck Is.)	8 Jul	*C. c. atlanticus*	4.6 ± 1.5 (3–6)	5	1	0	6	2/4
76022(A)	Iterlassuup Qeqertaarsuq	25 Jul	*C. c. atlanticus*		0	5	0	5	None
76022(C)	(Three Sister Bees)	25 Jul	*C. c. atlanticus*		0	38	0	38	None
76031	Igannaq (Conical Rock)	2 Aug	*C. c. atlanticus*	–	0	0	0	0	2/0
76037	Iterlassuaq	26 Jul	*Clangula hyemalis*	–	0	1	0	1	None

Data for common eiders have been published elsewhere (Burnham et al. 2012a)

[a] Colony number from Greenland seabird colony database (Boertmann et al. 1996)

[b] For the Manson Islands and Three Sister Bees, letters after colony numbers are used to identify individual islands in Fig. 1 inset maps

[c] Some nests had chicks and eggs

[d] Does not include adults or goslings observed at nests

snow geese was observed with two goslings in 1998. Lake 2 was no longer present after 1998 possibly due to flooding from the Greenland Ice Sheet. From 2009 to 2012, the number of snow goose nests increased from 6 to 17 and from 18 to at least 28 on islands 76016 and 76001(A), respectively.

Ross's goose

A single Ross's goose was captured on July 22, 2008, during the trapping of non-breeding snow geese in the Booth Sound wetland area. The Ross's goose head measured 86.4, 13.7 mm shorter than the smallest snow goose head ($n = 282$, mean = 126.0 ± 5.9, range = 101.7–137.9 mm), and the tarsus (86.4 mm) was only slightly larger than the smallest snow goose tarsus (mean = 102.6 ± 4.5, range = 86.1–114.0 mm). Photos of the Ross's Goose were reviewed and confirmed by R. Alisauskas, K. Drake, and J. Leafloor (pers. comm.).

Canada goose

Canada geese were observed at TAB from 1993 to 2012, and breeding at TAB was documented from 2000 to 2012 and in the Booth Sound wetland area from 2008 to 2012. Outside of these areas, a single nest with eggs was found on island 76016 in 2009 (breeding not observed in subsequent years), and at Lake 1 along the York Peninsula, a single pair with three goslings was observed on August 6, 1999, and two pairs with goslings were observed on July 28, 2006. Eleven pairs were observed in 2008 on the lakes and ponds located on TAB and to the north and east, and at least eight of the pairs produced young with eggs hatching between 10 and 15 July. In the south Booth Sound area on 21 and 22 of July 2008, a minimum of seven pairs were observed, all with young, including one brood that had hatched within the past 48 h. More pairs were likely present, but due to their cryptic behavior and difficulty in surveying the entire wetland, all individuals were difficult to detect.

Along the York Peninsula, flocks of non-breeding Canada geese in full molt were observed at three locations in association with small lakes and/or ponds. Lake 1 had between 15 (2006) and 43 (2008) geese each year it was visited (1998–1999, 2002, 2005–2006, 2008, 2011), while Lake 2 had 30 geese in 1998 (note: this lake did not exist in subsequent years). Although no adults were observed at Lake 3 during our surveys, a large number of molted feathers and feces were observed on the shore and vegetation around the small ponds.

In most years, a flock of non-breeding Canada geese was observed in the large lake directly over the ridge (referred to as "north mountain" by local residents) north of TAB. In 2008, the flock was captured (24 adults) and all geese were banded, swabbed, measured, and blood samples were collected. Mean head and tarsus length were 114.4 mm (SD ±5.3, range = 104.1–126.9) and 98.8 mm (SD ±5.4, range = 91.2–108.7), respectively. These measurements have since been compared by Fox et al. (2012) with similar measurements from 99 Canada geese (*B. c. interior*) captured in Isunngua (central-west Greenland, 67.08°N, 50.53°W), and no statistical differences were found. Field observations from 1993 to 2012 suggest that no subspecies of Canada goose other than the *B. c. interior* exists in northwest Greenland. Although large flocks of non-breeding Canada Geese in full molt were observed at TAB and along the York Peninsula, none were observed in the Booth Sound or Drown Bay wetland areas.

White-fronted goose

A single white-fronted goose (*Anser albifrons*) was observed near island 76019 on the morning of August 5, 2012, and later that afternoon near the harbor at TAB.

Brent goose

Three pairs of brent geese (*B. bernicla*) were observed in 2008 with 10 young on island 76019, and two pairs were observed with seven young in 2009. Goslings likely hatched between 5 and 10 July based on size. Pairs with young were also observed on island 76019 in 1999, 2003, 2005, and 2010–2012. Two brent were observed on Hakluyt Island, just to the north of our primary study area, on July 20, 2012 (Fig. 1).

King eider

In 2012, a single female king eider was observed incubating eggs in the Booth Sound wetland area near a pond approximately 1.2 km inland. Additionally, adult males were commonly observed flying in mixed flocks with common eiders from 2007 to 2012 within Booth Sound. No breeding was documented elsewhere in the study area, and observations of mixed eider flocks were rare.

Long-tailed duck

Nesting long-tailed ducks were observed in 2009 on islands (Table 1) 76001(A), 76003, 76037, and New 1 and were nesting in close proximity to nesting Arctic terns (*Sterna paradisaea*) except for island 76037. Island 76003 had 45 long-tailed duck nests on July 26, 2009, with long-tailed duck eggs also observed in 38 common eider nests. Clutch size on island 76003 ranged from 1 to 13 eggs (mean = 4.6 ± 3.3) and hatching began on 26 July in

2009. Island 76001(A) had 11 nests and clutch size ranged from 2 to 11 eggs (mean = 5.2 ± 2.6) with eggs starting to hatch on July 29–30, 2009. Although island 76037 had a single nest in 2009, no nests were observed in 2011 and 2012 coinciding with no nesting Arctic terns on the island. Only two additional long-tailed duck nests were observed elsewhere, at ponds on TAB in 2010 and 2012.

A flock of several hundred males and females was observed on the water throughout the summer on south Drown Bay from 1999–2006 and 2008–2012 (2007 not surveyed). Similar numbers were also regularly observed scattered along the shoreline within Booth Sound. At TAB, males and females are relatively common on the many small ponds and lakes prior to the nesting period, while lesser numbers of non-breeders are present during the nesting period.

Northern pintail

A pair of northern pintails was observed on one of the large lakes in the Booth Sound wetland area on July 22, 2008.

Common teal

A single adult female common teal (*Anas crecca*) was observed regularly from mid-July through early August in 2010 on the small ponds and lakes on the north side of TAB.

Discussion

When results from our study are compared with historical data for the Avanersuaq District, it is evident that significant changes have occurred in both the abundance and diversity of local waterfowl. In particular, numbers of greater and lesser snow geese and Canada geese have increased. Furthermore, since 2008, northern pintail and Ross's goose were documented, and common teal and white-fronted goose were observed for only the second and third time in the Avanersuaq District, respectively. Aside from snow geese and common eiders, limited historical information exists for species such as long-tailed ducks and king eiders, and it is difficult to determine what changes, if any, have occurred in local abundance.

New or rare species

Ross's geese have increased in abundance for the past several decades throughout their geographic distribution with their breeding range expanding rapidly eastward across Arctic North America (Ryder and Alisauskas 1995; Kelley et al. 2001; Jonsson et al. 2013). Observing a single Ross's goose in 2008 is likely a result of this expansion, with the nearest Ross's goose documented on Bylot Island (Nunavut) approximately 450 km southwest from our sighted location (Lepage et al. 1998).

Although northern pintail are an annual vagrant and rare breeder in Greenland (Boertmann 1994), the pintail pair observed in 2008 was the first case documented in the Avanersuaq District. The furthest north northern pintails had been observed in Greenland prior to our observation was 74.30°N in East Greenland (Rasch 1999). Based on banding records, both Palearctic and Nearctic birds occur in Greenland (Lyngs 2003), and it is not known to which geographic group the observed pair belonged.

The only previous record of a common teal in northwest Greenland was for a male Palearctic subspecies *A. c. crecca*, shot on June 18, 1985; however, the Nearctic subspecies *carolinensis* is also known to occur in Greenland (Boertmann 1994). Common teal are considered vagrants in Greenland, although breeding may have occurred in southwest Greenland in 1974 (Boertmann 1979). We were unable to determine the subspecies of the observed female.

Although the brent goose was considered a regular breeder throughout north Greenland in the early- to mid-twentieth Century (Salomonsen 1950), island 76021 in our study area is the only other location within Greenland along with the Carey Islands (Burnham and Burnham 2010) and Kronprins Christian Land (Hjort et al. 1987; Hjort 1995; a large peninsula in north Greenland) where the species is currently known to regularly breed. While we have banded both breeding adults and goslings on island 76021, no band recoveries have been obtained to date, and it remains unknown as to which geographic population brent geese in northwest Greenland belong (for a review of geographic populations see Merne et al. 1999; Robinson et al. 2004).

White-fronted goose observations are extremely rare for northwest Greenland, and aside from our observation of a single adult in 2012, only two previous records exist: three adults observed by Best and Higgs (1990) in 1989 near Taserssuit (Fig. 1; a wetland area to the north of our study area) and a flock of 10 adults observed by Burnham and Burnham (2010) on the Carey Islands in 2008. It is unknown to which subspecies the observed individual belonged.

Species showing increasing abundance

Prior to 1950, Salomonsen (1950) documented greater snow geese breeding at only two locations in the Avanersuaq District; the wetland area where TAB is now located and at Taserssuit. Each population was estimated to be no more than 10–20 breeding pairs (Salomonsen 1950). While

the population at TAB ceased to exist after the base was built in the 1950s, sporadic surveys of Taserssuit have shown a large increase, and survey results from 1969 to 1998 have ranged from 235 to at least 610 individuals (Heyland and Boyd 1970; Best and Higgs 1990; D. Boertman pers. comm. for 1998 survey).

During a visit to Booth Sound in mid-September 1959, Røen (1960) observed approximately 135, identifying the area as important for snow geese. While he found no nests, local inhabitants confirmed that snow geese did breed in the area. Salomonsen observed 48 adults in the same area in 1968, and approximately 250 geese were observed in 1987 (K. Kampp, pers. comm.). Vaughan (1988) similarly observed 250 non-breeders in full molt in mid-July 1984, and an additional 15 birds in flight, although he did not document any breeding. Based on our observations from 1999 to 2012, their abundance has increased, with approximately 1,000 snow geese counted in the Booth Sound and Drown Bay wetland areas during the 2008 survey (Table 2).

Through the late 1950s, only islands 76021 and 76037 in our study area had documented breeding snow geese (Røen 1960). The first mention of snow geese regularly nesting on islands in our study area was by Salomonsen (1981), although it is possible he was referencing the same islands as Røen (1960), and no specifics were provided. Similarly, Vaughan (1988) makes mention of "established colonies on rocky offshore islets," and further states that snow geese nesting on islands in the area were most definitely a recent event, which likely occurred sometime after the mid-1970s.

During common eider nest surveys in 1998, K. Diget (pers. comm.) only observed pairs of snow geese with young on three of the eight islands where we observed nesting snow geese and also on an island where we did not observe nesting snow geese (76001(B), single pair with four young). Diget observed 24 adults and 31 young on island 76001(A), 10 adults and one pair with three young on 76016, and four adults and two pairs with four young each on 76022(C). When compared to our results, the number of pairs has increased on each island, with island 76022(C) showing the largest increase, from two pairs in 1998 to 38 pairs in 2009.

White morph lesser snow geese have long been considered an occasional visitor to Greenland, although breeding had never been documented prior to this study (Salomonsen 1950; Boertmann 1994). The first blue morph lesser snow goose was documented in Greenland in 1975 (Thing 1976; McGary Island, north of our study area), and only a single additional observation of five individuals in 1989 has been made since (Best and Higgs 1990; at Taserssuit). Despite visiting Taserssuit and both Booth Sound and Drown Bay areas, no observations of lesser snow geese (white or blue morph) were made during Vaughan's (Vaughan 1988) three summers in the Avanersuaq District in the mid-1980s. Both blue and white morph lesser and greater snow geese now appear as regular visitors to the Avanersuaq District based on our observation and measurements, and it suggests that the number of blue morph lesser snow geese in Greenland is increasing, similar to population trends observed in north-central and northeast Canada (Kerbes et al. 2006).

The first observation of Canada geese in north Greenland was in 1984, when four adults were observed at Taserssuit and three to five adults were observed among snow geese near Drown Bay (Vaughan 1988). The abundance of Canada geese has increased since 1984, with breeding now documented at TAB, the York Peninsula, and Booth Sound. Both TAB and Booth Sound wetland appear as important breeding grounds for Canada geese with between 5–10 pairs nesting at TAB each year during our surveys and approximately 10–25 pairs nesting in the Booth Sound wetland. The summer of 2008 had 11 breeding pairs at TAB, with only half the number of nests observed in 2009–2012. This decline in the number of breeding pairs coincided with an intentional removal of ponds in late spring 2009 as part of a mosquito abatement effort on TAB.

Species of concern

Salomonsen (1950) considered the king eider as a common breeder in the Avanersuaq District and described it as "numerous" on the "Pitugfik plains" (now TAB) and at Taserssuit. Since the construction of TAB in the 1950s, the area is generally unsuitable for nesting king eiders and no individuals have been documented in the area. While traveling throughout the Avanersuaq District in 1975, Thing (1976) reported two large flocks of several hundred king eiders, mostly adult males, and only a single breeding pair. Similarly, Vaughan (1988) only reported four nests at Taserssuit during three different summer surveys in the mid-1980s. Burnham and Burnham (2010) documented large mixed flocks of common and king eider males around the Carey Islands in 2008, but considered king eiders rare along the mainland. A single king eider nest was documented in the Booth Sound wetland area in 2012; however, no systematic survey for the species was conducted to estimate its breeding density. It is probable that the Booth Sound wetland area and Taserssuit are now the primary breeding area for king eiders in the Avanersuaq District, although additional surveys of the inland lakes are required. With no specific information from Salomonsen (1950) other than it "breeds commonly" in the area, it is difficult to determine what changes have occurred in the size of the breeding population within the Avanersuaq District (aside from the loss of nesting habitat at TAB).

Table 2 Results of waterfowl surveys in the Booth Sound, Drown Bay, and TAB area and along the York Peninsula from July 11 to August 5, 2008

Location	Date	Species	Breeding adults	Chicks	Non-breeders	Comments
Booth Sound wetland[a]	22 Jul 08	*Anas acuta*	0	0	2	Pair of adults, first record for northwest Greenland
		Branta canadensis	10	Yes[b]	0	Only breeders were observed in this area in 2008–12, likely additional pairs in area but not seen
		C. c. atlanticus	32	58	636	Non-breeders were flightless and captured, breeders and non-breeders were in separate flocks
		C. c. caerulescens	0	0	11	
		Chen rossii	0	0	1	First record for Greenland
Drown Bay	3 Aug 08	*Clangula hyemalis*	0	0	~150	Large flock of adult males, limited immature males and non-breeding females, in shallows on south side of bay (present in similar numbers 1999–2005, 2007, 2009–2011, K. Burnham unpubl. data)
Drown Bay wetland[c]	22 Jul 08	*C. c. atlanticus*	37	19	204	May have included white morph *C.c. caerulescens* as well, breeders and non-breeders were in separate flocks, numbers based on photos from helicopter
Thule Air Base	11–15 Jul 08	*Branta canadensis*	22	13	39	Breeding pairs most common on ponds on base, chicks appeared recently hatched to 4 days old
	15 Jul 08	*Clangula hyemalis*	0	0	8	Common on ponds early in year, during mid-summer non-breeders found on large pond among fuel tanks and on lakes in valley north of base (similar 1993–2012, K. Burnham unpubl. data)
Lake 1	5 Aug 08	*Branta canadensis*	0	0	43	Likely flightless based on behavior (present in similar numbers 1998–99, 2002, 2005–06, 2011, K. Burnham unpubl. data)

Comments on observations from additional field seasons are also included. See Fig. 1 for locations of each area

[a] Area B in Fig. 2

[b] All pairs had chicks

[c] Area C in Fig. 2

Species with stable populations

Although considered a common and widespread breeder in Greenland, little information is available on long-tailed duck abundance. The Avanersuaq District and Scoresbysund area (central-east Greenland) are believed to have the highest nesting density (Salomonsen 1950; Boertmann 1994). Although the Booth Sound area within our study area had the largest number of nests and non-breeders, nests were observed only on islands and not around the numerous inland ponds and lakes. With the exception of TAB and islands 76001(A) and 76017, no additional long-tailed ducks were observed outside the Booth Sound area.

A large clutch size range (1–13 eggs; mean 4.6 ± 3.3) was observed for long-tailed ducks on island 76003 in Booth Sound and was likely a result of intraspecific nest parasitism as the normal clutch size range is 5–9 eggs (Salomonsen 1950; Alison 1975). We also observed nest parasitism between long-tailed ducks and common eiders on island 76003; however, we suspect (yet not confirmed) that the long-tailed duck eggs did not produce viable offspring because common eider eggs normally hatch 2–3 weeks prior to long-tailed duck eggs in the study area (Salomonsen 1950; K. Burnham pers. obs.), and long-tailed duck young were never observed with common eider hens.

Table 3 Measurements of non-breeding white and blue morph snow geese in full molt sampled in northwest Greenland in 2008

	Head	Tarsus
White morph ($n = 270$)		
Average ± SD	126.4 ± 5.2	102.9 ± 4.3
Range	106.3–137.9	90.8–114.0
Median	126.6	103.0
Blue morph ($n = 11$)		
Average ± SD	115.0 ± 10.2	96.7 ± 5.1
Range	101.7–130.7	86.1–101.9
Median	103.0	98.5

Possible mechanisms for observed abundance changes

Over the past half-century, modern agriculture practices in mid-continent North America and Europe have provided

wintering waterfowl a nearly unlimited source of food leading to dramatic increases in abundance and expanded breeding ranges for many Arctic nesting species (Ankney 1996; Abraham and Jefferies 1997; Moser 2001; Jefferies et al. 2003; Fox et al. 2005; Gauthier et al. 2005; Fox et al. 2010). In particular, continental North American populations of greater and lesser snow geese have increased in size and expanded their breeding range with similar patterns observed in the Canada goose population in Greenland (Bennike 1990; Fox et al. 1996; Abraham and Jefferies 1997; Menu et al. 2002; Abraham et al. 2005; Fox and Gladher 2010). It is believed that most goose populations that nest in the Arctic will continue to increase in size until carrying capacity of northern breeding grounds is reached, and density-dependent factors begin to slow population growth (Alisauskas et al. 2011; Leafloor et al. 2012).

Recent changes in weather and climate have allowed for a northward range expansion of many species from almost all major taxonomic groups including mammals, birds, insects and plants (Parmesan and Yohe 2003). Long-term studies of breeding birds in both European and North American temperate zones have shown that climate change correlates with a significant expansion of the northern boundaries for many species (Thomas and Lennon 1999; Hitch and Leberg 2007). Information on range expansion in the Arctic is more limited, with Brommer et al. (2012) documenting a northern range shift of 0.81 km/year for northern boreal and Arctic nesting species in Finland for the 20.5-year period from 1989 to 2006. As waterfowl populations continue to increase in abundance to the south, longer breeding periods due to increasing temperatures will allow species to expand north and utilize unoccupied habitat and food.

Northwest Greenland has experienced increased daily temperatures from spring through autumn and a decrease in sea ice coverage with thawing and ice breakup occurring earlier in the year (Serreze et al. 2000; Mountain et al. 2001; Born et al. 2011; Burnham et al. 2012b). Within our study area in the Avanersuaq District, an ameliorating climate has been suggested as a contributing factor to recent increases in both local common eider and peregrine falcon populations, and earlier nest initiation dates for gyrfalcon (Burnham and Burnham 2011; Burnham et al. 2012a, b). As daily temperatures increase, the number of days available to breed and successfully raise offspring also increases, thereby allowing for a northward expansion among many species. Fox et al. (2011) suggest a similar pattern for Canada geese in central-west Greenland. Warmer temperatures may also explain the number of new and rare visitors to the area.

Based on our findings, it is clear that significant changes in waterfowl population abundance have occurred over the past 50 years within the Avanersuaq District. The increase in abundance of snow and Canada geese and common eiders and the more and recent observations of both new and rare waterfowl species to the area is likely attributed to a combination of factors, including density-dependent dispersal and range expansion (i.e., increasing abundance in more southern breeding areas) and an ameliorating climate allowing for more suitable breeding conditions. The Booth Sound and Drown Bay wetland areas and the many small islands throughout the area provide critical nesting habitat for these species and should be protected from human disturbance. If current trends hold, it is likely that populations will increase in size, and additional waterfowl species may find the area suitable for breeding. These results provide a baseline for monitoring future changes in abundance and species composition in the Avanersuaq District.

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