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A Review of Thick-Billed Murre Banding in the Canadian Arctic, 1950–2010

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ABSTRACT. Banding of Thick-billed Murres *Uria lomvia* in the Canadian Arctic was initiated by L.M. Tuck in the 1950s, when he visited three of the largest breeding colonies in Canada. Up to 2010, banding had been carried out at eight of the 10 major breeding colonies, with totals of more than 1000 birds banded at Coburg Island and Cape Hay, Bylot Island, in the High Arctic and at Digges Sound and Coats Island in northern Hudson Bay. Because murres are long-lived birds, large-scale banding can continue to provide useful results for decades. A total of about 89 000 bandings in Arctic Canada resulted in 1757 usable recoveries up to 2010, the vast majority of which were birds killed by hunters in West Greenland or Newfoundland and Labrador. There was no apparent change in the large-scale geographical pattern of recoveries over the period reviewed, but the proportion of bands recovered has fallen. Several periods of higher- or lower-than-expected recoveries can be attributed to particular events: anomalous ice conditions, intensive gill-net fisheries, and oiling at sea. Thus, banding provided a useful tool not only for identifying migration and wintering areas, but also for identifying transient sources of increased mortality.

Key words: L.M. Tuck, Thick-billed Murre, *Uria lomvia*, hunting, banding, populations

RÉSUMÉ. Les débuts du baguage des guillemots de Brünnich *Uria lomvia* dans l'Arctique canadien remontent aux années 1950, sous l'égide de L.M. Tuck à l'occasion de sa visite de trois des plus grandes colonies de nidification au Canada. Jusqu'en 2010, le baguage a été effectué à huit des dix grandes colonies de nidification, pour un total de plus de 1 000 oiseaux bagués à l'île Coburg, à cap Hay et à l'île Bylot, dans l'Extrême-Arctique, ainsi qu'au détroit de Digges et à l'île Coats, dans le nord de la baie d'Hudson. Puisque les guillemots de Brünnich sont des oiseaux qui vivent longtemps, le baguage à grande échelle peut donner des résultats pendant des années. Jusqu'en 2010, les quelque 89 000 baguages effectués dans l'Arctique canadien se sont traduits par 1 757 récupérations d'oiseaux utilisables, la vaste majorité d'entre eux ayant été tuée par des chasseurs de l'ouest du Groenland ou de Terre-Neuve-Labrador. Il n'y avait aucun changement apparent dans le modèle géographique à grande échelle des oiseaux récupérés au cours de la période examinée, mais la proportion de bagues récupérées a diminué. Plusieurs périodes de récupérations plus grandes ou moins grandes que prévu peuvent être attribuées à des événements particuliers : un état anormal des glaces, la pêche intensive au filet maillant et le mazoutage en mer. Par conséquent, le baguage a représenté un outil utile non seulement pour déterminer les lieux de migration et les aires d'hivernage, mais aussi pour repérer les sources transitoires de mortalité accrue.

Mots clés : L.M. Tuck, guillemot de Brünnich, *Uria lomvia*, chasse, baguage, populations

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INTRODUCTION

> I have examined every known colony [of murres] in Newfoundland and along the Labrador coast and representative colonies in Ungava Bay, Hudson Bay and Lancaster Sound. The story of the murres is far from complete: a great deal more will be known about them twenty years hence.
>
> (Tuck, 1961:14)

The Thick-billed Murre (*Uria lomvia*) is the most numerous seabird breeding in the Canadian Arctic, with large breeding colonies extending to 76° N (Gaston et al., 2012). The species is subject to major hunting mortality in winter around the coast of Newfoundland and Labrador and in West Greenland (Tuck, 1961; Merkel and Barry, 2008). The influence of winter hunting on murre populations in Canada and Greenland has been the subject of considerable speculation and has stimulated much research on the species (e.g., Gaston and Nettleship, 1981; Gaston and Elliot, 1991; Falk and Durinck, 1992). The first to carry out fieldwork on this topic in Canada was L.M. Tuck, who in the 1950s and 1960s was the regional biologist with the Canadian Wildlife Service, based in St. John's, Newfoundland (Fig. 1).

Tuck was tasked with providing baseline information on the size and distribution of the murre population visiting Newfoundland and Labrador during the non-breeding season (Tuck, 1961) to determine the likely impact of the

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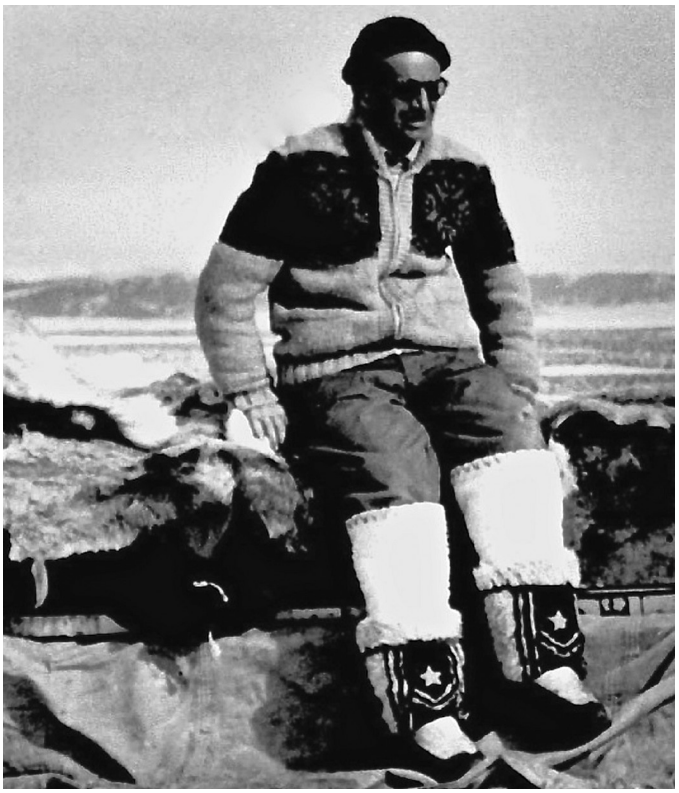

FIG. 1. Leslie M. Tuck at Bylot Island in 1957 (photographer unknown, supplied courtesy of W.A. Montevecchi).

widespread "turr" hunt occurring in the province in winter. As part of this program, he visited two of Canada's largest breeding colonies of Thick-billed Murres, both in Nunavut: Digges Sound, which he estimated at 400 000 pairs, in 1955, and Cape Hay, Bylot Island, estimated at half a million pairs, in 1957 (Fig. 2). His intention was to count the numbers of murres present and to band a sample in order to discover, from subsequent band encounters, whether or not birds from these two breeding colonies were represented in the annual hunt (Tuck, 1961). Tuck also visited the enormous colonies at Akpatok Island in 1954, but he did not band any birds there, presumably owing to the danger of climbing on the very fragile cliffs. In addition, at Tuck's instigation, a few hundred Thick-billed Murres were banded by A. Loughrey at Coats Island in northern Hudson Bay in 1953 and 1954.

Further large-scale banding by Environment Canada staff took place at Digges Sound in 1979–82 and 1992–99 (Donaldson et al., 1997; Gaston and Robertson, 2010). Although few murres have been banded at Cape Hay since Tuck's visit (small numbers were banded in 1979, resulting in 13 recoveries), large-scale banding took place at another Canadian High Arctic colony, at Cambridge Point, Coburg Island, in 1979–80, 1987, and 1993 (Donaldson et al., 1997; A.J. Gaston, unpubl. data). Elsewhere in the Canadian Arctic, banding has been carried out in one or more years since 1975 on Prince Leopold, Hantzsch, Akpatok, and Coats Islands and at the Minarets on Baffin Island (Gaston et al., 2008).

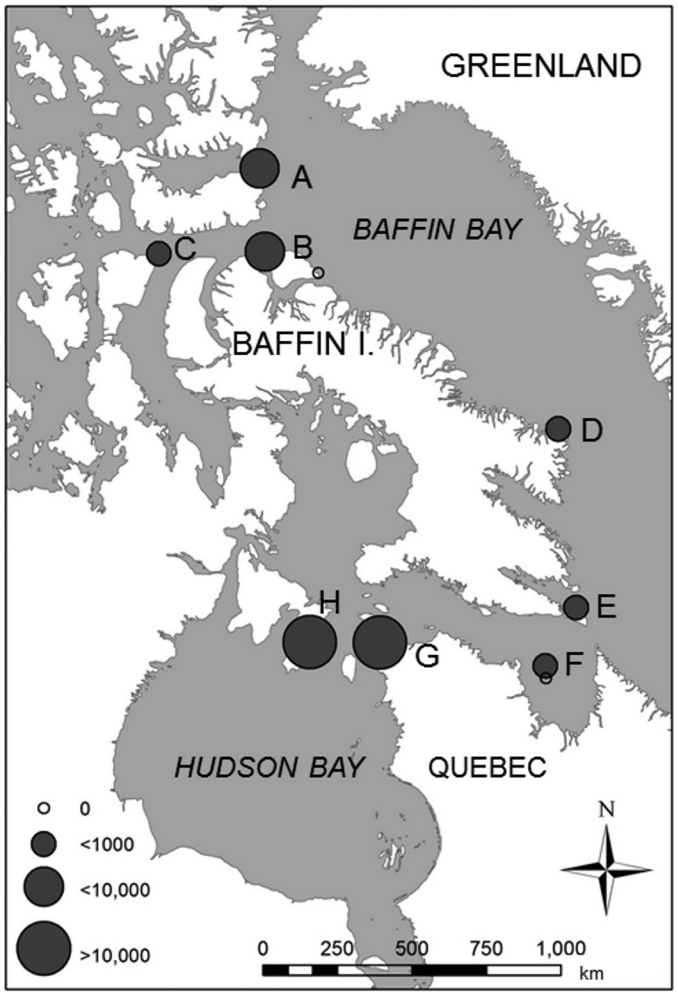

FIG. 2. Canadian eastern Arctic, showing the position of Thick-billed Murre colonies where banding has been conducted since 1953 and the approximate numbers banded at A: Coburg Island; B: Cape Hay, Bylot Island; C: Prince Leopold Island; D: The Minarets; E: Hantzsch Island; F: Akpatok Island, north colony; G: Digges Sound; and H: Coats Island.

Tuck himself described the results of his Arctic banding expeditions in his monograph on the genus *Uria* (Tuck, 1961), although not all the recoveries that resulted from that banding had been reported by the time he wrote. He concluded that the majority of birds from Cape Hay wintered off Greenland, whereas most birds from Digges Sound, and probably also from Coats Island, wintered off Newfoundland. Subsequent to that publication, additional encounters from Tuck's banding efforts were reported and analyzed by Gaston (1980). A detailed analysis of the geographical distribution and timing of recoveries in Newfoundland and Labrador up to 1993 was presented by Donaldson et al. (1997). Results from recoveries made elsewhere around the North Atlantic of Thick-billed Murres banded in Greenland (Kampp, 1988; Lyngs, 2003) and Svalbard (Bakken and Mehlum, 2005) have also been analyzed.

Apart from Tuck's efforts, little banding information is available for Canadian Arctic seabirds prior to the 1970s (Gaston et al., 2008). Given the rapid change in Arctic marine conditions that has taken place over the past

few decades (Gagnon and Gough, 2005; Derksen et al., 2012), we compare the results of banding in the 1950s with encounters from later banding efforts to assess changes since the 1950s. We review all encounters of banded Thick-billed Murres obtained from (1) Canadian High Arctic colonies (Cape Hay, Coburg Island, Prince Leopold Island, and the Minarets) and (2) Canadian colonies in Hudson Bay and Hudson Strait (Digges Sound and Coats, Akpatok, and Hantzsch Islands). We examine the frequency of encounters in relation to age and time from banding (for birds banded as adults), the encounter locations, and the nature of the recovery. The analyses are intended to provide broad overviews of banding results, with an emphasis on changes since the 1950s, rather than detailed analyses of survival or dispersal from individual sites.

METHODS

Details of all banding and encounters of eastern Canadian Arctic-banded Thick-billed Murres up to 2010 were obtained from the Bird Banding Office of the Canadian Wildlife Service. The data were sorted by colony of origin, age at banding, and date and country of recovery. We checked for mismatches between recovery country and encounter coordinates and discarded data with such mismatches. Recovery countries were Canada, Greenland, the United States, and France (represented by St. Pierre and Miquelon islands, just off Newfoundland), but the two recoveries from St. Pierre and Miquelon were pooled with those from Canada. The small number from the United States (3) and those reported away from the coast (5, some or all of which may have involved incorrect locations) were excluded from any analyses. From the original 1814 records received, 57 unreliable, inland, or U.S. records were eliminated, leaving a basic set of 1757 recovery records for analysis. However, not all information was available for all records.

Regulations on murre hunting in Newfoundland and Labrador, the only region of Canada where hunting murres is legal, were changed radically in 1993, resulting in a much smaller take in subsequent years (Chardine et al., 1999). Consequently, recoveries of birds from Coats Island and Digges Sound have been split into years up to 1992 and later years. For Coats Island recoveries, the period after 1992 was further divided into years before and after 2000 to take into account ongoing changes in the recovery patterns from that site (Gaston and Robertson, 2010). Analyses of recoveries in relation to time elapsed from banding were restricted to the first 10 years after banding because Tuck had used aluminum bands, which are subject to premature loss from abrasion and corrosion (Donaldson et al., 1997; Gaston et al., 2013). Statistical analyses were carried out using Statistica 7.1 (Statsoft, 2005). All percentage data were arcsin transformed, and all *p*-values reported are two-tailed.

RESULTS

More than 89 000 Thick-billed Murres were banded in the Canadian Arctic (north of 60˚ N) up to 2010, of which 10% were banded as adults and the remainder as nestlings or fledglings (Table 1). Banding was carried out in the Hudson Bay–Hudson Strait region at Digges Sound (mainly on East Digges Island) by L.M. Tuck in 1955 and by other Environment Canada staff in 1979–82, 1992–94, and 1999 (A.J. Gaston, unpubl. data). Elsewhere, banding took place at Coats Island in 1981 and annually from 1984 onwards (Gaston and Robertson, 2010), at Hantzsch Island in 1982 (A.J. Gaston, unpubl. data), and at the north colony on Akpatok Island in 1993 (G. Chapdelaine, unpubl. data) (Table 1).

In the High Arctic, banding was carried out by L.M. Tuck at Cape Hay in 1957. Subsequent banding there was carried out in 1978–79. Banding was also done at Prince Leopold Island in 1975–77 and sporadically after 2000 (although no recoveries have been obtained from this period); at the Minarets, Baffin Island, in 1985 (no recoveries to date); and at Cambridge Point, Coburg Island, in 1979–81, 1987, 1993, and 1998 (A.J. Gaston, D.N. Nettleship, and H.G. Gilchrist, unpubl. data). The only Canadian Arctic colonies where no banding has taken place are the south colony on Akpatok Island and Cape Graham Moore on Bylot Island (see Gaston et al., 2012 for colony sizes).

Recoveries

Overall, 2.7% of birds banded as adults and 1.7% of those banded as chicks resulted in recoveries (Table 1). The highest rates of recovery resulted from banding at Cape Hay in both periods: 9.5% of 1363 adults banded in 1957 were recovered (Table 1), the last one in 1976, 19 years after banding. The lowest rates of recovery were for Digges Sound, where not one of the 758 adults banded in 1979–99 was recovered. The proportion recovered fell over time at all colonies where banding was carried out more than once, except for nestlings banded at Digges Sound, where the proportion increased between 1955 (0.7%) and 1979–82 (1.4%). The change was especially marked at Coats Island, where recoveries of adults fell from 2.7% in 1953 to 0.4% in 1981–92, and recoveries of chicks from 2.8% in 1981–92 to 1.5% in 1993–2000 and 0.4% in 2001–10.

Method of Recovery

Most recoveries came from birds shot in Newfoundland and Labrador (97% of those recovered in Canada) and West Greenland (92% of those recovered in Greenland). The only other known sources of mortality (as opposed to "found dead," etc.) were oiling (0.3% of birds recovered in Canada, none in Greenland), and drowning in fishing nets (0.3% of recoveries in Canada, 2.3% of those in Greenland). All but one of the oiled recoveries (5) took place between 1988 and 2004 and involved birds banded at Coats Island (the

TABLE 1. Numbers of adult and nestling Thick-billed Murres banded at Canadian Arctic colonies during 1955–2010 and proportions recovered in Canada and Greenland.

		Banded		Recovered in Canada		Recovered in Greenland		% of recoveries in Greenland	
Colony	Year	Adult	Chick	Adult	Chick	Adult	Chick	Adult	Chick
Digges Sound	1955	2002	8027	22 (1.1%)	53 (0.7%)	2 (0.01%)	5 (0.06%)	8.3	8.6
	1979–82	605	5080	0 (0%)	68 (1.3%)	0 (0%)	4 (0.08%)		5.6
	1992–99	153	7963	0 (0%)	132 (1.7%)	0 (0%)	6 (0.07%)		4.3
Coats I.	1953–54	525	0	7 (1.3%)		1 (0.2%)		12.5	
	1981–92	1384	19545	33 (2.4%)	529 (2.7%)	1 (0.07%)	18 (0.09%)	2.9	3.4
	1993–2000	894	14639	2 (0.2%)	205 (1.4%)	2 (0.2%)	10 (0.07%)	50	4.7
	2001–10	882	13941	1 (0.1%)	53 (0.4%)	0 (0%)	2 (0.01%)	0	3.6
Hantzsch I.	1982	72	448	3 (4.2%)	7 (1.6%)	0 (0%)	2 (0.4%)	0	22
Akpatok I.	1993	18	542	0 (0%)	8 (1.5%)	0 (0%)	0 (0%)		0
The Minarets	1985	115	35	0 (0%)	0 (0%)	0 (0%)	0 (0%)		
C. Hay, Bylot I.	1957	1363	1137	23 (1.7%)	27 (2.4%)	107 (7.6%)	40 (3.5%)	82	60
	1978–79	148	65	4 (2.7%)	0 (0%)	6 (4.1%)	3 (4.6%)	60	100
Coburg I.	1979–81	33	3229	4 (12.1%)	89 (2.8%)	2 (6.1%)	22 (0.7%)	33	20
	1987	1	1680	0 (0%)	51 (3.0%)	1 (100%)	5 (0.3%)	100	8.9
	1993	186	4310	0 (0%)	68 (1.6%)	1 (0.5%)	18 (0.4%)	100	21
	1998	0	85		0 (0%)		0 (0%)		
Prince Leopold I.	1975–78	42	167	0 (0%)	0 (0%)	6 (14.3%)	4 (2.4%)	100	100
	1998–2010	410	22	0 (0%)	0 (0%)	0 (0%)	0 (0%)		

other one was banded at Coburg Island). All the net drowning recoveries in Canada (4) were made in 1981–86 and involved birds from Coats Island, while all the net drownings in Greenland (6) took place during 1969–73 and involved birds banded by Tuck at Cape Hay.

Hudson Bay and Hudson Strait Colonies

The rates and geographical patterns of recoveries of birds banded at Digges Sound in 1955 and those banded from 1979 onwards were very similar (Table 1). The proportion of recoveries in Greenland ranged from 4% to 9% among time periods, with no significant variation ($\chi^2 = 3.9$, df = 2, $p > 0.1$; Table 1). However, although 1.1% of adults banded in 1955 were subsequently recovered, there have been no recoveries of adults banded later.

When the number of recoveries of birds banded as nestlings is plotted against age for 1955 and the later periods, the relationships are very similar, which suggests that the mortality rate did not change much for this population (Fig. 3). Likewise, although the 1953 sample from Coats Island is small, there is no indication of any major change in wintering pattern between 1953 and 1981–92 (Table 1). The radical change that occurred in the proportion of birds banded as adults and recovered in Greenland between 1981–92 (3%) and 1993–2000 (50%; Fisher exact $p = 0.02$) is mostly due to a dramatic decline in the number of adults recovered in Canada.

Of the 12 recoveries of birds from Hantzsch Island, two took place in Greenland (both banded as nestlings) and 10 in Newfoundland and Labrador. Three of these 10 were banded as adults and seven as nestlings; the latter ranged in age from one to five years at recovery. Eight birds from Akpatok Island, all banded as fledglings, were recovered in Newfoundland and Labrador between one and 10 years after banding.

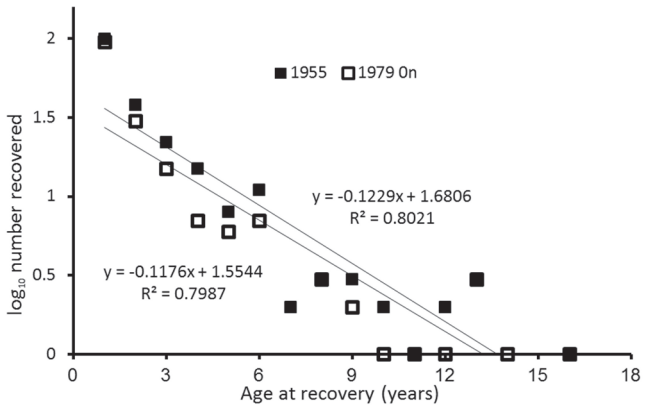

FIG. 3. Number of recoveries ($\log_{10}$) by age class for Thick-billed Murres banded as nestlings at Digges Sound by L.M. Tuck in 1955 and at the same location by others during 1979–99. The slopes of these two regressions were not detectably different $F_{1,24} = 0.32$, $p = 0.57$.

High Arctic Colonies

Recoveries of birds banded at Cape Hay, both in 1957 and in 1978–79, were made predominantly in Greenland, mostly between 66° and 69° N (Disko Bay south to Søndre Strømfjord). For the 1957 sample, 40% of birds banded as nestlings were recovered in Canada, compared to only 18% of those banded as adults (Fisher exact $p < 0.01$). Birds banded as nestlings were mainly recovered in their first year (67% of recoveries in Greenland, 50% of those in Canada). All recoveries of birds banded at Prince Leopold Island were made in Greenland. A startling 14% (6/42) of those banded as adults in the 1970s were recovered, whereas no recoveries have been reported from 410 adults banded since 1998 (Fisher exact $p < 0.001$). Birds banded at Coburg Island, in contrast to those banded at the other High Arctic colonies, were recovered primarily in Newfoundland and Labrador in all three periods, with no significant variation among periods ($\chi^2 = 3.9$, df = 2, $p > 0.1$).

Age Effects

The only colonies at which substantial numbers of adults were banded were Digges Sound (1955), Cape Hay (1957), and Coats Island (1981–2000). The distribution of these recoveries in relation to time elapsed from banding over the first 10 years does not follow the expected decline with age (Fig. 4) for either the Cape Hay sample ($R^2 = 0.06$, $p > 0.1$) or the Digges Sound sample ($R^2 = 0.20$, $p > 0.1$), although there is a more typical relationship for the Coats Island sample ($R^2 = 0.64$, $p = 0.006$). In contrast, all three samples of birds banded as nestlings at the same time show a typical decline in recoveries with increased time from banding (Fig. 4).

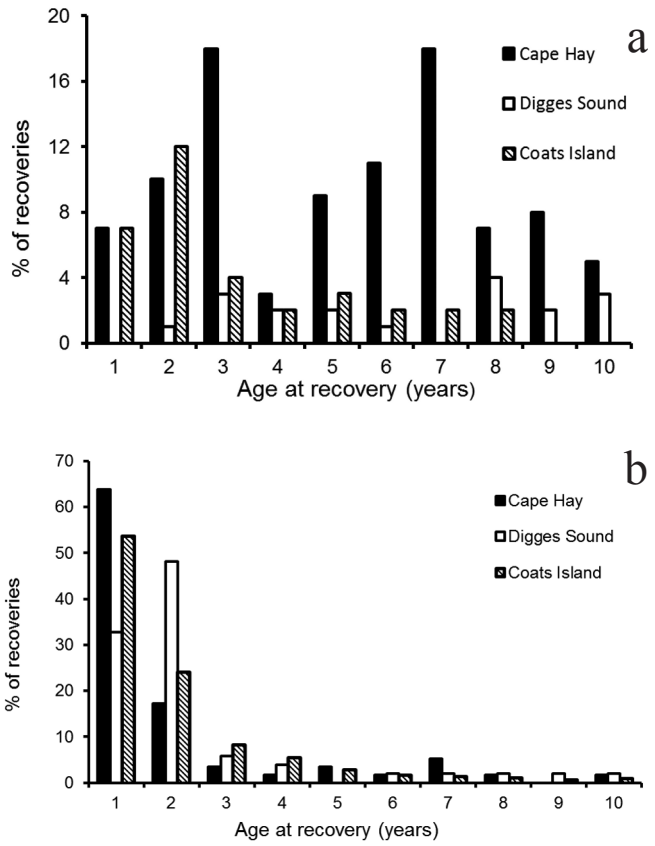

FIG. 4. Age at recovery for Thick-billed Murres banded (a) as adults and (b) as chicks at Digges Sound in 1955, Cape Hay in 1957, and Coats Island in 1981–92. Note that the vertical scale differs for adults and chicks.

DISCUSSION

The results presented here relating to the geographical distribution of recoveries generally confirm previous analyses in showing that there is much variation among colonies. Birds from colonies in the Hudson Bay–Hudson Strait region were mostly recovered in Newfoundland and Labrador, while those from the High Arctic were mostly recovered on the west coast of Greenland, except that those from Coburg Island were recovered in both regions and birds banded as nestlings were predominantly recovered in Newfoundland and Labrador. Given that hunting continues in West Greenland and in Newfoundland and Labrador and that bird deaths from other causes are very unlikely to be encountered, it is not surprising that these regions provided the main source of recoveries throughout the period analyzed. However, for birds banded at Coats Island, the proportion of recoveries in Greenland has increased in spite of a reduction in the Greenlandic harvest (Merkel and Christensen, 2008), presumably because of an even steeper decline since the 1980s in the numbers hunted in Newfoundland and Labrador (Gaston and Robertson, 2010).

Although comparison of the 1950s banding events with later banding on the same or nearby colonies does not suggest much change in the geographical patterns of recovery, the proportion recovered has declined, except in the case of nestlings banded at Digges Sound in 1955, of which only 0.7% were recovered (compared with 1.3% in the 1980s). A decline in the proportion of Thick-billed Murres recovered among those banded at colonies in Svalbard was reported by Bakken and Mehlum (2005), with a reduction from 2.9% for birds banded as adults before 1980 to 0.3% for those banded after 1989. The decline in recoveries from Newfoundland and Labrador, especially of birds from Coats Island, for which available samples were large, probably results from a combination of declining harvest levels and decreased winter ice, which has caused birds to winter to the north of their former range, out of reach of potential hunters (Gaston and Robertson, 2010).

Tuck used standard U.S. Fish and Wildlife Service size 6 bands, which are rather large for Thick-billed Murres, especially small nestlings. During banding at Digges Sound in the 1980s, Environment Canada banding crews found that such bands had to be squeezed to an oval shape to stop them from slipping over the foot. Later, they changed to using size 5 bands (Gaston and Donaldson, 1994). Recoveries of birds banded as nestlings with size 5 bands in 1981–82 (1.5%) were almost double those for birds banded with size 6 bands in 1979–80 (0.8%), although this result could have been affected by inter-year variation. Given the enormous number of nestlings banded in 1955 at Digges Sound (8000), Tuck's Inuit assistants must have had to work very fast, and it seems likely that they did not always squeeze the bands to the necessary shape and many bands fell off as a result. This situation probably led to an overestimate of the effective banding sample and a consequent depression in the percentage recovered.

The problem of band loss was also recognized by banders in Greenland, where reported banding numbers were probably similarly inflated (Kampp, 1991). Given that Thick-billed Murres leave the colony at less than 25% of adult body mass, band loss prior to colony departure is always a possibility. The incidence probably varies substantially among banded samples depending on the size of the bands used and the skill of the bander, which complicates the comparison of recovery rates among samples. Banding at all Canadian Arctic colonies since 1981 has been carried

out with size 5 bands, except at Coats Island, where special triangular murre bands, designed originally by the British Trust for Ornithology (Harris and Rothery, 2004), have been used since 1985. These bands rarely fall off, if properly applied (A.J. Gaston, pers. obs.), so the relatively low recovery rate for Coats Island birds, especially since 2001, is unlikely to have been caused by band loss.

The proportion of banded birds recovered from Cape Hay in 1957 was unusually high (9.5%) for birds banded as adults. Lyngs (2003) gives 8.8%, but the source of that sample is different from the one used here. This high proportion is especially noteworthy because aluminum bands were used. For gulls, the probability of recovery was twice as great for stainless steel as for aluminum bands (Gaston et al., 2013), suggesting that, in the case of the 1950s samples, modern bands would have yielded even higher recovery rates. In fact, Tuck himself considered that "because of abrasion and salt-water corrosion bands do not last more than five years" (Tuck, 1961:88), an assumption proved overly pessimistic by the subsequent pattern of recoveries. One bird presumably banded by Tuck in 1955 was captured at Digges Sound in 1980, but by that time the band was very thin and unreadable. In contrast, numerous stainless steel bands used on Thick-billed Murres at Coats Island and elsewhere have remained readable after more than 20 years on the birds (A.J. Gaston, pers. obs.).

Although the sample banded at Prince Leopold Island in the 1970s was small, the recovery of 14% in Greenland up to 1980 suggests that high hunting pressure persisted there at least through the 1970s. Considering that a normal adult annual survival rate for Canadian Thick-billed Murres is ~90% (Gaston and Robertson, 2010; Smith and Gaston, 2012), recovery rates in the region of 10%, mostly shot, indicate a very high hunting pressure. The maximum recovery rate for Svalbard-banded adults was only 2.2% at Kongsfjorden/Krossfjorden (Bakken and Mehlum, 2005). However, numbers given by Kampp (1991) for recoveries of Thick-billed Murres banded in West Greenland suggest recovery rates higher than those for Cape Hay–banded birds. Among 2424 chicks banded in Disko Bay in 1946–63, 12.7% were recovered, while of 708 adults banded in the Upernavik district in 1952–80, 18.5% were recovered. Many recoveries of Cape Hay birds were reported from these districts, and these observations confirm the suggestions of Evans and Kampp (1991) and Kampp et al. (1994) that hunting pressure in West Greenland during the 1950s to 1970s was extremely heavy. In contrast, no birds from Prince Leopold have been recovered from bandings since 1998, indicating that hunting pressure was indeed reduced by the harvest restrictions put in place in Greenland in 1977 (Evans and Kampp, 1991) and further restrictions placed in 2002 (Merkel and Barry, 2008).

Despite the high overall recovery rates from Tuck's banding at Cape Hay in 1957, the timing of recoveries of adults was unusual in being low during the first three years after banding (Fig. 4). In the period 1957–59, a large sea-ice anomaly in Davis Strait produced heavier-than-normal ice conditions (Deser et al., 2002; Stern and Heide-Jørgensen, 2003). If ice conditions in 1957–59 excluded the Cape Hay murres from areas off Greenland where they would normally have wintered, this change could explain the low rate of recoveries during that period. Conversely, the peak of recoveries in the 1962–63 and 1963–64 winters coincided with a very low North Atlantic Oscillation (NAO) index (Hurrell and NCAR Staff, 2014), which is correlated with low ice in the Labrador Sea and West Greenland. Perhaps the low ice enabled birds to winter farther north than usual, creating the peak of recoveries during that period (Fig. 4).

Tull et al. (1972) reported a very high mortality of murres, mainly *U. lomvia*, in a salmon drift net fishery off West Greenland during 1969–71. This fishery continued for several years thereafter (Falk and Durinck, 1991) and resulted in many recoveries of Greenland-banded Thick-billed Murres (Lyngs, 2003). It may not be surprising, therefore, that all six net-drowned recoveries of Thick-billed Murres from Cape Hay occurred in Greenland during the same period. The bycatch recoveries constituted 54% of all recoveries in Greenland during 1969–73, suggesting that gill nets constituted an important source of mortality for Cape Hay birds during that period. If the fishery had taken place sooner after the banding, presumably the number of recoveries from that source would have been much greater.

This fishery was regulated in ways that greatly reduced the bycatch after 1973 (Falk and Durinck, 1991), which probably accounts for the lack of net-drowned recoveries subsequently. By the same token, Canadian net-drowned recoveries took place in the 1980s, a period when bycatch in the Atlantic cod *Gadus morhua* fishery off Newfoundland was high (Piatt and Nettleship, 1987). There have been no recoveries from fishing nets since the moratorium on groundfish fishing off Newfoundland in 1992, and almost all of the murres in the bycatch of the reduced fishery off Newfoundland are breeding Common Murres (*U. aalge*) (Ellis et al., 2013).

The relatively small proportion of recoveries that involved oiled birds is surprising, given that hundreds of thousands probably were oiled annually in the 1990s (Wiese et al., 2004). However, the vast majority of these birds may never have come to shore, and even those that did so had little chance of being recovered, given the very few beaches examined for beached birds (Robertson et al., 2006).

Given that numbers of bands being reported by hunters in both West Greenland and Newfoundland and Labrador appear to have greatly diminished since the 1970s, and assuming that reporting rates have not changed, it is worth considering evidence that heavy hunting pressure has had an adverse effect on populations. Tuck estimated 400 000 pairs of murres breeding at Cape Hay in 1957. In 1976, the population was estimated at 140 000 pairs (Birkhead and Nettleship, 1980). Although no later estimates are available for Cape Hay, monitoring at other Arctic colonies suggests a modest increase since the 1970s (Gaston, 2002; Gaston et al., 2012). We have no details of Tuck's census methods,

and the technique used in 1976 probably underestimated the population (Gaston et al., 2012), so it is difficult to assess the significance of the apparent change in numbers between the 1950s and 1970s. However, the very heavy hunting pressure experienced by birds from this colony, both in West Greenland and in Newfoundland and Labrador, could well have caused a substantial decrease over two decades.

In Canada, a transition from rowing boats and muzzle-loading shotguns to speedboats and pump-action shotguns took place from the 1950s onwards (Elliot, 1991; Elliot et al., 1991). Probably a similar transition took place in Greenland at about the same time. The greater efficiency of the new tools almost certainly increased the harvest of murres. However, the kill in both nations has decreased progressively since the 1970s, partly through reduced hunting, partly through bag limits and other regulations (Chardine et al., 1999; Merkel and Barry, 2008). Although the evidence is scarce, it seems reasonable to suggest that in the period following Tuck's visit to Cape Hay, heavy hunting, as well as gill-net mortality off West Greenland, may have caused a decrease in that population. Further observations are required to determine whether this very significant colony has recovered since the 1970s.

CONCLUSIONS

Banding of Thick-billed Murres since the 1950s has served mainly to track the relative impact of hunting in Greenland and Canada. Because murres are long-lived, the one-year mass banding programs conducted by L.M Tuck provided useful information for many years. Subsequently, revival of Arctic banding after 1975 confirmed and reinforced the conclusions originally derived from Tuck's work. Information on the method of recovery seems to have provided a sensitive signal of changes in bycatch and oiling, although in the case of oiling, increased surveying and reporting from the 1980s onward will have affected recovery probability. Given the burgeoning use of electronic position recording devices in recent years (Robertson et al., 2012), it seems likely that banding, as a means of monitoring migration routes and wintering areas, will decline in importance. Nevertheless, the substantial efforts of L.M Tuck in the 1950s and of other Environment Canada personnel since 1975 have provided irreplaceable data on the movements, mortality, and survival of Thick-billed Murres during the past six decades.

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