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Incidental Observations of Birds in the Vicinity of Hell Gate Polynya, Nunavut: Species, Timing, and Diversity

AMIE L. BLACK,[1,2] H. GRANT GILCHRIST,[1] KAREL A. ALLARD[3] and MARK L. MALLORY[4]

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ABSTRACT. Our knowledge of the distribution of Arctic birds and how their ranges may be responding to environmental changes in the Canadian Arctic is limited. We gathered five years of species observation data from three sites in the Hell Gate–Cardigan Strait Polynya (Cape Vera, St. Helena Island, and Devil Island) to create an inventory of avian species observed in the polynya, and we compared it to previous observations made at our sites and other sites throughout the Arctic. We examined species diversity measurements over time to suggest possible effects of the polynya on the timing of spring arrival of breeding and migrant species. Of the 39 species observed during our study, 12 were local breeders. Our records provide the northernmost observations for eight species. Species diversity index values at St. Helena Island peaked quickly in mid-June and stabilized by late June, reflecting the arrival and dispersal of migrating species relatively early in the season. These data highlight the importance of the open-water feeding habitat of the polynya not only for breeding birds, but also for migrants.

Key words: polynya, Arctic, Arctic birds, species diversity, spring arrival, Hell Gate, species inventory

RÉSUMÉ. Nos connaissances de la distribution des oiseaux de l'Arctique et de la façon dont leurs parcours sont adaptés en fonction des changements environnementaux de l'Arctique canadien sont restreintes. Nous avons rassemblé les données d'observation d'espèces diverses échelonnées sur cinq ans à partir de trois emplacements de la polynie de Hell Gate–Cardigan Strait (cap Vera, île St. Helena et île Devil) dans le but de dresser l'inventaire des espèces aviaires observées dans la polynie, puis nous les avons comparées aux observations faites antérieurement à nos emplacements de même qu'à d'autres emplacements de l'Arctique. Nous avons examiné les mesures de la diversité des espèces au fil du temps afin de pouvoir suggérer les effets possibles de la polynie sur le moment de l'arrivée du printemps des espèces nicheuses et des espèces migrantes. Au nombre des 39 espèces ayant fait l'objet de notre étude, 12 étaient des oiseaux nicheurs de la région. Nos données constituent les observations prélevées les plus au nord pour huit des espèces. Les valeurs de l'indice de la diversité des espèces à l'île St. Helena ont atteint leur sommet à la mi-juin, puis se sont stabilisées vers la fin juin, ce qui était le reflet de l'arrivée et de la dispersion d'espèces migrantes relativement tôt dans la saison. Ces données font ressortir l'importance de l'habitat alimentaire en eaux libres de la polynie, non seulement pour les oiseaux nicheurs mais également pour les oiseaux migrants.

Mots clés : polynie, Arctique, oiseaux de l'Arctique, diversité des espèces, arrivée du printemps, Hell Gate, inventaire des espèces

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INTRODUCTION

As a result of climate warming, the Arctic landscape is currently experiencing changes to long-term patterns of sea ice and snow (ACIA, 2005). Over many parts of the Arctic, localized shifts in environmental conditions have already occurred. In Hudson Bay, for example, seabird diets have changed in response to a shift in the local fish population structure. Formerly dominated by arctic cod (*Boreogadus saida*), a species associated with ice, this population is now dominated by capelin (*Mallotus villosus*), which live in somewhat warmer water (Gaston et al., 2003). Species range extensions are being documented by both residents of Arctic communities and scientific surveys (e.g., Mallory et al., 2005). Smol and Douglas (2007) found that High Arctic tundra ponds that used to provide freshwater habitat for species until freeze-up now dry up each year.

Because of the vast, relatively pristine landscapes of the Canadian Arctic and its small human population dispersed in a few settlements, our knowledge of the distribution of Arctic birds in Canada remains limited and patchy. Most information has come from early expeditions by museums (e.g., MacDonald, 1953; MacPherson and McLaren, 1959; Parmelee and MacDonald, 1960), survey work for

[1] National Wildlife Research Centre, Raven Road, Carleton University, Ottawa, Ontario K1S 5B6, Canada
[2] Corresponding author: Amie.Black@ec.gc.ca
[3] Canadian Wildlife Service, 17 Waterfowl Lane, Sackville, New Brunswick E4L 1G6, Canada
[4] Acadia University, 33 Westwood Avenue, Wolfville, Nova Scotia B4P 2R6, Canada

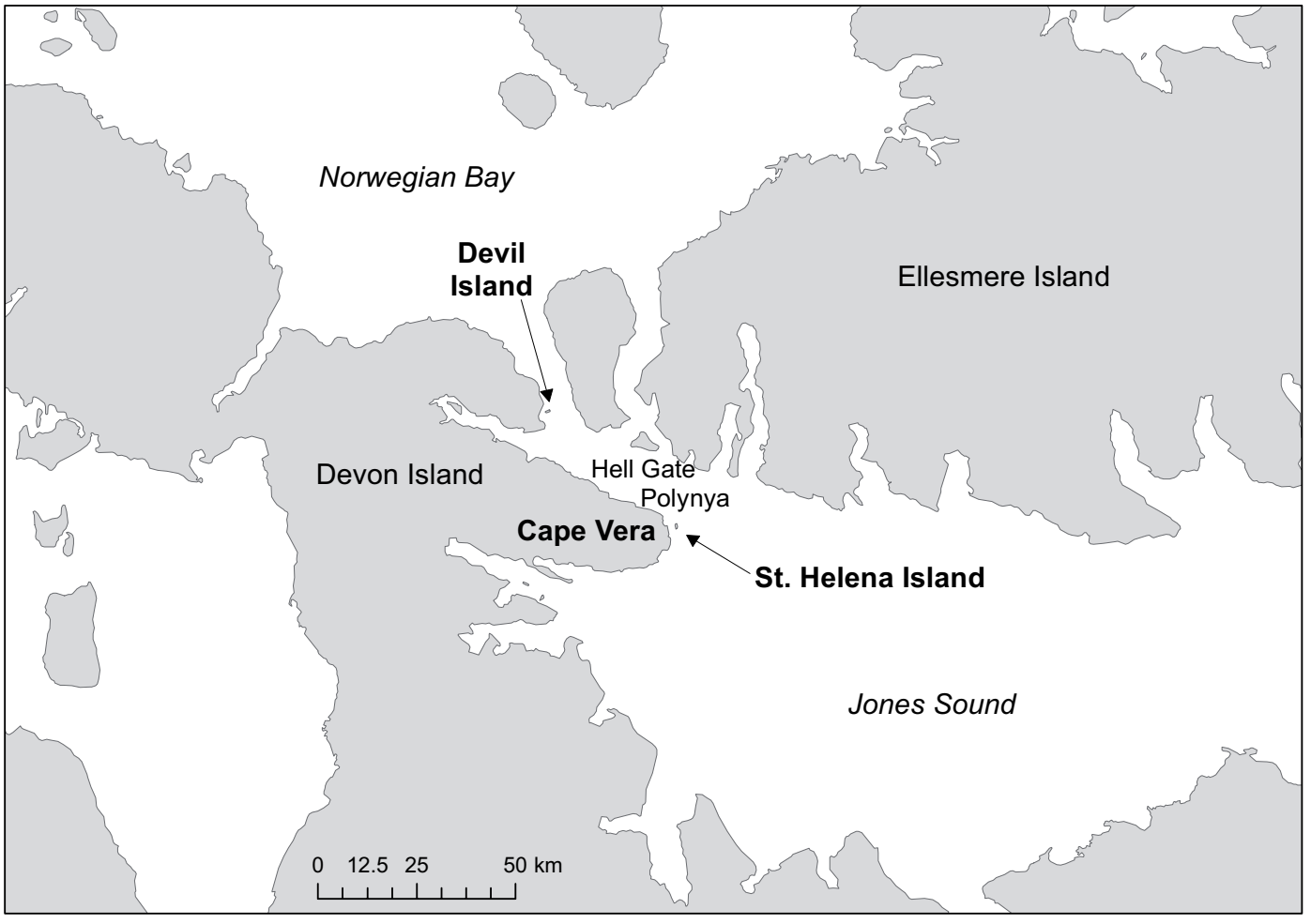

FIG. 1. Map of Devon and Ellesmere Islands showing the study sites at Cape Vera, St. Helena Island, and Devil Island.

environmental assessment (McLaren and McLaren, 1982; McLaren and Renaud, 1982; Smith et al., 2005), or sites of long-term research (Freedman and Svoboda, 1982; Pattie, 1990; Lepage et al., 1998; Gaston, 2002). These data sets provide essential information for a baseline to which we can compare recent changes observed in wildlife distributions occurring concomitantly with other environmental change.

From 2003 to 2007, we conducted ecological studies in the Canadian High Arctic near the Hell Gate-Cardigan Strait Polynya (hereafter Hell Gate Polynya), between Devon Island and Ellesmere Island, Nunavut, Canada. This polynya is a 2800 km^2 area of recurring open water that is kept relatively free of ice from December to September by strong tidal currents (Smith and Rigby, 1981; Mallory and Fontaine, 2004; Hannah et al., 2009). Ice conditions vary between years and within seasons, but the polynya is typically covered in ice from September to November. Ice is transported from Norwegian Bay through Cardigan Strait and Hell Gate by strong currents, and remains mobile in the polynya (Smith and Rigby, 1981; Barber and Massom, 2007) until open water reappears in December (Mallory and Fontaine, 2004). Open water in the polynya provides predictable feeding opportunities for marine birds early in the spring in a marine landscape that is otherwise covered in ice (Brown and Nettleship, 1981). Consequently, it is widely recognized as an important breeding and migration staging area for marine birds and marine mammals (Stirling, 1980; Mallory and Fontaine, 2004; Mallory and Gilchrist, 2005).

While previous surveys have documented the importance of this site to marine birds (Nettleship, 1974; Prach and Smith, 1992; Mallory and Gilchrist, 2005), an inventory of all avian species using the area has not been published, nor have spring arrival dates of birds to the area been examined. Here, we describe all bird species observed in the vicinity of the polynya from 2003 to 2007, and we report observations from earlier, unpublished work conducted from 1980 to 1984 by Prach (1986). We also suggest how the predictable open water of the polynya may affect spring arrival dates of breeding birds by comparing long-term data from multiple Arctic research sites.

METHODS

From April to August in 2003–07, field crews were situated at three sites in the Hell Gate-Cardigan Strait polynya:

TABLE 1. Arrival and departure dates of field crews at each field site from 2003 to 2007.

	2003	2004	2005	2006	2007
Cape Vera	29 May – 11 August	9 May – 9 August	20 April – 16 August	16 June – 24 July	–
St. Helena Island	7 July – 17 July	12 June – 2 August	18 May – 31 July	20 May – 5 August	2 June – 2 July
Devil Island	–	–	–	1 July – 24 July	–

1) Cape Vera (76˚15′ N, 89˚15′ W; 2003–07), on the mainland of Devon Island; 2) St. Helena Island (76˚18′ N, 89˚05′ W; 2003–07), a small island located within the polynya itself; and 3) Devil Island (76˚31′ N, 90˚27′ W; 2006), also occurring in the polynya, approximately 40 km northwest of St. Helena (Table 1, Fig. 1).

The Cape Vera study site consists of a 100–200 m cobble beach leading to tall cliffs (245 m above sea level) where a colony of northern fulmar (*Fulmarus glacialis*) is located. Numerous freshwater ponds, as well as meltwater streams, dot the beach beneath the cliffs. Nutrient subsidies from the fulmar colony have led to relatively lush vegetation below the cliffs (Michelutti et al., 2009). The area above the cliffs is a barren polar desert of cobble-sized sedimentary stones, interspersed occasionally with saxifrage or mustard plants. The perimeter of St. Helena Island is a combination of cobble beaches and rocky flats dotted with small freshwater ponds. Talus slopes lead to a central rocky ridge that reaches approximately 25 m in height. Numerous free-standing vertical towers flank the ridge, and short (1–2 m high) rock platforms in the flat areas of the island provide nesting sites for Thayer's (*Larus thayeri*) and glaucous gulls (*L. hyperboreus*). On St. Helena Island, as at Cape Vera, nutrients from feces of nesting birds (particularly common eiders, *Somateria mollissima borealis*) have promoted lush growth of mosses and lichens on parts of the island, especially near ponds. Devil Island is similar in structure to St. Helena Island, except that it is smaller and has a much larger scree slope on the southern shore, along which gulls and guillemots nest. There is little vegetation development at this site.

Work at the sites included focal studies on seabirds (e.g., Mallory and Forbes, 2007; Allard et al., 2010), which required field staff to hike around the sites or spend hours in observation blinds recording wildlife numbers and behaviour. For the latter work, staff used 10× binoculars, or 20–60× spotting scopes. Daily scans of birds on the water within 2 km of the coast were also conducted when visibility was suitable. At the end of each day, field crews (2–12 people) would summarize the species and number of individuals opportunistically observed throughout the day. The number of individuals recorded each day was not an exact count, but an estimate based on either the frequency with which an individual was seen or the average size of a flock of birds. While coverage of the sites was not systematic, St. Helena and Devil Islands were completely surveyed each day of the field season, except for a few days each year when poor weather precluded outdoor work. Given the larger size of the Cape Vera study site (~6 km long), daily surveys did not cover the entire area (we estimate that 20%–60% of the site was walked most days when weather was suitable). Weather data (maximum, minimum, and mean temperatures, precipitation, wind speed, and direction) were recorded at Cape Vera in 2003–05 using a Davis® Vantage Pro weather station set to record hourly, and data on sea-ice distributions were acquired from the Environment Canada Ice Service archives at <http://ice-glaces.ec.gc.ca>.

Changes in biodiversity over time at Cape Vera and St. Helena Island were examined by calculating daily Simpson's Diversity Indices (SDI):

$$D = 1 - (\sum (n/N)^2)$$

where n = the total number of individuals of a species and N = the total number of individuals of all species. Reliable daily counts for northern fulmars were unavailable because of the large size of the colony and the nature of nesting areas (tall, steep cliffs and deep ravines), so fulmars were excluded from biodiversity calculations.

From 14 March to 14 August in 1980–84, Prach (1986) surveyed the coastline of the Hell Gate region as frequently as once a week, using a de Havilland Twin Otter flown 50 m above the water at 185 km/h. His team also worked on the ground at Cape Vera for various lengths of time during those field seasons. We present observations from these unpublished surveys where they are relevant.

RESULTS AND DISCUSSION

Weather

Although we did not record snow cover quantitatively, we noted that much of the ground around the polynya typically remained snow-covered until mid-June. Daily maximum temperatures were generally below 0˚C until the end of the first week of June (Fig. 2). Temperatures warmed from May through to early August, but overall mean daily maximum temperatures during most of the nesting season (8 June–11 August) were cool (2003–05 daily means; 3.4 ± 0.4˚C, n = 65 days, range -2.7–14.0˚C). Mean daily maximum wind speed was 13.2 ± 1.6 km/h (8.0–62.8 km/h; n = 65), and wind gusts exceeded 100 km/h at least once each month. During the field seasons, fog was frequent (more than 25% of field days in each year of study), and snowfall occurred in every month, with significant wet snow accumulation (> 10 cm) in July of each year.

Daily sea-ice cover in the polynya varied substantially, depending on wind and tide, but there was always open water available from our earliest arrival (20 April

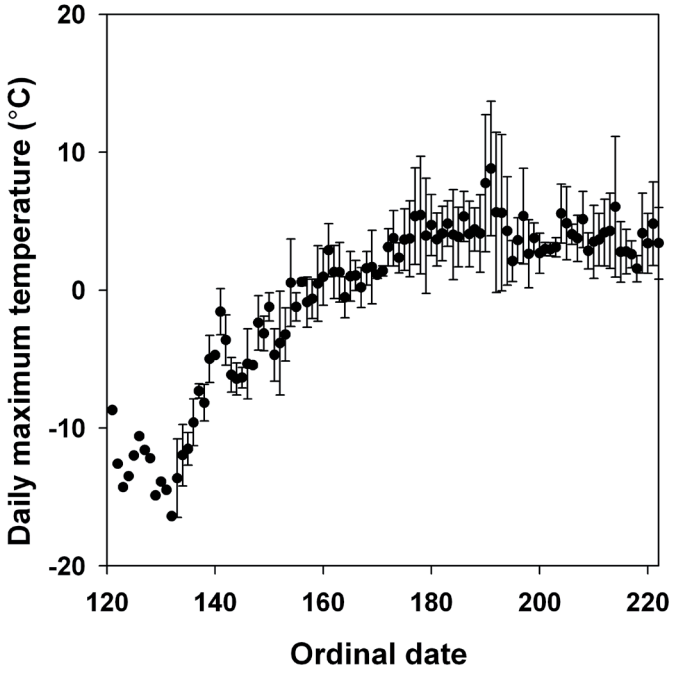

FIG. 2. Daily maximum air temperatures recorded at Cape Vera during the summers from 2003 to 2005.

2005) to our latest departure (16 August 2005). However, solid ice covered Jones Sound from the floe edge (approximately 2–10 km east of St. Helena Island) for approximately 200 km to the east, and this ice usually persisted into August. During the years 1996–2005, the mean distance from Cape Vera to open water (excluding the Hell Gate Polynya) in the second week of June was 190 ± 5 km, a distance that was consistent across years (coefficient of variation 9%) (Environment Canada Ice Service archives; this study).

Species Diversity

Forty-eight species of birds have been observed in the Hell Gate Polynya region, of which 39 species were observed between 2003 and 2007. Of these species, 17 have been recorded as breeding in the region, but only 12 could be confirmed as breeders during our study, almost all at Cape Vera, St. Helena Island, or Devil Island (Table 2). Birds were confirmed as breeders if a nest or young chicks were found.

St. Helena Island was the most thoroughly surveyed site: it had complete coverage daily during the study period, and these data were used to generate daily SDI for the island. Pooling data from all years, the overall mean SDI was 0.66 ± 0.10 SD (n = 247 days), but this mean clearly varied temporally (Fig. 3). Prior to the second week of June in 2005 to 2007, SDI values were variable and relatively low compared to later in the breeding season (Fig. 3). Presumably, SDI became more constant as numbers of migrating birds declined, leaving principally breeding birds that remained on the island. In contrast, species diversity in 2004 was relatively high in the second week of June, and instead of leveling off as in 2005 to 2007, it decreased steadily to the beginning of August (Fig. 3).

At Cape Vera, diversity trends were not clear. From 2003 to 2006, the overall mean SDI was 0.62 ± 0.18 (n = 251 days). Using the period 7 – 17 July, when field crews were present at both sites in 2003–06 (Table 1), species diversity was similar at St. Helena (0.68 ± 0.05, n = 44) and Cape Vera (0.67 ± 0.14, n = 36; Mann-Whitney, U = 626, $p = 0.11$). However, the coefficient of variation of SDI at Cape Vera (22%) was three times as high as that for St. Helena Island (7%). Weather conditions (mostly fog) and the much larger area of study (~ 6 km long) contributed to the greater variation in SDI values at Cape Vera (Fig. 3), because it was difficult to conduct complete surveys of the site daily. Also, field crews regularly spent entire days on cliff-tops or at camp, located in a gravel area; both these habitats have been found to have lower bird diversity than the vegetated areas directly below the cliffs. Thus diversity indexes at Cape Vera may have been influenced by the number of days on which people were able to search below the cliffs.

Species Accounts for Breeding Birds

The first birds to arrive in the polynya region were common ravens (*Corvus corax*; 22 April), snow buntings (*Plectrophenax nivalis*; 23 April), and rock ptarmigan (*Lagopus mutus*; 23 April), and the first marine birds observed were northern fulmars (30 April; Table 2), although Prach and Smith (1992) found black guillemots (*Cepphus grylle*) in the polynya in March. By the end of May, 24 different bird species could be found in the polynya region. Below we summarize key dates for birds known to breed near the polynya.

Arctic Tern: Arctic terns (*Sterna paradisaea*) bred on St. Helena and Devil Islands and were known to nest on Olsen Island (Prach, 1986). The earliest terns were observed on 30 May 2003, but most terns generally arrived in the area between mid-June and mid-July. Nonetheless, this arrival date is approximately two weeks earlier than arrival dates reported from the Fosheim Peninsula, Ellesmere Island (Parmelee and MacDonald, 1960); Truelove Lowland, Devon Island (Hussell and Holroyd, 1974); and areas near Resolute Bay on Cornwallis Island (Geale, 1971). Up to 48 nests have been found on the polynya islands (Prach, 1986).

Brant: Eastern High Arctic brant (*Branta bernicla hrota*) nested in small numbers (< 10 nests) at all three locations in all years. During the study years, the earliest arrival of brant in the polynya occurred on 30 May (in 2004), and the latest arrival date was 4 June (in 2003). The fact that brant arrival in the polynya had been observed on 1 June 1981 (Prach, 1986) suggests high consistency in their arrival time across years. This timing is similar to that of brant arrival on Bylot Island (Lepage et al., 1998) and in Lancaster Sound (Johnson et al., 1976).

TABLE 2. Summary of the avian species recorded at Cape Vera and St. Helena and Devil Islands from 2003 to 2007 and during earlier surveys. Dates indicate the first sighting of each species. "B" = breeding, "O" = observed, but not breeding, and "–" = not observed. The Research column indicates those species that were part of our focused research program (Y = yes). Data from earlier surveys are from unpublished information in Prach (1986).

		Earlier surveys				This study (2003–07)		
Name	Scientific name	Pre-1910	1940s	1980s	Breed	Earliest	Max #	Research
American pipit	*Anthus rubescens*	–	–	O	O	16 June	1	–
American tree sparrow	*Spizella arborea*	–	–	O	–	–	–	–
Arctic tern	*Sterna paradisaea*	–	B	B	B	30 May	14	–
Brant	*Branta bernicla hrota*	O	B	B	B	30 May	540	–
Baird's sandpiper	*Calidris bairdi*	–	–	B	O	30 May	9	–
Bank swallow	*Riparia riparia*	–	–	O	–	–	–	–
Black guillemot	*Cepphus grylle*	B	O	B	B	17 May	300	Y
Black-bellied plover	*Pluvialis squatarola*	–	–	O	–	–	–	–
Black-legged kittiwake	*Rissa tridactyla*	–	O	O	O	30 May	8	–
Cackling goose	*Branta hutchinsii*	–	–	–	O	12 June	–	–
Canada goose	*Branta canadensis*	–	–	–	O	30 May	1	–
Common eider	*Somateria mollissima borealis*	B	B	B	B	15 May	2000	Y
Common raven	*Corvus corax*	O	–	B	B	22 April	8	–
Dovekie	*Alle alle*	O	–	O	O	17 July	12	–
Glaucous gull	*Larus hyperboreus*	B	O	B	B	6 May	59	Y
Great black-backed gull	*Larus marinus*	–	–	O	–	–	–	–
Greater white-fronted goose	*Anser albifrons*	–	–	O	–	–	–	–
Gyrfalcon	*Falco rusticolus*	O		O	B	19 May	1	–
Hoary redpoll	*Acanthis hornemanni*	–	–	O	O	30 May	2	–
Horned lark	*Eremophila alpestris*	–	–	O	–	–	–	–
Ivory gull	*Pagophila eburnea*	–	–	O	O	17 May	11	–
King eider	*Somateria spectabilis*	–	–	O	O	15 May	1500	–
Lapland longspur	*Calcarius lapponicus*	–	–	O	O	3 June	4	–
Long-tailed duck	*Clangula hyemalis*	B	–	O	O	22 May	10	–
Long-tailed jaeger	*Stercorarius longicaudus*	–	–	O	O	29 May	8	–
Northern fulmar	*Fulmarus glacialis*	B	O	B	B	30 April	22000	Y
Northern wheatear	*Oenanthe oenanthe*	–	–	–	O	16 June	2	–
Pacific loon	*Gavia pacifica*	–	–	–	O	4 June	8	–
Parasitic jaeger	*Stercorarius parasitica*	B	–	B	O	29 May	3	–
Pectoral sandpiper	*Calidris melanotos*	–	–	–	O	15 June	4	–
Peregrine falcon	*Falco peregrinus tundrius*	–	–	O	O	12 June	1	–
Pomarine jaeger	*Stercorarius pomarinus*	–	–	–	O	10 June	1	–
Purple sandpiper	*Calidris maritima*	O	–	O	O	30 May	16	–
Red knot	*Calidris canutus*	B	–	O	O	2 June	10	–
Red phalarope	*Phalaropus fulicarius*	–	–	O	O	12 June	1	–
Red-throated loon	*Gavia stellata*	B	O	B	B	5 June	12	–
Rock ptarmigan	*Lagopus mutus*	O	–	B	O	23 April	6	–
Ruddy turnstone	*Arenaria interpres*	–	O	O	O	28 May	20	–
Savannah sparrow	*Passerculus sandwichensis*	–	–	O	O	10 June	3	–
Snow bunting	*Plectrophenax nivalis*	–	O	B	B	20 April	120	Y
Snow goose	*Chen caerulescens*	–	–	B	B	1 June	6	–
Snowy owl	*Nyctea scandiaca*	–	O	O	O	16 May	1	–
Thayer's gull	*Larus thayeri*	–	O	B	B	26 May	57	Y
Thick-billed murre	*Uria lomvia*	–	–	O	O	30 May	32	–
White-crowned sparrow	*Zonotrichia leucophrys*	–	–	O	–	–	–	–
White-rumped sandpiper	*Calidris fuscicollis*	–	–	–	O	10 June	2	–
Yellow-billed loon	*Gavia adamsii*	–	–	O	O	14 June	1	–
Yellow-rumped warbler	*Setophaga coronata*	–	–	O	–	–	–	–
Total breeding species		8	3	14	12			
Total species observed		14	12	41	39			

Black Guillemot: Black guillemots (*Cepphus grille*) bred at all three sites. Guillemots were observed on the first day that crews were on St. Helena in every year except 2005, when they were first observed on 18 May, and they were recorded at Cape Vera as early as 17 May. However, in 1982 there were 207 guillemots observed in the polynya on 14 March (Prach and Smith, 1992). This very early presence may mean that some guillemots overwinter in the polynya (Renaud and Bradstreet, 1980; Mallory and Gilchrist, 2005). Densities, breeding locations, and seasonal abundance of black guillemots in the Hell Gate Polynya were reported in detail by Prach and Smith (1992).

Common Eider: Common eiders (northern race, *Somateria mollissima borealis*) bred on St. Helena and Devil Islands, as well as North Kent Island (Reed, 1986), but not on the mainland at Cape Vera. In years when crews were at field sites early in the season, common eiders were first observed upon their arrival between 15 May (2004) and 30 May (2003), and 251 common eiders were spotted on 20 May 1983 (Prach, 1986).

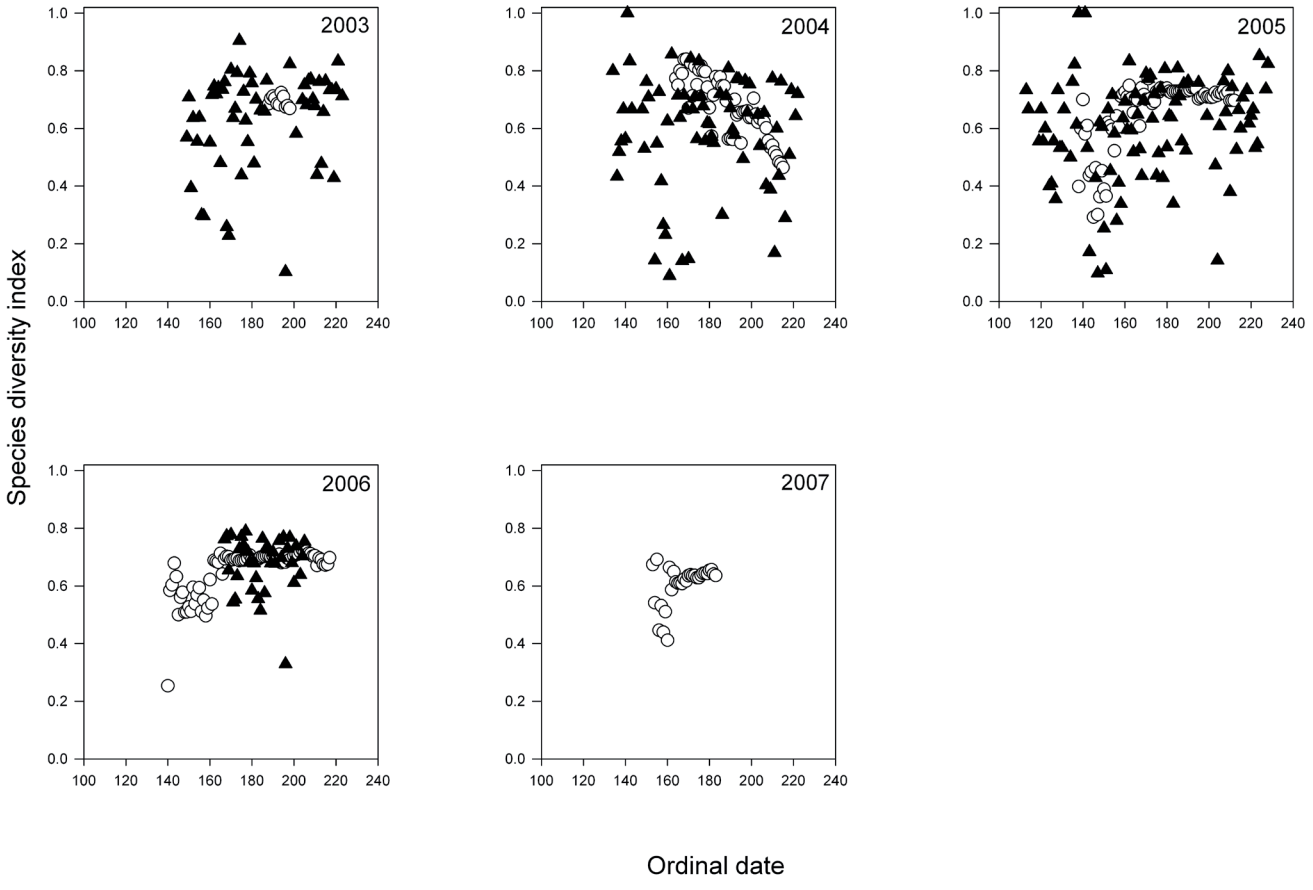

FIG. 3. Simpson's diversity indices for St. Helena Island (open circles) and Cape Vera Island (closed triangles) from 2003 to 2007.

Between early June and mid-July, large flocks of eiders were observed in the polynya from vantage points on the cliffs at Cape Vera. These flocks typically consisted of 100–500 individuals (maximum estimate of 2000 individuals on 7 June 2004), and were often a mix of common and king eiders (*S. spectabilis*), with common eiders far outnumbering king eiders (although 1140 king eiders were observed on 24 May 1982; Mallory and Gilchrist, 2005). Eider counts did not follow a typical pattern of decline through the season, as might be expected if they were migrants moving through the polynya. For example, in 1981, 831 were counted on 29 July, and 601 on 11 August (Prach, 1986). These birds were probably failed breeders or birds that came to molt.

Numbers of common eiders nesting on St. Helena and Devil Islands in 2003–07 appeared to be lower than in the 1980s (Reed, 1986), which may be attributable to harvest practices in Greenland where these eiders overwinter (Mallory and Gilchrist, 2005) or possible changes in breeding distribution.

Common Raven: Ravens (*Corvus corax*) bred at Cape Vera in all years, representing one of the northernmost confirmed nesting locations for this species (Boarman and Heinrich, 1999), and they were seen at St. Helena in all years. They were observed as early as 13 May 2004 at Cape Vera and were seen in low numbers (1–8 birds) almost every day. Where these birds overwinter is unknown, but in the last few decades, ravens have been staying year-round at High Arctic communities like Grise Fiord (M.L. Mallory, pers. obs.). At St. Helena, they were also seen throughout the season, but were consistently at the colony every few days starting from mid or late June. While ravens do not feed in the polynya directly, they rely on the eggs and young of resident seabirds, supporting Salomonsen's (1950) suggestion that breeding by ravens in the Arctic may be linked to seabird colony distribution.

Northern Fulmar: Northern fulmars (*Fulmarus glacialis*) bred only at Cape Vera, but were observed at St. Helena and Devil Islands in all years. They almost always arrived in the polynya before field crews except in 2005, when they were first recorded on 30 April (Mallory and Forbes, 2007). Except for guillemots (above), fulmars were the first seabirds to arrive each spring, and annual numbers peaked near 10 May (Prach, 1986; Mallory and Forbes, 2007). Breeding fulmars do not appear to use the Hell Gate polynya for feeding, even when chicks begin hatching after sea ice has retreated; instead, they travel hundreds of kilometres to the waters between Ellesmere Island and Greenland to forage (Mallory et al., 2008). Gaston et al. (2006) estimated that Cape Vera supported a breeding population of 9000 breeding pairs.

TABLE 3. Numbers of species observed at selected sites in the eastern Canadian Arctic.

Study area	Location	Number of species observed	Number of breeding species	Reference
Fosheim Peninsula, Ellesmere Island	80˚ N, 86˚ W	23	20	Parmelee and MacDonald, 1960
Isachsen, Ellef Ringnes Island	78.5˚ N, 103.5˚ W	12	5	MacDonald 1961
Alexandra Fiord, Ellesmere Island	78˚ N, 75˚ W	24	10	Freedman and Svoboda, 1982
Hell Gate Polynya	76˚ N, 89˚ W	48	17	this study
Truelove Lowland, Devon Island	75˚ N, 84˚ W	43	28	Pattie, 1990
Resolute Bay, Cornwallis Island	74.75˚ N, 94.75˚ W	35	10	Geale, 1971
Bylot Island	73˚ N, 80˚ W	63	35	Lepage et al., 1998
Arctic Bay, Baffin Island	73˚ N, 84˚ W	38	22	Renaud et al., 1979
Rassmussen Lowlands	68.5˚ N, 93˚ W	35	22	Johnston et al., 2000
Prince Charles Island	67.5˚ N, 75˚ W	42	25	Johnston and Pepper, 2009
Cape Dorset, Baffin Island	64.25˚ N, 76.5˚ W	54	34	MacPherson and McLaren, 1959

Glaucous Gull: Glaucous gulls (*Larus hyperboreus*) bred at all sites in all years. Prach (1986) recorded 122 pairs of glaucous gulls nesting around the polynya, but these surveys have not been repeated. Gulls were observed on 6 May 2005, two weeks earlier than observations from Bylot Island (Lepage et al., 1998), and much earlier than observations at Resolute Bay on 28 May 1969 (Geale, 1971).

Gyrfalcon: Gyrfalcons (*Falco rusticolus*) infrequently hunted fulmars along the cliffs of Cape Vera in 2003–05. In 2004, one gyrfalcon nest was found on the cliffs on the north side of the polynya, just east of the entrance to Goose Fiord. Presumably this site is used repeatedly (Burnham et al., 2009), although we were unable to return in other years to check on it. Gyrfalcons have been seen at Alexandra Fiord (78˚ N; Freedman and Svoboda, 1982) and are known to breed on most Arctic islands (Booms et al., 2008).

Red-throated Loon: One pair of red-throated loons (*Gavia stellata*) bred at Cape Vera in each year of 1980–84 and 2003–06, although a maximum daily count of 12 birds was noted in 2006. Loons were observed at St. Helena Island in 2003–05. The earliest observation of loons in the polynya was on 5 June 2005, 10–22 days earlier than observations on Devon, Ellesmere, and Cornwallis Islands (Parmelee and MacDonald, 1960; Geale, 1971; Hussell and Holroyd, 1974).

Snow Bunting: Snow buntings (*Plectrophenax nivalis*) bred at all three locations in all years. In 2005, fresh tracks found on 20 April indicated that they had arrived at Cape Vera, although they were first observed on 23 April. These dates precede all other reports of bunting arrival north of 73˚ N in eastern Nunavut (24 April, Bylot Island, Lepage et al., 1998; 29 April, Isachsen, Ellef Ringnes Island, MacDonald, 1961; 27 April, Alert, Ellesmere Island, MacDonald, 1953; 13 May, Resolute Bay, Geale, 1971). Buntings do not rely on the polynya to find food, so their breeding schedule is likely less affected by the polynya than seabird breeding schedules. However, the apparent high suitability of breeding and feeding habitat at Cape Vera (Falconer et al., 2008) probably leads to high nest site competition, and thus males may arrive relatively early at this site to choose and defend nests. Annual nesting densities of buntings at Cape Vera range from 16 to 27 pairs/km^2, one of the highest densities ever reported (Prach, 1986; Falconer et al., 2008).

Snow Goose: Snow geese ("greater" race; *Chen caerulescens*) were observed infrequently around Cape Vera or from St. Helena Island or Devil Island, but at least two pairs were nesting on the slopes below the cliffs on North Kent Island in July 2004. Prior to that year, Prach (1986) had observed adults with young in four locations on the north and west sides of the polynya in 1982 and 1984. Molting snow geese regularly use the north side of the polynya near Cape Storm (Heyland and Boyd, 1969; Prach, 1986).

Thayer's Gull: Thayer's gulls (*Larus thayeri*) bred on St. Helena and Devil Islands in all years, but not at Cape Vera. The gulls' arrival in the polynya was observed at St. Helena as early as 26 May in 2005, four days earlier than at Bylot Island, where Thayer's gull is an uncommon breeder (Lepage et al., 1998).

Species Accounts of Non-Breeding Birds

During four periods of observation (Table 2), 31 bird species have been observed in the Hell Gate Polynya, but with no record of breeding. Evidence of breeding had been found in earlier expeditions to the site for Baird's sandpiper (*Calidris bairdii*), long-tailed duck (*Clangula hyemalis*), parasitic jaeger (*Stercorarius parasitica*), red knot (*Calidris canutus*), and rock ptarmigan (*Lagopus mutus*) (Table 2), but during our seasons of study, we could not confirm that these species still bred there. However, they do not typically breed in the rocky sites where we conducted studies, and thus they may still occur in the flatter, vegetated tundra that can be found in areas like Goose Fiord. This habitat preference probably also explains why we rarely, if ever, saw some of the other typical, tundra-nesting shorebird species that are found at Truelove Lowland only 150 km to the east (Pattie, 1990; Table 3).

The consistency of observation across the studies suggests that purple sandpipers (*Calidris maritima*) and ruddy turnstones (*Arenaria interpres*) regularly use the coastline of the polynya during migration to and from breeding areas such as northern Ellesmere Island (Parmelee and MacDonald, 1960). Similarly, black-legged kittiwakes (*Rissa tridactyla*), thick-billed murres (*Uria lomvia*), yellow-billed loons (*Gavia adamsii*), and dovekies (*Alle alle*) have been spotted in the polynya on multiple occasions, and it is likely that these birds are non-breeders. The nearest breeding site for

murres is at Coburg Island, 270 km to the east, while dovekie breeding sites are even farther away in West Greenland (500 km), and the closest breeding sites for yellow-billed loons are on Somerset Island, 275 km to the south (Godfrey, 1966). Kittiwakes also breed at Coburg Island, as well as at Baillie-Hamilton Island, 150 km to the west. The lack of a breeding colony of kittiwakes near this polynya is somewhat surprising, given that these birds have frequented the area for at least 60 years (Duvall and Handley, 1948), that there are suitable cliffs for them around the polynya (e.g., Cape Hawes, North Kent Island), and that small colonies of kittiwakes are located at other polynyas or even at breeding sites more remote from open water elsewhere in the High Arctic (Mallory et al., 2009).

Mallory and Gilchrist (2005) noted that ivory gulls (*Pagophila eburnea*) were observed at Cape Vera, and at St. Helena they were seen in all five years of the study. Prach (1986) infrequently saw flocks of up to five birds during work in the 1980s. A colony of ivory gulls exists about 80 km to the south of Cape Vera (Robertson et al., 2007), and birds have also been observed at sea to the north in Norwegian Bay (Chardine et al., 2004). Thus, it is unclear whether birds at Cape Vera are breeding birds foraging away from their nesting colony or (more likely) non-breeders.

Mallory et al. (2005) observed Canada (*Branta canadensis*) and cackling geese (*B. hutchinsii*) at Cape Vera, non-breeding birds in both cases, and these observations represent extensions of the known range of these species. The observation of non-breeding greater white-fronted geese (*Anser albifrons*) on 2 August 1984 was the first record of this species north of Parry Channel (Prach, 1986). We did not see this species in the recent work at the site, and it is unclear whether the birds observed in 1984 were affiliated with the population in Greenland or that in western Nunavut. Long-tailed ducks were first observed on 22 May, about the same time as the earliest observations at Bylot Island, 450 km to the southeast (Lepage et al., 1998), and one month earlier than the first observations at Arctic Bay, 375 km to the south (Renaud et al., 1979). MacPherson and McLaren (1959) first saw long-tailed ducks on 29 April 1954 and 13 May 1955 near Cape Dorset, 1400 km to the south (i.e., 16 and 2 days earlier than at Hell Gate).

King eiders were observed in substantial numbers in the 1980s and during our study, but, somewhat surprisingly, not in early expeditions (Table 2). Because they are often flocked with common eiders, it is possible that earlier reconnaissance surveys could have overlooked them, especially the females. However, king eiders were observed as early as 27 April in 1980 (Prach, 1986), six weeks earlier than they have been reported elsewhere in the Queen Elizabeth Islands (Parmelee and MacDonald, 1960; Geale, 1971; Hussell and Holroyd, 1974). We did not see any king eiders prior to 15 May (2004), but this is still three weeks earlier than records at these other locations.

For some species, like American pipits (*Anthus rubescens*) and savannah sparrows (*Passerculus sandwichensis*), the Hell Gate Polynya is at the northern limit of their known distribution. The closest known breeding site of American pipits is at Truelove Lowland, Devon Island (Pattie, 1990), and we know of no reports north of the Hell Gate Polynya. Savannah sparrows typically breed as far north as the Ungava Peninsula, Quebec (1700 km to the south) (Andres, 2006; Wheelwright and Rising, 2008). This species has also been observed at Bylot Island (Lepage et al., 1998), Truelove Lowland (Pattie, 1990), and Resolute Bay (Canadian Wildlife Service, Prairie and Northern Region, 2011), but not north of the Hell Gate Polynya.

Our reports of bank swallows (*Riparia riparia*), yellow-rumped warblers (*Dendroica coronata*), American tree sparrows (*Spizella arborea*), and great black-backed gulls (*Larus marinus*) provide the northernmost records for these species. In fact, all but two species (bank swallow and yellow-rumped warbler) that we observed in the Hell Gate Polynya have been recorded as far north as Bylot Island (Lepage et al., 1998), and all but eight species (Canada geese, dovekies, gyrfalcons, thick-billed murres, great black-backed gull, American tree swallow, bank swallow, yellow-rumped warbler) have been seen at Truelove Lowland (Pattie, 1990).

CONCLUSION

The marine and terrestrial habitats around the Hell Gate Polynya clearly form a key site for migratory birds in the Canadian High Arctic (Mallory and Fontaine, 2004). In addition to the large fulmar colony at Cape Vera, important breeding colonies of common eiders, Thayer's and glaucous gulls, and black guillemots are situated on islands and shorelines around the polynya (Prach and Smith, 1992; Mallory and Gilchrist, 2005). However, the site is used by at least 48 species of birds, 17 of which are known to breed around the polynya. This proportion of birds that breed locally at Hell Gate (35%) is relatively low compared to other locations in the Arctic (42–87%; Table 3), which emphasizes the importance of this site as a migratory staging site or a site for non-breeding and molting birds.

Species diversity peaks quickly and early in the season (mid-June; Fig. 3), coinciding with air temperatures rising above 0˚C (Fig. 2). Even with seasonally warming temperatures, there is still a lot of ice in the polynya at this time, so some birds must be flying up to 200 km over sea ice to find food in the open water of Jones Sound (Mallory et al., 2008).

While the limitations of our research method increased the coefficient of variation at Cape Vera compared to that of St. Helena Island, it is important to note that the maximum species diversity values were similar at both sites. The trend in species diversity at St. Helena Island from 2005 to 2007 indicated that species composition on the island was uneven until the second week of June, likely because of the presence of migrants. However, it became stable around mid-June, probably because by this time non-breeding species

are not seen as often, and breeding species are relatively consistent in their numbers. In 2004, the diversity index was very high at the beginning of the season compared to other years. Although the index dropped to comparable levels around the third week of June, it continued to drop until the end of the season. This pattern contrasts with all other years, when the diversity indices remain relatively constant: it is likely due to a smaller total number of birds at the end of June (80–170, compared to 364–621 in other years) and fewer species at the end of July (7–8). The discrepancy in total number of birds observed reflects the number of common eiders and black guillemots recorded. The 2004 diversity index should therefore be considered atypical.

The Hell Gate Polynya provides open water feeding habitat in a vast sea of ice at a critical time, and the number of migrant species observed attests to the importance of open water early in the season. The influence of the polynya on local breeders is also important and more complex. In northern Greenland, where sea ice persists late into the spring, there is a high positive correlation between primary production and sea-ice cover (Laidre et al., 2008). This causes a large and predictable chlorophyll *a* pulse at high latitudes where sea ice recedes rapidly (for example, the North Water Polynya), to coincide with seabird arrival. The plankton bloom quickly recedes as sea ice breaks up (Laidre et al., 2008). This phenomenon likely also occurs in the Hell Gate Polynya, enabling birds to arrive in the area earlier than at breeding sites farther south (for example, Bylot Island), but the rapid decline of productivity may not allow high numbers of seabirds to remain in the area to breed.

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