A First Count of Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) Breeding on Bylot Island

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Bylot Island, part of Sirmilik National Park, supports two major breeding colonies of intermingled Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*): at Cape Hay near the northwest tip and at Cape Graham Moore at the opposite end of the island. Although the size of these colonies has been estimated previously, there is no information on how the estimates were made, except for Thick-billed Murres at Cape Hay in 1977, when the numbers were based on sampling only about 30% of the colony. In 2013, high-resolution digital photographs of the whole area of both colonies were taken in July, when most birds were probably incubating eggs. Individual birds were counted on the photographs, and the numbers were corrected for image quality and converted to numbers of breeding pairs based on correction factors from another High Arctic colony. Our estimates were similar to those from earlier years for kittiwakes at Cape Graham Moore and for murres at Cape Hay, but suggested that numbers of murres were higher than previously thought at Cape Graham Moore, while numbers of kittiwakes were lower at Cape Hay. The overall total for the Canadian population of Thick-billed Murres was unaffected by these changes, but the total number of Black-legged Kittiwakes nesting in the Canadian Arctic may be 20% lower than previously thought.

Key Words: Population census; Bylot Island; Nunavut; Thick-billed Murre; *Uria lomvia*; Black-legged Kittiwake; *Rissa tridactyla*; Sirmilik National Park; Cape Graham Moore; Cape Hay

Introduction

The Lancaster Sound/Baffin Bay region is one of the richest marine areas in the Canadian Arctic (Nettleship 1974; McLaren and Renaud 1982; Finley *et al*. 1983; Wong *et al*. 2014). In summer, it supports large populations of marine mammals and birds, including most of the Canadian population of Narwhals (*Monodon monoceros*), large numbers of Belugas (*Delphinapterus leucas*) and Bowhead Whales (*Balaena mysticetus*; Laidre *et al*. 2015), and large colonies of marine birds, including Thick-billed Murres (*Uria lomvia*), Northern Fulmars (*Fulmarus glacialis*), and Black-legged Kittiwakes (*Rissa tridactyla*; Nettleship 1974; Brown *et al.* 1975; McLaren 1982). Despite the importance of this region for marine top predators, the size of populations, especially breeding populations of marine birds, is poorly known and many of the estimates available originate from surveys in the 1970s or earlier (Gaston *et al*. 2012).

The Thick-billed Murre is the most abundant seabird in the Canadian Arctic, breeding in ten large colonies from Akpatok Island, in Ungava Bay (60°15'N), north to Coburg Island (75°47'N), with an estimated total population of 1.5 million breeding pairs (Gaston *et al.* 2012). Knowledge of the total size of the population is important in managing the extensive hunt of these birds in their wintering area off Newfoundland and Labrador (Elliot 1991; Chardine *et al.* 1999). In the Lancaster Sound/Baffin Bay region, an accurate estimate of population size is available for only one colony, at Prince Leopold Island at the western end of Lancaster Sound (Gaston and Nettleship 1981; Gaston *et al.* 2012).

Bylot Island, close to the north end of Baffin Island, is a Migratory Bird Sanctuary administered by Environment and Climate Change Canada and is also part of Sirmilik National Park. The island is the site of two major seabird colonies: one near Cape Graham Moore, at the southeast tip of the island (72°53'N, 76°10'W) and the other 8 km to the west of Cape Hay, near the northwestern tip (73°36'N, 80°19'W; Figure 1; Nettleship and Smith 1975). Both colonies are used by intermingled Thick-billed Murres and Black-legged Kittiwakes.

According to previous information, the colony at Cape Graham Moore was the smallest of the Canadian Thick-billed Murre colonies, estimated at 20 000 breeding pairs, based on an aerial survey in 1972 (Brown *et al.* 1975). However, the statement "Order 5" appeared in parentheses beside the number, indicating that it was a very approximate estimate. The larger colony near Cape Hay was estimated to contain 400 000 breeding pairs in 1957 (Tuck and Lemieux 1959), but an estimate by Birkhead and Nettleship (1980), based on counts of parts of the colony (about 30%) from photographs tak-

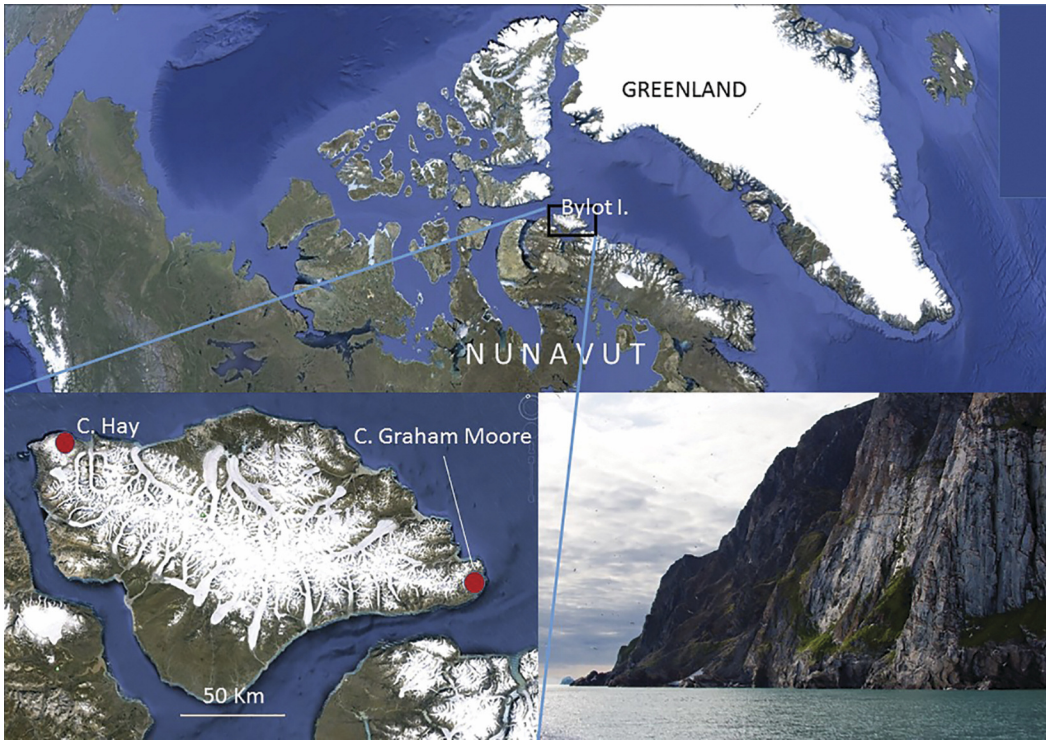

FIGURE 1. Google Earth image and inset show the location the Thick-billed Murre (*Uria lomvia*) and Black-legged Kittiwake (*Rissa tridactyla*) colonies studied: Cape Hay and Cape Graham Moore on Bylot Island (inset map: Google Earth V 7.1.5.1557 [13 December 2015]; accessed 30 April 2016). Inset photograph shows the Cape Graham Moore colony from the sea. Photo: K. O'Donovan.

en in 1976, suggested 140 000 pairs. More recent estimates were not available before the present study.

The cliffs of both colonies support smaller numbers of breeding Black-legged Kittiwakes. Tuck and Lemieux (1959) estimated 3000 pairs at Cape Graham Moore and 50 000 at Cape Hay in 1957, and Lepage *et al.* (1998) estimated 3000 and 20 000, respectively, based on surveys in the 1970s. However, there is no information on how any of these estimates were obtained.

No further attempts were made to census either of these colonies until 2013, when a set of high-resolution digital photographs was taken of both colonies. The objective was to count Thick-billed Murres and Black-legged Kittiwakes using a standardized procedure, so that subsequent counts can be readily compared with those obtained in 2013. We describe here the analysis of the photographs and provide a new census for the colonies: the first known to be based on complete counts of all the birds present.

Methods

Thick-billed Murres nest in large, dense colonies concentrated on the narrow ledges of steep cliffs. In most cases, part or all of the cliffs is invisible from land. Hence counts must be made from out at sea. However, large colonies, such as those on Bylot Island, are extremely difficult to count from a ship, because of the movement of the vessel, which makes it difficult to keep track of what parts have already been counted. In addition, substantial time is required for the ship to reposition itself along the colony. The Cape Hay colony extends along 3.5 km of 300-m-high cliffs (area about 1 km^2, see Birkhead and Nettleship 1980), while that at Cape Graham Moore is 1 km long on 250-m cliffs (0.25 km^2; Nettleship and Smith 1975).

It is customary elsewhere to take high-resolution photographs of these colonies and to count the birds on the resulting images (e.g., Birkhead and Nettleship 1980; Gaston 2002). Photographic surveys were made on 17 July 2013 at Cape Graham Moore and on 22 and 24 July 2013 at Cape Hay. On 22 July, the colony was partly obscured by fog, making bird counts from the photographs difficult. Consequently, we used only those taken on 24 July. Because of the size of the colonies and the need for photos to be taken as perpendicular to the cliffs as possible, the ship had to be repositioned frequently; thus, photography took most of the day. Photographs counted covered the entire length of occupied cliffs at Cape Graham Moore and Cape Hay with up to 50% overlap between adjacent photos.

At both locations, photographs were obtained using a Canon 5D Mark 3 camera and Canon EF 70–200 mm f2.8L IS II USM lens (Canon Inc., Brampton, Ontario, Canada) by a photographer (K.O.) stationed about 2 m above the sea and roughly 200 m from the cliffs on board the MV *Arctic Tern*. Original images were in cr2 format, the output format from Canon cameras. They were converted to jpeg images for processing using Irfanview free software for batch image conversion (version 4.38; Irfan Skiljan, Wiener Neustadt, Austria; www.irfanview.com/).

On the photographs, Thick-billed Murres were distinguished from other birds that might have been present by the sharp distinction between their white front and black backs and their robust shape. The white tips of their secondary feathers, contrasting with the charcoal primary feathers, were also a useful identification feature in poor lighting conditions. Black-legged Kittiwakes were identified by their strikingly white heads, shared at these colonies only by small numbers of the much larger Glaucous Gull (*Larus hyperboreus*). Only birds perched on the cliffs were counted; those in flight or on the sea were ignored.

Counts of birds were made using GIMP photo-editing software (version 2.6.11; The GIMP Team, www.gimp.org/). Before counting, all photos were inspected and compared to identify the clearest images for each section of the colony. In GIMP, transparent layers were created and superimposed over the colony photos. Portions of a photo that were already counted were delimited in a layer named "Boundary."

Birds were counted by placing a dot of known pixel number on each bird in a layer named "Count" using the Pencil tool with brush setting at Circle (11) and scale at 0.27, giving a square dot of 9 pixels (3 pixels by 3 pixels). The number of pixels in a layer was counted automatically in the Histogram tool with channel set to "Value". Histogram pixel counts were verified for the first birds counted and regularly during the count to ensure that drawing settings were not accidentally modified. When a dot had been placed on every bird, the histogram pixel count was recorded and divided by the dot size (9 pixels) to obtain the number of birds.

Photo quality was recorded on a scale of 1 (best) to 3 (worst; Figure 2). Quality 1 photos had good lighting conditions, and individual Thick-billed Murres could be readily distinguished. Quality 3 photos had poor lighting, fog, or low picture resolution because of distance, so that some individuals could not be accurately distinguished or were obscured on dark areas of the cliff. To obtain an idea of the bias created by image quality, we counted some images very carefully to assess where birds might have been missed, but found only a small number of "possible birds", which could not be identified with certainty; the exact number could not be determined, but these amounted to fewer than 5% of those counted. Hence, to correct for image quality, we assumed, arbitrarily, that all birds present could be counted on quality 1 images, 97% on quality 2 images, and 95% on quality 3 images.

Corrected counts of Thick-billed Murres were converted to numbers of breeding pairs using a conversion factor k, where k is the number of known breeding pairs divided by number of birds counted and is derived from breeding study plots on the colony at Prince Leopold Island (Gaston and Nettleship 1981). The Prince Leopold Island counts were made at a similar date (8–26 July) to those conducted here, which was mid-late incubation period at that colony. Although we do not know the timing of breeding at Bylot Island in 2013, it is likely that birds counted in this study would also have been in the middle of incubation (Gaston and Hipfner 2000). The mean value of k for Prince Leopold Island in 1976 and 1977 was 0.73 (standard deviation [SD] 0.07; Appendix 8 of Gaston and Nettleship 1981).

Data on the conversion of counts of individual Black-legged Kittiwakes to breeding pairs is less extensive than for Thick-billed Murres. We used the ratio during incubation of known breeding pairs (sites where at least one egg was laid) to individuals, counted at one study plot containing 75 active nests on Prince Leopold Island in 2012, where the ratio was 0.56 (A.J.G., unpublished data).

FIGURE 2. Sample photos of Thick-billed Murre (*Uria lomvia*) colonies with assigned quality of, left to right, 1, 2, and 3. Photos: K. O'Donovan.

Results

The Cape Graham Moore count resulted in 69 255 Thick-billed Murres (time taken to count the images 22 h 44 m). Picture quality was variable, with most birds counted on quality 2 images (Table 1). The estimate after correcting for quality was 71 568 birds which, after *k* correction, suggests 51 887 breeding pairs (SD 4723; 95% range 42 440–61 334). We counted 4568 Black-legged Kittiwakes on the same photographs, of which all but 1% were on images of quality 1 or 2. After correction for image quality, this becomes 2620 breeding pairs (Table 1).

The Cape Hay count for 24 July 2013 resulted in 110 813 Thick-billed Murres (counting time 29 h 2 m) with most counted on quality 2 images. This converts to an estimate of 83 012 breeding pairs (SD 7557; 95% range 67 898–98 126; Table 1). Corresponding numbers for Black-legged Kittiwakes were 20 682 counted representing 11 922 breeding pairs (counting time 6 h 4 m).

Discussion

Single "snapshot" counts of seabird colonies will not normally give an accurate estimate of the number of breeding pairs because the number of birds present varies with weather, time of day, and season (Gaston and Nettleship 1981; Gaston 2002). In all cases, our counts were likely to have been underestimates, because in high concentrations of murres, it may be difficult to distinguish individuals on low-quality photos. This effect was probably more pronounced where photo quality was low or near the top of cliffs where the angle between the direction of the camera and the horizontal was greatest. Because Black-legged Kittiwakes nest exclusively on vertical portions of cliffs and because their white heads are prominent, we think that few are likely to have been missed, except where one bird was sitting behind another.

Given that our photos were taken in good weather and at various times of day, at the same stage of the breeding season as when the correction factors were derived, weather and seasonal bias should be relatively small. The main source of inaccuracy was probably the conversion ratios from individuals counted to breeding pairs. Variance in the value of *k* for Prince Leopold Island may not be representative of that for Cape Hay; even if they were similar under similar conditions, 2013 may have been an unusual year in ways that we cannot measure. Nevertheless, our estimates should represent a closer approximation of the true size of these colonies than previous estimates at the time they were made. Our value of $k = 0.73$ falls in the middle of the range of published values for Thick-billed Murre colonies from Alaska to eastern Nunavut (Chapdelaine *et al.* 1986; Hatch and Hatch 1989; Gaston *et al.* 1993).

Black-legged Kittiwakes elsewhere are often counted as "apparently occupied nests", based on a bird in attendance or a nest that looks as though it had been constructed or reconstructed in the year of the count (Mitchell *et al.* 2004; Mallory *et al.* 2009). We chose not to adopt this technique because, given the greyish colour of the rock and the nests, on most of the images it was much easier to identify birds than nests. This can be seen in Figure 2C, where five kittiwakes can be discerned, but no nests are visible, although several of the birds would almost certainly have been standing on nests.

With a minimum estimate of more than 40 000 pairs of murres at Cape Graham Moore, our results suggest that the size of this colony is more than double previous estimates. On the other hand, the maximum estimate for Cape Hay, at less than 100 000 pairs, is 29% below the previous estimate (140 000 pairs; Birkhead and Nettleship 1980). However, given that the earlier estimate was based on a count of only about 30% of the colony, the current estimate cannot be taken as evidence of a population reduction since 1976, when the previous photos were taken. Pending better information from locally derived *k* values or better photographs, we suggest that the size of the Cape Hay murre colony be

TABLE 1. Counts of Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) at the Cape Graham Moore and Cape Hay colonies, Bylot Island in 2013, and estimated numbers of breeding pairs.

		Thick-billed Murre			Black-legged Kittiwake		
Colony	Photo quality	% photos of this quality	Bird count	Corrected count	% photos of this quality	Bird count	Corrected count
Cape Graham Moore	1	6	3 928	3 928	22	1 011	1 011
	2	75	51 846	53 449	77	3 536	3 645
	3	19	13 481	14 191	1	21	22
Total			69 255	71 568		4 568	4 678
Pair equivalent			50 210	51 887		2 558	2 620
Standard deviation			4 571	4 723			
Cape Hay	1	10	11 160	11 160	17	3 499	3 499
	2	65	71 793	74 013	66	13 652	14 074
	3	25	27 860	29 326	17	3 531	3 717
Total			110 813	114 500		20 682	21 290
Pair equivalent			80 339	83 012		11 582	11 922
Standard deviation			7 314	7 557			

treated as 70 000–100 000 breeding pairs (rounded to the nearest 10 000) and the Cape Graham Moore colony as 40 000–60 000 breeding pairs. The aggregate count for the two colonies is similar to previous estimates of their combined population (160 000 pairs; Brown *et al.* 1975). Hence our estimates do not adjust the estimate of the total population of Canada's eastern Arctic.

It is impossible to say with certainty that there was a decrease at Cape Hay between Tuck and Lemieux's (1959) estimate of 400 000 pairs in 1957 and the estimate of 140 000 pairs presented by Birkhead and Nettleship (1980) based on photos taken in 1976, as we have no indication of Tuck and Lemieux's earlier methods. Lepage *et al.* (1998) and Gaston and Robertson (2014) suggested that the murre population of Cape Hay may have declined during the 1960s because of incidental drowning of birds in the west Greenland salmon drift-net fishery and excessive hunting during fall and winter in west Greenland and Newfoundland–Labrador (Tull *et al.* 1972; Nettleship and Evans 1985). Monitoring in 1989 suggested that both murre colonies on Bylot Island were "relatively stable" (Lepage *et al.* 1998), but, again, details are unknown. However, it seems from our result that the size of the colony at Cape Hay has changed little since 1975.

We have no way to estimate variance for our kittiwake counts, but, if they are similar to those of the murres, we can expect that the true breeding population of the Cape Graham Moore colony is 2000–3000 pairs and the Cape Hay colony 10 000–15 000 pairs. The Cape Graham Moore estimate is similar to Tuck and Lemieux's (1959) 1957 estimate (3000 pairs), but the estimate for Cape Hay is substantially lower than earlier estimates. In the absence of more details on the earlier counts, it is impossible to know whether this represents a decrease in numbers since the 1970s. However, it adjusts the total estimate for Black-legged Kittiwakes in Canada's eastern Arctic downward by about 20%, from 123 000 (Gaston *et al.* 2012) to about 100 000 breeding pairs.

The difference between our estimates and earlier ones suggests that similar intensive counts would be useful for many other large Arctic seabird colonies where population numbers are currently based on undocumented and, in many cases, decades-old estimates.

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