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Status, Trends and Attendance Patterns of the Northern Fulmar *Fulmarus glacialis* in Nunavut, Canada

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ABSTRACT. Nunavut supports ten breeding colonies of northern fulmars (*Fulmarus glacialis*), most of which have rarely been visited on the ground by biologists. During 2000–04, we surveyed six colonies previously thought to support more than 80% of the Canadian Arctic population, which was believed to number about 300 000 breeding pairs. Our counts suggested that the breeding populations of some colonies, especially those at the largest colonies, Cape Searle and Prince Leopold Island, were substantially smaller than previously estimated. Our estimate for the total population of Nunavut was approximately 200 000 occupied sites. However, counts made at fixed monitoring plots at Prince Leopold Island and total colony estimates at Cape Vera, Devon Island, suggested no change in numbers at those colonies since the 1970s. Numbers present at the colony peaked in late June–early July and fell sharply after the end of July. Cyclical attendance, identified in an earlier study, was irregular in period length and was not seen in all years. We concluded that counts of Apparently Occupied Sites (AOS) conducted daily for 10–15 days are the best monitoring protocol for northern fulmars at these Arctic colonies. The great day-to-day variability in counts may have contributed to the large differences between past and recent population estimates.

Key words: northern fulmar, *Fulmarus glacialis*, Arctic, population status, population trend, colony attendance

RÉSUMÉ. Le Nunavut permet la subsistance de dix colonies de nidification de fulmars boréaux (*Fulmarus glacialis*), et rares sont les colonies qui ont été visitées par des biologistes au sol. De 2000 à 2004, nous avons recensé six colonies qui, croyait-on, soutenaient plus de 80 % de la population arctique canadienne, estimée à environ 300 000 couples reproducteurs. Nos dénombrements laissent supposer que les populations d'oiseaux nicheurs de certaines colonies, surtout les colonies les plus grosses, soit celles de cap Searle et de l'île Prince Leopold, sont nettement inférieures aux anciennes estimations. Notre estimation pour toute la population du Nunavut se chiffrait à environ 200 000 sites occupés. Toutefois, les dénombrements effectués à des lieux de surveillance fixes établis sur l'île Prince Leopold et les estimations totales des colonies de cap Vera, sur l'île Devon, laissent supposer qu'il n'y a pas eu de changement en ce qui a trait à ce nombre de colonies depuis les années 1970. Les nombres présents à la colonie ont atteint leur sommet vers la fin juin et le début juillet, après quoi ils ont chuté considérablement après la fin juillet. La fréquentation cyclique, dont il a été question dans une étude antérieure, était irrégulière pour ce qui est de la longueur de la période et n'était pas vue à toutes les années. Nous en avons donc conclu que les dénombrements de sites apparemment occupés qui ont été effectués quotidiennement pendant 10 à 15 jours représentent le meilleur protocole de surveillance des fulmars boréaux de ces colonies arctiques. L'importante variabilité enregistrée d'un jour à l'autre sur le plan des dénombrements pourrait avoir contribué aux grandes différences entre les estimations de population passées et récentes.

Mots clés : fulmar boréal, *Fulmarus glacialis*, Arctique, état de la population, mouvement de population, fréquentation des colonies

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INTRODUCTION

The northern fulmar (*Fulmarus glacialis*), is one of the most abundant seabirds nesting in eastern Arctic Canada (Hatch and Nettleship, 1998). The species has a circumpolar distribution, with substantial populations breeding both in the Pacific basin, on the coasts of the Okhotsk, Chukchi, and Bering seas and the Gulf of Alaska, and in the Atlantic basin, in western Europe, Spitzbergen, Iceland, and Greenland (Fisher, 1952; Snow and Perrins, 1998). In Canada, small numbers breed in Newfoundland and Labrador and large populations breed in Nunavut (Hatch and Nettleship, 1998), where breeding is confined to a few large colonies on eastern Baffin Island, around Barrow Strait and Lancaster Sound (Parry Channel), and in Jones Sound (Fig. 1).

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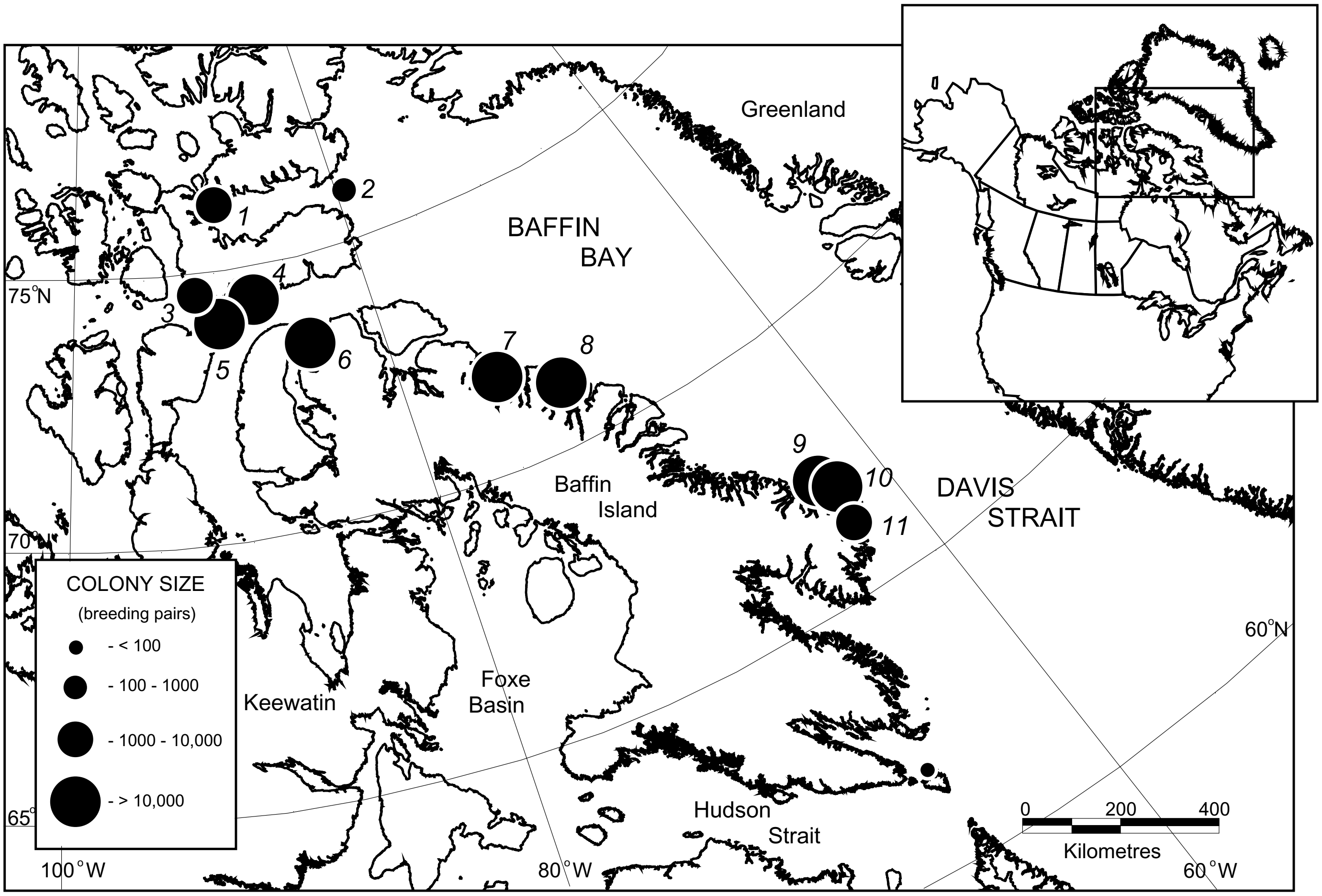

FIG. 1. Location of major northern fulmar colonies in Nunavut. Numbers correspond to those given in Table 5.

Nesting Habitat

In Nunavut, northern fulmars breed exclusively on sea cliffs. All colonies except the small groups on Princess Charlotte Monument and Hantzsch Island are situated on cliffs over 200 m in elevation. Nests are placed either on rocky ledges or on small scree slopes supported by broad cliff ledges. At Cape Searle, fulmars also breed on the broad, flat tops of the large rock stacks. Basal scree slopes, a prominent feature of many colony cliffs, are not used.

Northern fulmars nest on the surface, constructing low structures of pebbles, or sometimes laying their single egg on bare rock if no pebbles are within reach (Hatch and Nettleship, 1998). Nests are sometimes situated on vegetated areas, in which case the actual site forms a depression among the vegetation. The plant growth may have developed partly as a result of manuring by the birds. Because some sites are unmodified by nesting and other nests are only faintly detectable, in most cases nest sites cannot be identified from a distance unless occupied by a bird.

Breeding Biology

Breeding birds attend colonies in Nunavut from late April or early May onwards. In mid-May most birds leave their colony for a 10–15 day pre-laying exodus, after which they return. Females lay their single egg soon after arrival, and their mates undertake a prolonged (about 10 day) incubation shift (Hatch and Nettleship, 1998). Thereafter, the two sexes alternate incubation for about 45 days. After hatching, the chick is brooded for a further 10–12 days and then left alone while both parents forage (Gaston et al., 2005a). The breeding site is occupied continuously as long as an egg or young chick is present, but both parents are rarely present together, the exchange of duty being brief compared with the duration of incubation shifts (A.J. Gaston and M.L. Mallory, unpubl. data).

Abundance and Climate Change

Previous estimates of population size for one or more colonies have been published by Nettleship (1974a, b, 1980), Nettleship and Smith (1975), Brown et al. (1975), Gaston and Smith (1987), Hatch and Nettleship (1998), and Robards et al. (2000). The most recent published estimates covering the entire territory suggested a total Nunavut population of 604 000 breeding individuals (Hatch and Nettleship, 1998). Although several different estimates have been published for some colonies, all estimates refer to the same initial surveys, from which estimates of total colony size have been successively refined (D.N. Nettleship pers. comm. 2004). Consequently, until recently, most of the Nunavut colonies had been subjected to only one survey. All of the previous censuses quoted by Hatch and Nettleship (1998) were carried out in the 1970s, except for those at Scott Inlet and Buchan Gulf (1986). In addition, most previous censuses were based on estimates from brief fixed-wing surveys and did not involve actual counts of birds from the ground.

Although the northern fulmar is an abundant bird at present, climate changes ongoing in the Arctic (Vinnikov et al., 1999), along with associated changes in sea-ice conditions (Parkinson et al., 1999; Parkinson, 2000; Grumet et al., 2001), seem likely to affect populations in the long term. In support of this hypothesis, several recent studies have demonstrated linkages between climate change, sea ice, and annual reproduction or population levels in fulmarine petrels (Thompson and Ollason, 2001; Jenouvrier et al., 2003; Gaston et al., 2005a). Wildlife management organizations in Canada are concerned because existing data on Nunavut populations (except for a single colony on Prince Leopold Island) are insufficient to determine population trends unless they involve extremely rapid change.

Consequently, during 2000–04, we updated census information for the majority of northern fulmar colonies in Nunavut. In addition, we carried out detailed counts at specific areas of several colonies to allow comparisons with future monitoring efforts. Here we provide recent estimates for most of the large northern fulmar colonies in Nunavut, comprising 83% of the previously estimated Canadian population, as well as trend information (1976 to 2003) for the most studied colony, Prince Leopold Island. To compare results of counts made on different dates and at different colonies, we also present information on trends and variation in seasonal attendance among years and colonies.

METHODS

Counting and Estimation Techniques

Birds were counted either from specific points at the cliff top, or from vantage points facing the cliffs from the seaward side, on the beach or on landfast ice. The positions of all count points were recorded by GPS and are given in Mallory and Gaston (2005). Many non-breeding birds, which may be either pre-breeders or mature birds that are not breeding that year (10–15% of population; Hatch and Nettleship, 1998), occupy potential breeding sites during the breeding season. Proof that a breeding attempt has been made cannot be obtained from a brief observation of a site with a bird. Consequently, counts can be made of individuals, or of occupied sites, but these can be translated into numbers of breeding pairs only by prolonged and detailed observations. In addition, the proportion of sites where two birds are present varies enormously from day to day (A.J. Gaston and M.L. Mallory, unpubl. data). Consequently, we used "apparently occupied sites" or AOS (Lloyd et al., 1991; Walsh et al., 1995) as our measure of population at most colonies counted. As defined by Lloyd et al. (1991:40), this method excludes "obvious non-breeding birds on precarious ledges unsuitable for nesting." However, when counting from long distance, it was difficult to assess whether a single bird was occupying a potential nest site or merely loafing on a non-breeding area, so in our counts "apparently occupied sites" was equal to the number of single birds sitting on ledges plus the number of evident pairs. Below, we examine how these numbers are likely to relate to numbers of breeding pairs and to total population size. To make estimates of different colonies more comparable, we converted counts of individual birds to AOS by multiplying colony totals by 0.8 (see below).

Previous reports of northern fulmars in the Canadian Arctic have expressed population size in terms of numbers of breeding pairs (Brown et al., 1975; Hatch and Nettleship, 1998). For comparison with these earlier numbers, we converted our counts for Cape Vera and Prince Leopold Island to numbers of breeding pairs, using information on ratios of breeding sites to AOS obtained from intensive daily observation of selected study plots (Mallory and Gaston, 2005; Gaston et al., 2005a). Ratios for Prince Leopold Island for the relevant dates were used to convert counts of AOS for Cape Liddon and Hobhouse Inlet. To increase the comparability of counts made at different dates, we adjusted counts of AOS to correspond with numbers at the period of peak attendance (9 July), using daily counts made throughout the breeding period at Prince Leopold Island. This was accomplished by dividing estimated breeding numbers by 0.62, the smallest ratio of breeding sites to AOS recorded at Prince Leopold Island in 2001 (see Results).

The northern fulmars breeding in Nunavut belong to the race *F. g. glacialis* (L.), which is characterized by highly polymorphic plumage. Variation involves a gradation of coloration over most of the feathers, typically scored on a four-point scale from the palest form (LL), with white head, neck, and underparts and pale, dove-grey wings and mantle, through L and D, to the darkest form (DD), dark slate-grey plumage all over (van Franeker and Wattel, 1982; van Franeker, 1995). The majority of birds breeding in the Canadian High Arctic (north of Baffin Island) are light or intermediate in colour, while most of those in the Cumberland Peninsula region are towards the dark end of the scale. When counting birds on cliffs, it is much easier to see the white heads of pale-morph birds than the heads of darker birds. Consequently, where the rock is dark, or where areas are in shade, dark-morph birds may easily be missed, especially by a counter some distance away.

Because of irregularities in cliff faces, it was never possible to count all birds from a single vantage point. After each count, therefore, we assessed the proportion of sites likely to be hidden, judging by our general experience of the area. These corrections, made separately for each colony, are explained in detail below. Our census counts were greatly assisted by the very late date of ice breakup in Lancaster Sound and Barrow Strait in 2001 and 2002. The presence of landfast ice on the sea adjacent to several colonies allowed us to count birds from a stable platform facing the cliffs. In 2003, in contrast, all areas from which counts had been made in the previous two years were open water by the time fulmars returned from their pre-laying exodus. All times are reported as Central Daylight Time.

Cape Vera, Devon Island: All birds visible were counted on 10 July 2004 between 1600 and 2000 h (at this colony we counted total birds, rather than AOS), using 10 × 42 binoculars, from 18 stations on the cobble beach that extends 100–200 m from the base of the cliffs. At that time of day, much of the colony was out of direct sunlight, but the sky was clear and bright, so viewing conditions were good. We counted additional birds (not clearly visible from below because they were on broad ledges) from the cliff top.

Princess Charlotte Monument, Coburg Island: We visited Princess Charlotte Monument twice in 1998 (on 20 and 21 July; 4–8 hours per visit), gaining access by inflatable boat from our camp on Cambridge Point, 15 km to the northwest. We counted the total number of fulmars present from a boat below the cliffs, with the aid of binoculars, and on foot when we climbed up to an accessible area at the base of the Monument.

Cape Liddon, Devon Island: Two observers counted fulmars between 1915 and 2200 h on 2 July 2002 from the consolidated pack ice extending out from the foot of the cliff. They used 40 × 80 telescopes at distances estimated from GPS fixes as 0.5–1.0 km. A closer observation point would have meant a steeper angle to upper ledges, making birds on deep ledges less likely to be detected. Light conditions were considered less than ideal, as the sun was behind the cliffs, especially at the east end, where birds were most dense. We estimated that 20% of AOS were either obscured by irregularities in the cliff or missed because of shadow.

Hobhouse Inlet, Devon Island: Fulmars were counted using the same methods as at Cape Liddon. Counts were made by two observers on 2 July 2002 between 1000 and 1600 h. We counted from six observation points spread at approximately 1.5 km intervals along the colony. From each point, we defined vertical sections of cliff, recorded them by drawing on Polaroid photographs, and counted all birds visible. We estimated the width of each section from photographs, using trigonometry based on cliff height (known from GPS elevation fixes, which provided a repeatability of ± 20 m). Width of vertical sections ranged from 488 to 1194 m. The total length for which birds were counted was 4.73 km, 45% of the occupied length. Light conditions were excellent, with sun behind the observers and on the cliffs throughout, so undercounting of dark-morph birds was negligible. We felt that the counts were close to complete, but some undercounting is inevitable even in the best conditions. We estimated that we counted 90% of birds present.

Prince Leopold Island: Counts covering different parts of the colony were made on four different days over two years (Table 1). All counts were conducted from the cliff top in fine, calm weather with good visibility, using promontories regularly spaced along the cliffs as vantage points. We counted all occupied sites that were visible and estimated the proportion of sites in each view likely to be obscured by irregularities in the cliff. Some sections could not be counted, because no suitable vantage point was available. The lengths of cliff counted and uncounted were measured by means of GPS fixes, and missing numbers were extrapolated using the density of birds per linear distance estimated (Table 1). The proportion of cliff counted and the density of sites per metre varied among sections. Therefore, we estimated numbers of AOS separately by section (Table 1). For section E, we estimated the proportion of sites likely to be obscured by irregularities in the cliff separately for each individual viewing point (details available in Mallory and Gaston, 2005). Hence, for this section the correction for the proportion of AOS out of sight was variable, as indicated in Table 1.

Baillarge Bay, Baffin Island: Using the same methods as at Hobhouse Inlet, two observers made census counts from 1315 to 1800 h on 11 June 2002. Light on the cliffs was good, with sun or light cloud, but glare from the snow underfoot made observation conditions less than ideal. The colony is divided into seven sections by gullies that descend to sea level. We counted all sites visible from the east end of the colony to the sixth gully proceeding west (the last before Baillarge Bay). The final colony section consists of eight similar buttresses with intervening indentations. Because time was short, we counted only sites on the easternmost buttress, extrapolating this count to the rest of the section by multiplying it eight times.

Cape Searle, Baffin Island: We counted fulmars between 0800 and 2100 h on 11–14 June 2001 and 6–8 June 2002, from sea-ice locations 100–1000 m from the base of the cliffs, using a 20–60× spotting scope. In 2001, conditions were generally poor, with local fog during much of the survey. In 2002, however, all locations counted were in sunlight. We used the 2002 census, but refer to the 2001 work for some points. We counted numbers of birds in total, and did not distinguish pairs or occupied sites. Much of the rock at Cape Searle is gray, so that dark birds nesting against dark rock or in shadow could have been missed.

The top of the outer, eastern tower is visible only from the sea ice north of Cape Searle, and the top of the second, inner tower is not visible from sea ice. Hence, using the estimated number of birds on the outer tower and an aerial photograph of Cape Searle, we assumed similar nesting densities and compared the surface area of the two towers to extrapolate the number of birds nesting on top of the inner tower. Finally, we made a high-resolution scan of a photograph (1986; P. Mineau, 35 mm camera) of the outer tower and counted fulmars from a digital enlargement.

TABLE 1. Census details for northern fulmar colonies counted in 2000–04. The second row, "variables and calculations" assigns letters to each column and shows how derived variables were calculated. Colony numbers refer to Figure 1.

Colony	Section	Year	Date	Units[1]	Count	Length Occupied (m)	Length Counted (m)	Proportion of AOS Visible	Density (sites/m)	Extrapolated Total (AOS) at Date of Count	Ratio of Breeding Pairs/AOS	Estimated Breeding Pairs	Corrected to AOS Peak Attendance
Variables and Calculations					(A)	(B)	(C)	(D)	E = (A·0.8)/(C·D) or E = A/(C·D)	(F = B·E)	(G)	(F·G)	(F·G/0.62)
1. Cape Vera		2004	10 July	Birds	13150	6000	6000	1	1.75	10520	0.825	8679	13998
2. Princess Charlotte Mon.		1998		Birds	353			0.8		284		c. 250	c. 400
3. Cape Liddon[2]		2002	11 June	AOS	5091	2400	1700	0.8	3.74	8984	0.79	7097	11448
4. Hobhouse Inlet[2]		2001	02 July	AOS	8482	10500	4727	0.9	1.99	20934	0.7	14654	23636
5. Prince Leopold I.	W	2000	28 July	AOS	906	1500	940	0.8	1.20	1807	0.98	1771	
	NW		28 July	AOS	431	3000	600	0.8	0.90	2694	0.98	2640	
	S		31 July	AOS	3356	2510	2300	0.8	1.82	4578	0.98	4486	
	E	2001	30 June	AOS	5824	2440	2000	0.5–0.8	3.64	8883	0.74	6573	
	S		09 July	AOS	3099	2400	1895	0.8	2.04	4906	0.62	3042	
	SW		09 July	AOS	540	700	300	0.8	2.25	1575	0.62	977	
	NE	Not counted				2800				400	0.74	296	
	NNE	Not counted				1200			c. 1.2	1440	0.74	1066	
Prince Leopold I.	Total (S coast est for 2001)				14156	14040	8035		2.35	21705	various	16364	26394
6. Baillarge Bay		2002	11 June	AOS	11755	8500	~8500	? < 0.5	? > 2.77	? > 23000	0.8	> 18000	? > 27000
9. Cape Searle	Sides	2002	6–8 June	Birds	5129	6000	2567	0.8	2.00	12000			
	Top		6–8 June	Birds	14000			0.35[3]		32200			
Cape Searle	Total				19129					44200	0.8[4]	35350	57016

[1] For units = birds, E = (A·0.8)/(C·D); where units = AOS, E = A/(C·D).
[2] Ratio of pairs/sites based on same dates at Prince Leopold Island.
[3] Proportion of tower summits counted (0.44) · proportion visible (0.8).
[4] Based on early June ratios at Prince Leopold Island.

Detecting Population Trends

At Prince Leopold Island, seven study plots (AA, A, C, D, G, H, and J; see Mallory and Gaston, 2005) were defined in the 1970s by photographing easily visible areas of cliff and outlining the study plots on large-scale prints. The numbers of singles and pairs present on each plot were counted daily throughout the breeding season at 1700–1800 h. These counts were made during June-August in 1976, 1977, 2001, 2002, and 2003, and for shorter periods in 1980, 1984, and 1988. To determine trends, we used the longest period for which counts were available from all eight years, 17 July–1 August, which was also a period during which numbers were relatively stable. All birds counted were within 150 m of the count point, and counts were made with 8× or 10× binoculars. Given the distance and the familiarity of observers with the count plots, we think that the number of birds missed during these counts would have been negligible.

In 1976 and 2001–03, daily watches were conducted at six of the study plots (all except H) to determine the presence of birds and eggs at numbered sites. To estimate the number of pairs that attempted to breed in 1976, we used the number of sites where an egg was recorded (Nettleship et al., 1986). For 2001–03, we used the number of sites where an egg was seen, or a bird was present, on more than 70% of days during 20 June–20 July. All sites where an egg was laid and lost in June showed over 70% attendance (A.J. Gaston, unpubl. data). We compared these estimates of breeding pairs among years and used them in conjunction with daily counts of occupied sites at the same study plots to convert our census counts of occupied sites to numbers of breeding pairs (i.e., pairs that laid eggs in a given year).

Attendance Patterns

Because the number of northern fulmars attending the colony varies with time of year and perhaps among years, we analyzed information from our daily counts to determine seasonal patterns of attendance. We also estimated the coefficient of variation (standard deviation/mean) for number of birds and number of occupied sites to compare within- and between-year variation. Most of these comparisons were based on the period 18 June – 20 July, 18 June being about the end of egg-laying at Prince Leopold Island during 2001 – 03, and 20 July being the date when hatching commences and when variability among counts begins to increase.

Hatch and Nettleship (1998, based on Nettleship et al., 1986) reported a strongly cyclical attendance pattern at Prince Leopold Island, with a period of five days. As this pattern has strong implications for the interpretation of single-day counts, we examined our own attendance data for similar patterns, using the autocorrelation module of Statistica 6.1 (Statsoft, 2003).

RESULTS

Census

Cape Vera, Devon Island (76˚15'N, 89˚45'W): Northern fulmars breed along 6.4 km of cliffs on the eastern tip of the Colin Archer Peninsula, Devon Island, between Cape Vera and Cape Hawes (Nettleship, 1974a). The occupied cliffs vary irregularly in elevation from 245 to 313 m (GPS fixes). The colony cliffs face east and northeast and are split by two gullies that collectively reduce the functional extent of the colony to approximately 6 km. Many sections of the cliffs form vertical walls with few locations suitable for fulmar nests, while other sections are deeply eroded and incised, with numerous ledges, cracks, and small caves. Scree slopes are extensive along parts of the colony, notably the southern third, and extend up to half of the cliff height.

We counted 10 150 fulmars from the base of the cliff, plus another 783 fulmars on study plots visible only from above. We estimated that approximately 3000 fulmars in total (including the 783 we saw from above) could have been obscured from counting locations below the cliffs. Together, we estimate 13 150 birds on the colony that day, or 2.2 birds/linear m of cliff. More than half of these birds were observed in the southern third of the colony, where cliffs are more incised, and photographs indicate nesting densities of greater than 2 nests/m^2 on some ledges.

On 10 July 2004 we observed a ratio of 0.66 breeding sites per individual counted, equivalent to 0.825 breeding sites per AOS, on our monitoring plots (M.L. Mallory, unpubl. data). If this ratio was representative for the entire colony, then we estimate the total AOS on the day of count as 10 520 and the number of breeding pairs at Cape Vera in 2004 as 8679 pairs (Table 1). Of 265 fulmars monitored at nests on 10 July 2004, 65% were light morph (L or LL) and 35% were dark morph (almost all D).

Princess Charlotte Monument (75˚51'N, 78˚51'W): Although fulmars were commonly observed flying in the vicinity of the nearby murre colony at Cambridge Point, Coburg Island, fulmar nesting areas were found only on Princess Charlotte Monument (n = 323 sitting birds) and adjacent cliffs of the Marina Peninsula (n = 30 birds). Most nested high on cliffs (30–200 m in elevation), but approximately 100 pairs nested on steep grassy slopes at the base of the Monument's main rock tower.

Cape Liddon, Devon Island (74˚37'N, 91˚10'W): The colony is situated on a headland on the west side of Radstock Bay, a deep indentation on the south coast of Devon Island. The cliffs face south or southeast and vary from 100 to 220 m in elevation. The total length of the occupied cliffs was 2.4 km.

Three sections were counted, aggregating 1.7 km of cliff. A total of 5091 AOS were counted (Table 1), giving an estimated density of 3.74 sites/m and an estimated total of 8984 AOS (7176 without correction for hidden or overlooked birds). With only three sample areas counted, varying considerably in elevation, an estimate of confidence interval was not appropriate.

Hobhouse Inlet, Devon Island (74˚28'N, 86˚50'W): The colony occupies south-facing cliffs extending from Hobhouse Inlet to Stratton Inlet along the south coast of Devon Island (Nettleship, 1974a). The fulmars nest on horizontally banded limestone on the upper half of the cliffs. The lower part of the cliff is occupied by sloping basal screes that constitute about one-third of its total height. Total length of the occupied area was 10.5 km. The height of the cliff, measured by GPS at six points along the cliff edge, varied between 352 and 480 m.

We counted 8482 AOS, and the mean density of the six sections counted was 2.05 ± 0.36 SE sites/m (N = 6). The aggregated density (total birds/(total length counted • proportion of sites visible) was 1.99 sites/m (Table 1). Extrapolating the latter figure to the entire length of the colony gave an estimate of 20 934 sites (95% CI 14 388 – 28 662), or 14 654 breeding pairs. Without the correction for hidden birds, the estimate would be 19 425 AOS. We concluded that the true total probably fell between 15 000 and 30 000 AOS. At peak attendance, approximately 24 000 sites should have been occupied.

Prince Leopold Island (74˚02'N, 90˚W). This island is situated at the junction of Parry Channel (Lancaster Sound/ Barrow Strait) and Prince Regent Inlet. It consists of a large central plateau at about 250 – 300 m elevation, surrounded by cliffs. Below the cliffs lie several substantial gravel spits, of which those at the northeast, southeast, and southwest corners are the most prominent. Northern fulmars nest around most of the coastal cliffs, with the exception of those above the main gravel spits, and a portion of the north coast (Fig. 2). Fulmars are sparse on the northeast corner of the island, where the vertical cliffs, highly undercut in places, have few available ledges. Cliffs rise to near 300 m around the whole periphery of the island, with scree slopes covering up to half of the cliffs on

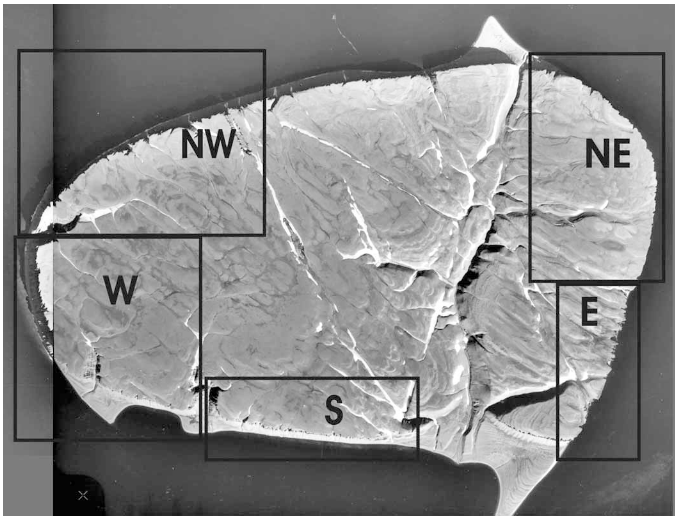

FIG. 2. Aerial photograph of Prince Leopold Island, showing the different counting areas detailed in Table 1.

the S, W, and NNE coasts (Fig. 2). In the absence of scree slopes, fulmars nest at all altitudes on the east coast, with the highest densities near the top.

Details of AOS counted, by section, are given in Table 1. Densities were highest on the east coast (3.6 sites/m), where fulmars nest among thick-billed murres *Uria lomvia* and black-legged kittiwakes *Rissa tridactyla*. This is also the area where the maximum height of cliff is available for nesting, because basal screes are absent. The density estimate for the northeast section was conjectural, as few parts of the cliff were visible from above. However, boat surveys and aerial reconnaissance suggested that only small number of fulmars nested on this section. We estimated 400 sites. A small section at the north-northeast corner of the island was not counted at all. It was known to support a moderate density of fulmars and was treated as having a density similar to that on the west coast (1.2 sites/m). Apart from the northeast section, lowest densities were recorded on the west and northwest sections (1.20, 0.90 sites/m). Our estimate of AOS on the island in 2000–01, using the south coast count for 2001, was 21705.

The replicate surveys of the south coast yielded very similar estimates for total occupied sites (4578, 4906; Table 1). A difference of 110 m for the occupied length of cliffs suggests that observers selected slightly different end points in the two years; it is unlikely that the extent of the occupied area changed. Variation in estimates of occupied cliff length for other sections also may have contributed to inaccuracy in those estimates. Formal confidence intervals cannot be calculated, so all estimates need to be treated as approximate.

There were 233 AOS on our six study plots on 30 June and 277 on 9 July 2001. At least 172 pairs attempted to breed on these plots. These figures suggest ratios of breeding pairs to occupied sites of 0.74 and 0.62, respectively. No counts of study plots were performed in 2000, but the mean count for the period 26 July–1 August 2001 was 198.2, suggesting a ratio of 0.98 for that stage in the season. Applying these correction factors to the relevant dates gives an estimate of 16364 breeding pairs. Similarly, we can use these correction factors to adjust our counts for seasonal variation in numbers, suggesting a peak of approximately 26000 apparently occupied sites around 9 July in 2001 (Table 1).

Baillarge Bay, Baffin Island (73°25'N, 84°30'W): Northern fulmars breed intermittently along the 14 km of cliffs between Elwyn Inlet and Baillarge Bay (Nettleship and Smith, 1975). No fulmars were observed on Ship Point, on the south side of Baillarge Bay, where they were reported by Nettleship (1980). The occupied cliffs rise from about 300 m at the northeast end to reach a maximum elevation of 440 m (GPS fix) near the southwest corner. The colony cliffs face northeast and are divided into sections by six gullies that descend to or near to sea level. Along with some unoccupied cliff sections, they reduce the length of the occupied colony to approximately 8.5 km. Extensive basal scree slopes occur in only a few areas, so for about half the length, potential breeding sites for fulmars are available at all elevations.

Counts and estimates of AOS were as follows: 521 from east end to gully 1; 313 from gully 1 to gully 2; 365 from gully 2 to gully 3; 0 from gully 3 to gully 4; 2244 from gully 4 to gully 5; 1648 from gully 5 to gully 6; and (est.) 6664 from gully 6 to Baillarge Bay, for a total of 11755 sites. Because about half the birds at this colony are intermediate to dark morph and glare caused observers discomfort, many birds probably were missed, especially on the densely occupied western end of the colony. However, we are unable to quantify this error and our suggested correction factor of 0.5 (Table 1) is conjectural. Consequently, the relationship between total number counted and the actual number present is uncertain. Our counts suggest that the true number of occupied sites substantially exceeded 12000 and we suggest a possible total in the region of 23000.

Cape Searle (67°14'N, 62°28'W): Northern fulmars breed across 6 km of the southern, eastern, and northern sides of three rock towers that form Cape Searle on the eastern end of Qaqulluit Island. In addition, the highest densities of nesting fulmars are on the tops of the two 430 m tall rock towers off the east end of the island (Watson, 1957). The cliffs of the towers themselves support few fulmars, as they are sheer or undercut in many places, but the west sides of the towers and the third (inmost) tower have many broad ledges that support high nesting densities.

We counted 5129 fulmars on the cliffs, but many incised sections could not be observed from the ice, and these probably supported many fulmars. With missing sections and undercounting of birds on sections that were visible, we estimated that 35% of birds were counted (Table 1). Along cracks and on small, easily identified plots, numbers of birds observed in 2001 and 2002 were similar (Mallory and Gaston, 2005). The western section of the northern side of the colony could not be counted in 2002 because it was obscured by local fog during each attempt. In 2001, 2000 fulmars were counted on this site. We estimated that in 2002 the cliff faces may have supported 12 000 AOS, or a cliff-nesting density of 2.0 sites/m.

On the top of the outer tower, we estimated that 14 000 fulmars were present (counted as 140 groups of 100 birds visible against a light overnight snowfall). From the 1986 photograph, we counted 3229 birds. This photograph covered an estimated 20% of the tower surface, which translates to 16 000 birds for the entire surface (close to the field estimate). The inner tower is 30% larger than the outer tower, so we calculated that 18 200 birds (14 000 × 1.3) might occupy the top of the second tower. We calculated that collectively, the cliffs and tops of the towers supported approximately 44 200 fulmars in June 2002. Given that some spots (e.g., between the towers, ledges sloping in to the cliff, gray birds on gray rock) could not be viewed well and the fact that we couldn't see the top of the second tower, we believe that this could be an underestimate by about 25%, and thus that Cape Searle might have held 53 000 or more fulmars during the census, equivalent to approximately 42 000 AOS, or 35 000 breeding pairs (Table 1). If the seasonal trend in attendance at Cape Searle is similar to that observed at Prince Leopold Island, this would indicate about 57 000 AOS at peak attendance.

Fulmars at Cape Searle are predominantly dark phase, as found in earlier investigations (Wynne-Edwards, 1952a; Watson, 1957). From the distance of the census, separation of L, D, and DD morphs was not reliable. However, of 1998 birds observed in 2001 and 2002, 13% were LL morph.

Other Colonies in Nunavut: Three other large (> 5000 pairs) fulmar colonies are known in Nunavut, but census data are more than 15 years old. At Buchan Gulf (71˚50′N, 74˚30′W), an estimated 25 000 pairs of fulmars nest on the promontories known as The Bastions and The Mitres (Hatch and Nettleship, 1998). Farther south, at Scott Inlet (71˚03′ N, 71˚08′ W), 10 000 fulmar pairs breed on the cliffs along the south coast of the inlet. Both of these colonies are anomalous in the Canadian Arctic, in that they are occupied almost wholly by light phase fulmars, more typical of populations in Greenland and Europe (Hatch and Nettleship, 1998). At The Minarets (also known as 'South of Reid Bay' or 'Akpait'; 66˚56′ N, 61˚46′ W), 12 000–20 000 birds were estimated to be present on 22–24 July 1985 (Gaston and Smith, 1987). This count, being rather late in the breeding season, probably comes close to numbers of AOS. For comparative purposes, we have assumed a figure of 15 000 AOS.

A smaller colony of 2000 pairs is located on Exeter Island (66˚13′ N, 62˚11′ W), along the eastern part of the Cumberland Peninsula of Baffin Island (Hatch and Nettleship, 1998). As well, a very small colony of less than 40 fulmars was noted by A.J. Gaston and Steven Smith on Hantzsch Island (61˚55′ N, 65˚ W) in 1982, but although birds were occupying breeding sites, breeding was not confirmed.

Former Fulmar Colonies: Fisher (1952), citing the journals of Ludwig Kumlien and Franz Boas, reported three small fulmar colonies in Cumberland Sound, one at the northern end near Quickstep Harbour (Qaqodlualung, possibly the Exeter Island colony; Wynne-Edwards, 1952a, b), and one each on the north (Leopold Island) and south (Cape Edwards) sides of the entrance to the Sound. Subsequent expeditions in this area failed to mention these sites, and surveys since the 1970s have revealed no fulmar colonies in this region. Cumberland Sound was an area of intense whaling operations in the 19th century, and Fisher hypothesized that the end of the whaling activities may have led to a corresponding decline in the local fulmars. However, Wynne-Edwards (1952a) questioned the actual existence of these colonies.

Population Trends

Cape Vera: Between 1980 and 1984, fulmars were counted at Cape Vera from below the cliffs on four occasions (Prach, 1986). The dates are not known, but were probably in June or July. Fulmars were counted with binoculars, and the count was adjusted slightly upwards (× 1.15) after comparing counts on subsections of the cliff with a spotting scope (further details on methods are unavailable). In 1980, 7541 birds were estimated from counts, and slightly lower values were obtained for 1982 (two counts: 5436 and 5503) and 1984 (6784). In 1983, Prach (1986) counted 2290 fulmars from the top of the cliffs, birds thought not to be visible from the beach below. Prach's beach counts should be comparable with our count of 10 150 made on 10 July 2004, and his count from the top, with our estimate of 3000 birds not visible from below. All counts suggest a possible increase in numbers at Cape Vera of more than 30% since the 1980s.

Prince Leopold Island: Mean numbers estimated for the study plots during 17 July–1 August ranged from 225 in 2002 to 367 in 2003. There was no significant trend in population between 1976 and 2003 (r_8 = -0.57, $p > 0.1$, Fig. 3). The low counts in 2001 and 2002 were associated with years of very late ice breakup and are unlikely to have been associated with changes in the overall population (Gaston et al., 2005b). The lack of apparent trend for numbers counted on the study plots is in strong contrast to our population estimate for the whole island (21 705 AOS), which is much lower than the number given by Hatch and Nettleship (1998: 62 000 breeding pairs). We consider this difference below.

Inter- and Intra-Year Variation in Attendance

Total numbers of birds and numbers of AOS on our monitoring plots were closely correlated in all three years (for 18 June – 20 July, R^2 = 0.97, 0.98, 0.95 in 2001, 2002 and 2003, respectively). Variation in numbers of occupied sites was concordant among plots, with all pairwise comparisons being positive during 18 June – 20 July (Table 2).

Counts of both individual birds and AOS increased from early June onwards, peaking in late June (2002) or

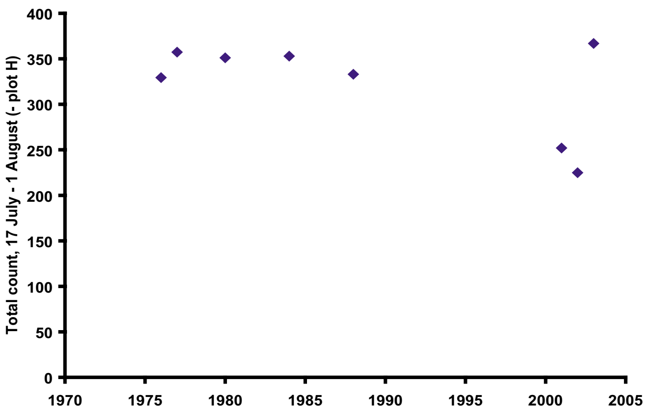

FIG. 3. Mean counts of occupied sites on six study plots at Prince Leopold Island during 17 July–1 August in eight years since 1976.

TABLE 2. Pearson correlation coefficients for pairwise inter-plot comparisons of day-to-day changes in numbers at Prince Leopold Island during the period 18 June – 20 July. Sample sizes range from 22 to 26.

Year	Plot	Plot C	Plot D	Plot G	Plot J
2001	A	.4137*	.4802*	.5181**	.2066
	C		.4838*	.6515**	.4075
	D			.2111	.2003
	G				.4037
2002	A	.5006**	.8498**	.7118**	.7384**
	C		.7997**	.7621**	.8129**
	D			.8680**	.7579**
	G				.7461**
2003	A	.5764**	.3206	.6277**	.6129**
	C		.6013**	.5107**	.6247**
	D			.5092*	.5367**
	G				.6534**

* $p < 0.05$; ** $p < 0.01$.

about 10 July (2001, 2003). A decrease in numbers occurred thereafter and became steeper in late July, following the start of hatching (Fig. 4). Total numbers of sites occupied varied among years (ANOVA; $F_{2,70} = 8.05$, $p < 0.001$), but explained only a small amount of variation (adjusted $R^2 = 0.16$). Inter-year variation was lower in June than in July (Fig. 4, Table 3).

The mean coefficient of variation among daily counts of AOS, based on seven-day running means and associated standard deviations, was lower in all years (significantly lower in two) than that among counts of all individuals (Table 4). The coefficient of variation showed no consistent trend from the beginning of incubation (about 10 June) to the start of hatching (about 20 July), but thereafter variability increased, especially once numbers began to decline rapidly (Fig. 5).

An autocorrelation analysis for the period 11 June – 20 July showed a strong positive correlation in all years, at lags of one and two days, between successive daily counts of occupied sites on our study plots. In 2001 there was a clear periodicity, with an interval of about 15 days, and in 2003 there appeared to be a weaker periodicity of 10 days. No cyclical behaviour was evident in 2002 (Fig. 6).

DISCUSSION

The northern fulmar is a challenging bird to survey in Arctic Canada. It nests at high elevations, often on ledges that may be difficult to see from above or from below. Viewing conditions are unlike those in Europe (Fisher, 1952), in that for many Arctic colonies, the colour of some birds closely matches the colour of the cliff. These birds are difficult to discern, making counts from photographs unreliable except under excellent light conditions. As well, the contrasts of sea ice, nearby water temperature, and air temperature mean that fog often obscures the sections of nesting cliffs that support the highest densities of birds. For these reasons, previous estimates of fulmar colonies in Nunavut have been derived principally from relative "order of magnitude" calculations based on initial aerial surveys (Nettleship, 1974a, b; Brown et al., 1975).

Total Population of Fulmars in Nunavut

We estimated ca. 130 000 AOS on colonies that we censused (Table 1, Table 5). Using a uniform correction factor, this suggests approximately 102 000 breeding pairs. Previous estimates gave an additional 57 000 pairs at colonies not censused, for an estimated total of 159 000 breeding pairs, or 318 000 individuals, in Nunavut (Table 5). These numbers do not include non-breeders, which probably add at least 100 000 birds. Our estimate is 53% of the 604 000 breeding northern fulmars reported by Hatch and Nettleship (1998) for Arctic Canada. However, in reality, most previous estimates are likely to have referred to occupied sites, rather than breeding sites, because no intensive studies had been carried out to determine ratios of birds to pairs anywhere except on Prince Leopold Island. If we assume that previous estimates represented AOS, the total AOS reported for Nunavut (our estimates, plus previous estimates for colonies not visited by us) is 189 000.

Counts conducted in 2001 and 2002 at Prince Leopold Island, Cape Liddon, Hobhouse Inlet, and Baillarge Bay were made in years of very late ice breakup. At Prince Leopold Island, fewer fulmars attended sites in these years (Gaston et al., 2005a), which may also have occurred at the other colonies. Numbers attending study plots at Prince Leopold Island were substantially lower in 2002, a year of very late ice dispersal in Lancaster Sound, than in 2003 (our Fig. 3, Table 2; Gaston et al., 2005a). Daily counts during the incubation period in 2001 were 25% lower, and those in 2002 nearly 30% lower, than in 2003. Hence, our census counts in those years probably were lower than they might otherwise have been by similar margins. It appears that 2001 and 2002 were unusual, but not unique years (Gaston et al., 2005b). We believe that in 1977, when Prince Leopold Island was previously censused, conditions were

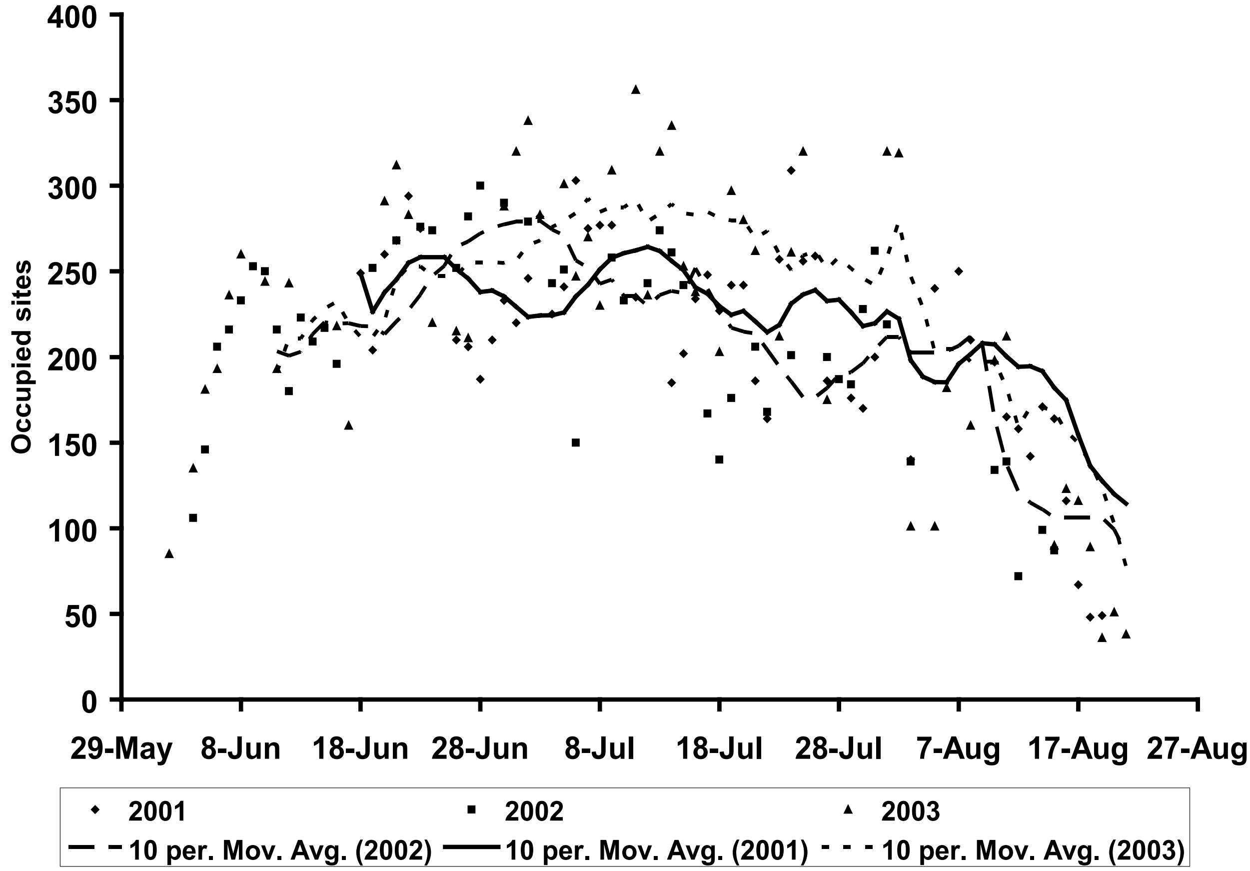

FIG. 4. Change in numbers of occupied sites on study plots at Prince Leopold Island over three seasons. Fitted lines are 10-day moving averages.

TABLE 3. Inter-year variation in mean numbers of occupied sites at Prince Leopold Island in June (after 17 June) and July (before 21 July). T-tests are for unequal variances. Levene's test for homogeneity of variance is also applied.

Year	Mean	SD	Comparison	df	*t* (separate variances)	*p*	Levene's test	*p*
June								
2001	236.0	35.1	vs 2003	16	-1.241	0.240	1.467	0.243
2002	274.3	16.9	vs 2001	17	-3.145	0.007	7.915	0.012
2003	260.0	42.8	vs 2002	13	0.826	0.434	21.880	0.000
July								
2001	244.8	30.4	vs 2003	32	-2.977	0.006	3.537	0.069
2002	224.4	48.3	vs 2001	28	1.333	0.198	5.319	0.029
2003	283.3	43.9	vs 2002	28	-3.443	0.002	0.256	0.617

likely to have been more like 2003 than 2002. We have no evidence for how other census years might have compared. However, inter-year variation in attendance may explain some of the differences between our estimates and earlier ones. If counts made at Prince Leopold Island in 2000–01 (~21 700 AOS) are increased by 25%, this adds 5400 AOS, suggesting that in a "normal" year the colony supports in the region of 27 000 AOS.

The main difference between recent and earlier estimates occurred at two sites: Prince Leopold Island (estimated ~26 000 AOS at peak attendance in this study, compared to the previous estimate of 62 000 breeding pairs) and Cape Searle (57 000 AOS at the period of peak attendance vs 100 000 pairs). The estimate of 100 000 pairs for Cape Searle derives from an estimate of 200 000 birds present on 15–16 August 1950, when "half-grown chicks" were present on the colony (Wynne-Edwards, 1952a, b). At that stage of breeding at Prince Leopold Island and Cape Vera, generally less than half of peak numbers are present. Watson (1957) estimated the colony at 25 000 birds, but his visit was in late May—presumably during the pre-laying exodus. Wynne-Edwards placed the likely limits on his estimate at 100 000–400 000 birds. His lowest estimate is almost double our estimate for June. Wynne-Edwards' estimate was supported by observations made in 1986 by D.N. Nettleship (pers. comm. 2004). The comparison suggests that the colony at Cape Searle may have declined since the 1950s. Despite this, our counts confirm that this colony continues to be, by some way, the largest in Nunavut and in Canada.

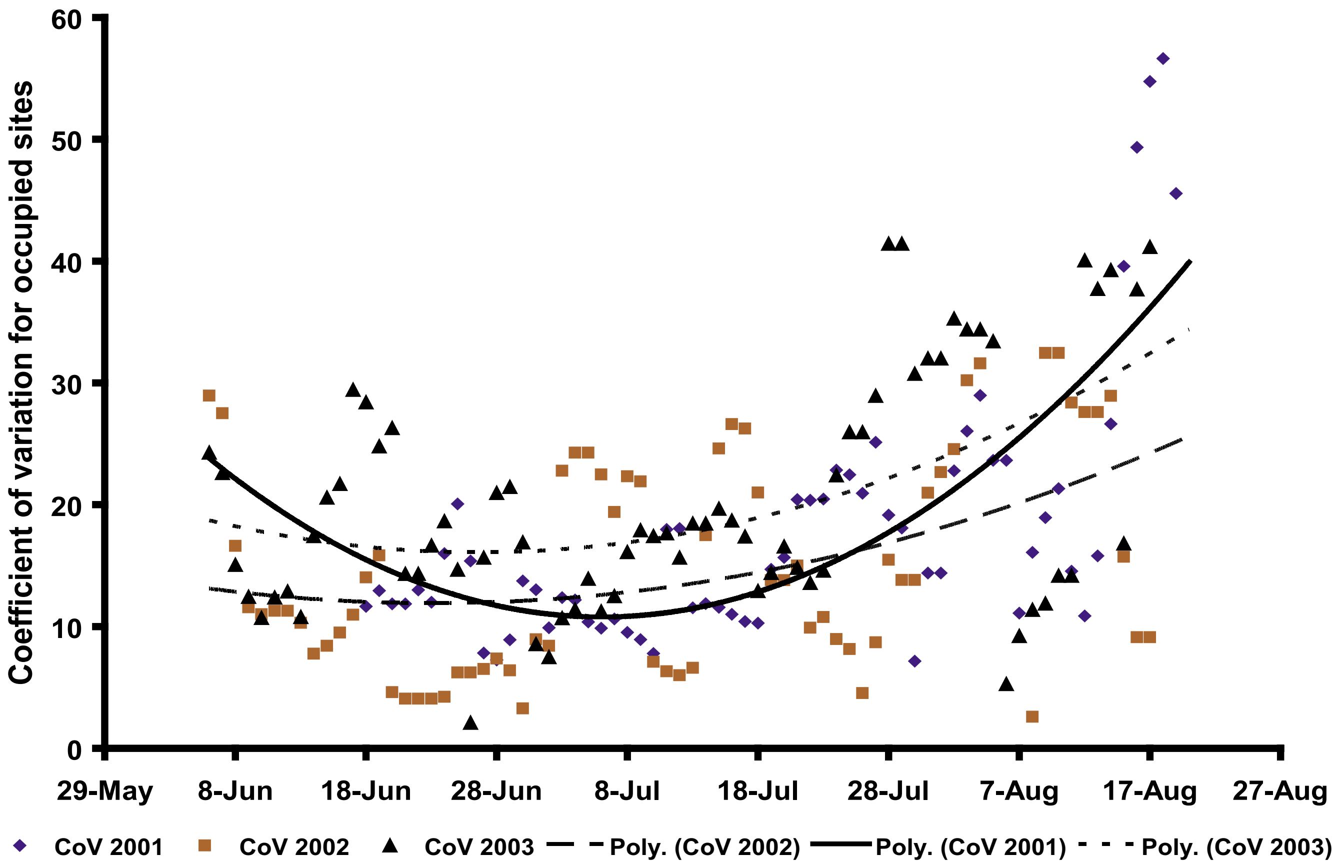

FIG. 5. Coefficients of variation calculated for seven-day moving averages of total occupied sites at Prince Leopold Island in 2001–03. Fitted curves are quadratic functions.

For Prince Leopold Island, where previous estimates were based on counts similar to those we made (D.N. Nettleship, pers. comm. 2004), the difference between estimates from the 1970s and more recent counts contradicts the evidence from permanent monitoring plots that no change had occurred since the 1970s. However, the earlier counts were extrapolated by area, rather than by cliff length, being based on counted areas close to the cliff top, rather than on counts made for the entire cliff height. If densities are highest near the cliff top (Mallory and Gaston, 2005), the earlier estimate may have exaggerated the total numbers present. It is worth noting that the 1977 estimate of 62 000 breeding pairs suggests a mean density of more than 5 AOS/m for the entire length of the occupied cliffs, including the sparsely populated NE and NW sections. This is much higher than observed at any other colony during our surveys. The difference emphasizes the extreme difficulty in reaching satisfactory estimates for northern fulmar populations.

Effects of Attendance Patterns on Census

All estimates based on single counts need to be treated with caution. First, there is diurnal variation in the number of fulmars that attend nests (Hatch and Nettleship, 1998). At some colonies, the number of fulmars on ledges peaks in the evening (Hatch, 1989), while at others there may be no clear pattern (Hatch and Nettleship, 1998). We did not standardize our counts or correction factors for time of day. As well, the dates of our census counts varied between 6 June and 31 July, a nearly two-month period during which the number of fulmars attending colonies tends to peak and then decline (Hatch, 1989; Hatch and Nettleship, 1998; our Fig. 3). Our corrections, based on study plots counted daily at Prince Leopold Island and Cape Vera, should have accounted for some of this variation, but we do not know how applicable the correction factors derived at those colonies would be elsewhere.

Inter-year comparisons are further complicated by the tendency, at least at Prince Leopold Island, for attendance to fluctuate in a cyclical fashion, but with a period length

TABLE 4. Coefficients of variation (SD as % mean for seven-day periods) for counts of total birds and of occupied sites at Prince Leopold Island during 18 June – 20 July, and *t*-statistics for within-year comparisons.

	Total birds		Occupied sites			
Year	Mean	SD	Mean	SD	t_{64}	*p*
2001	15.0	4.0	12.1	3.0	3.34	0.001
2002	16.0	9.4	13.1	8.2	1.34	0.18
2003	20.6	6.2	16.1	5.2	3.17	0.002

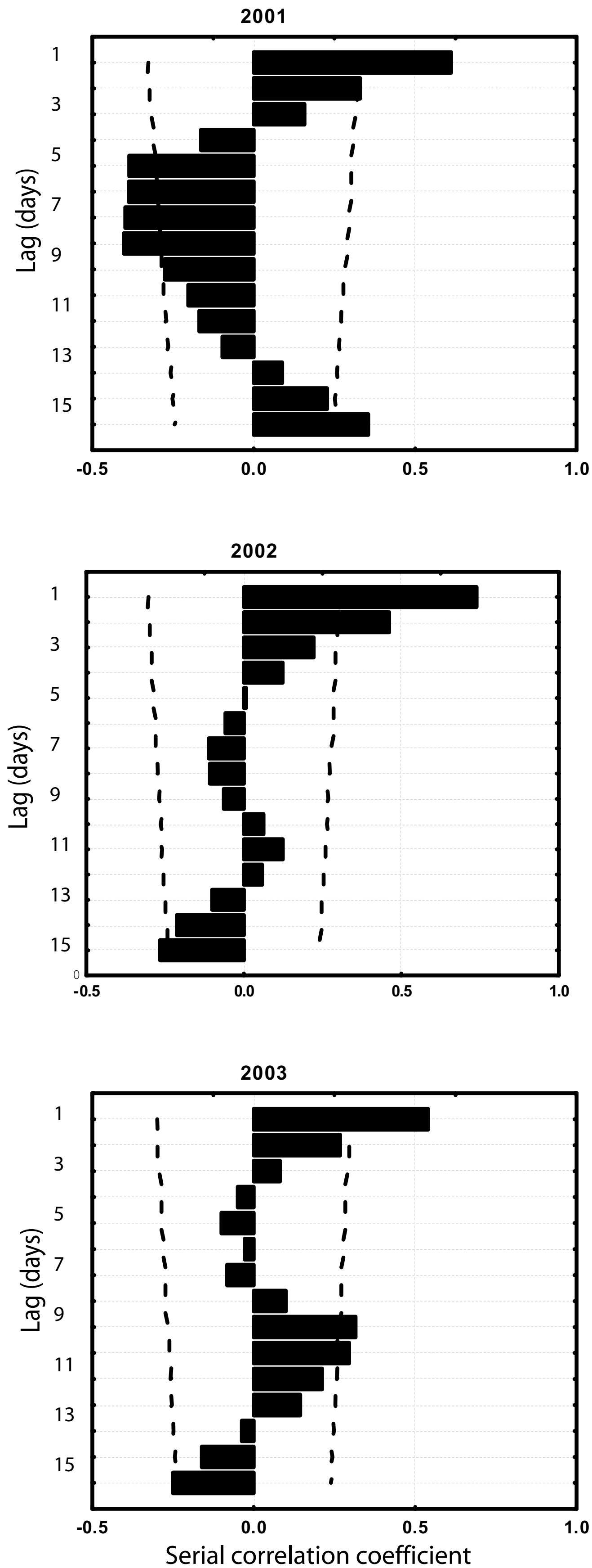

FIG. 6. Autocorrelograms for daily counts of occupied sites at Prince Leopold Island during 11 June–20 July. Dotted lines give 95% confidence intervals.

that varies from year to year. The pattern determined by Nettleship et al. (1986) in 1976 was very strong, and those we detected in 2001 and 2003 were equally striking. These cyclical patterns seem to be a regular feature of fulmar attendance at the Prince Leopold Island colony. These fluctuations, whose amplitude may reach 20% of peak numbers, could have a strong effect on results obtained over periods of less than a full cycle. They also cause great complexity for statistical treatment.

All estimates involve the application of correction factors for birds not counted because of irregularities in the cliff or the difficulty of seeing birds that matched the colour of the background. The correction factors thus applied cannot be assigned errors. They represent our best judgement, and the extent to which they contribute to differences between older and recent estimates is impossible to tell.

Previous estimates of population size have been expressed as "pairs" (e.g., Nettleship and Smith, 1975) or as "individuals" (Hatch and Nettleship, 1998). Our observations at Cape Vera and Prince Leopold Island indicate that our measure of "apparently occupied sites" will usually exceed the actual number of breeding pairs by 1.2 – 1.5 times during the period of minimum day-to-day variation (18 June – 20 July). It is not clear whether estimates given by earlier authors expressed in "pairs" (or "individuals" = 2 times "pairs") were comparable to our estimates of breeding pairs or to our numbers of occupied sites, because the derivation of previous estimates is unknown except for Prince Leopold Island. If earlier estimates actually represented estimates of the total birds present on the colony, then the relationship between numbers of individuals and number of sites would have varied according to the number of sites with both members of the pair in attendance.

We did find surprising consistency among colonies in numbers of sites per unit colony length, with estimates ranging from 1.75 birds/m at Cape Vera to 3.7 birds/m at Cape Liddon. At the largest colony, Cape Searle, birds are most dense on the summits of the two towers. Otherwise, colony estimates were rather well correlated with length of cliff occupied ($R^2 = 0.69$). This is probably because of the similarity of cliff structure—all High Arctic colonies, which are mostly situated on horizontally bedded limestone, make use of buttresses incised with regularly spaced gullies—allied with the rather regular spacing of northern fulmar nests.

Lessons for Censuses and Monitoring of Northern Fulmars

How can we improve our monitoring of northern fulmar colonies in Nunavut? We likely cannot rely on approaches possible for relatively conspicuous seabirds like murres or kittiwakes (Gaston et al., 1993), such as high-resolution photography and subsequent counts, to improve our accuracy. Even setting up a field research site at each location and conducting methodical and more complete coverage

TABLE 5. Comparison of previously published and latest estimates of northern fulmar colony size in Nunavut. All estimates over 1000 are rounded to the nearest thousand. Numbers in italics are previously published estimates not revised here. Colony numbers refer to Figure 1.

	Previously published estimates (breeding pairs)			Latest estimates		
Colony	Brown et al., 1975	Hatch and Nettleship, 1998	Year	Breeding Pairs	AOS at Date of Count	Year
1. Cape Vera, Devon I.	25 000	25 000	1971	9000	11 000	2004
2. Princess Charlotte Monument, Coburg I.		3000	1971	250	300	1998
3. Cape Liddon, Devon I.	10 000	10 000	1971	7000	9000	2002
4. Hobhouse Inlet, Devon I.	75 000	25 000	1971	15 000	21 000	2001
5. Prince Leopold I.	50 000	62 000	1977	16 000	22 000	2000/2001
6. Baillarge Bay, Baffin I.	25 000	30 000	1971	>20 000	>23 000	2002
7. Buchan Gulf, Baffin I.	25 000	25 000	1986	25 000	25 000	1986
8. Scott Inlet, Baffin I.	25 000	10 000	1986	10 000	10 000	1986
9. Cape Searle, Baffin I.	100 000	100 000	1974	35 000	44 000	2001
10. The Minarets, Baffin I.	10 000	10 000	1974	15 000	20 000	1985
11. Exeter I.	2000	2000	1974	2000	2000	1971
Totals	347 000	302 000		154 250	187 300	
Totals from post-1995 surveys				102 000	130 000	

of each location would not solve all challenges, because so many nesting locations on the cliffs cannot be observed from the ground or the summit. Our results confirm that the best approach to monitoring fulmars is to make counts on selected, clearly visible plots, as is typically done for murres (Birkhead and Nettleship, 1980), and to repeat full-colony counts at regular intervals—perhaps every five years. The considerable variation among days, as well as the cyclical pattern of attendance that appears to be characteristic of the population at Prince Leopold Island, shows that monitoring counts need to be repeated over a minimum of 10 and preferably 15 days to provide the most comparable results.

Total colony estimates can be compared only if corrected for date of counts, as shown in Table 1. However, standardization of counts for date or breeding stage or both would be preferable, as it reduces the number of corrections with their associated errors. Our results suggest that the period from the end of egg-laying to the start of hatching is likely to provide the lowest variation in counts. In addition, the use of AOS provides lower variability than counts of all individuals. Given the amount of effort required to derive conversion factors from counts to pairs, and the very limited areas for which such factors can be estimated, we recommend that counts for monitoring or censuses use AOS, rather than breeding pairs. This approach should provide evidence of population fluctuations or trends in the short term, and would also monitor changes in density, distribution, and perhaps overall numbers at a longer scale. In any case, it is essential that authors specify the units being used and how they were derived.

CONCLUSIONS

Despite the fact that some decrease may have occurred at Cape Searle, we do not believe that our data signal a general decline in fulmar populations in Nunavut. Neither the fairly robust evidence from the monitoring plots at Prince Leopold Island, nor the less reliable data from Cape Vera, indicate any negative trend. Perhaps the strongest evidence for population change is the difference between the 1950 and 2002 estimates at Cape Searle. Unfortunately, because of the wide confidence limits placed on his earlier estimate by Wynne-Edwards (1952a), it is hard to be sure that even that trend is real. We hope that the approaches and counts outlined in this paper will provide a suitable baseline against which future census counts can be compared.

Despite the substantial effort made from the 1970s onwards, the total population of northern fulmars in Nunavut remains very poorly known. Our best estimate of ~200 000 AOS assumes no change since the 1980s. We believe that all our corrections were conservative. That conservatism, combined with the fact that counts for some colonies were made in years when extreme ice conditions might have caused low attendance, suggests that 200 000 is close to the lower limit for the population. Future work will no doubt refine these numbers further, while providing better trend information from an expanded network of monitoring plots. Northern fulmars do not give up their secrets easily.

ACKNOWLEDGEMENTS

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