PEARY CARIBOU AND MUSKOX ABUNDANCE AND DISTRIBUTION ON THE WESTERN QUEEN ELIZABETH ISLANDS, NORTHWEST TERRITORIES AND NUNAVUT JUNE-JULY 1997

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ABSTRACT

Peary caribou (*Rangifer tarandus pearyi*) have been recognised nationally as "Endangered" since 1991. Both Peary caribou and muskoxen (*Ovibos moschatus*) experienced major winter/spring die-offs during 1994/95 and 1995/96 on, at least, the western Queen Elizabeth Islands of Bathurst and its satellite islands of Vanier, Cameron, Alexander, Massey and Marc. Those known losses and a lack of recent information for other western Queen Elizabeth Islands led us to carry out an aerial survey to estimate Peary caribou and muskox abundance and relative distributions in summer 1997. We used a standard, systematic, stratified, fixed-strip width (0.5 km either side of the transect line) aerial survey design. A fixed-over-winged, single engine Helio-courier was the survey aircraft and flew at *ca*. 100 m above ground level and at an airspeed of *ca*. 160 km • h^{-1}. We saw live caribou on only 6 of the 15 islands surveyed and caribou carcasses on 12 islands. We saw only 2 calves among 378 caribou counted. We estimated 1086 $\pm$ 131 SE 1+ yr-old Peary caribou within the 87 992 km^2 survey area: Melville Island, 787 $\pm$ 97 SE (1.9 caribou • 100 km^{-2}) at 18% aerial coverage; Bathurst Island, 74 $\pm$ 25 SE (0.5 caribou • 100 km^{-2} at 20% coverage; and Prince Patrick Island, 84 $\pm$ 34 SE (0.5 caribou • 100 km^{-2}) at 16% coverage. We estimated from carcass counts that 831 $\pm$ 86 SE Peary caribou had died during winter/spring 1996/97 on the western Queen Elizabeth Islands. The number of carcasses estimated for Bathurst and its satellite islands (408 $\pm$ 53 SE) indicates that most of the Peary caribou alive there in summer 1996 died during the third of three exceptionally severe winter/spring periods with twice the long-term average snowfall. The 1997 estimate is the lowest recorded for the western Queen Elizabeth Islands since the first aerial survey estimate in 1961 (when the mean estimate equalled 19 456 1+ yr-old Peary caribou) and represents an overall 94% decline in the mean estimated number over 36 years. The available evidence is that the 43% decline in the number of Peary caribou across the western Queen Elizabeth Islands during winter/spring 1996/97 was caused by caribou dying during the third consecutive unusually severe winter and spring on Bathurst and its satellite islands and a similarly severe winter/spring on the other western islands in at least 1996/97. We saw 1066 1+ yr-old muskoxen on only 4 of the 15 islands surveyed, 2 calves and 57 muskox carcasses on 3 of those 4 islands. We estimated 2515 ○ 276 SE 1+ yr-old muskoxen within the entire survey area with an overall mean density of only 2.9 muskoxen • 100 km^{-2}. We suggest that only exceptionally extreme environmental episodes could cause such a degree of spatially and temporally correlated deaths in two species with markedly different seasonal and annual site-use patterns on the same ranges.

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INTRODUCTION

In 1991, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed Peary caribou (*Rangifer tarandus pearyi*) as an "Endangered" form of wildlife in Canada based on their overall decline in the mean estimated number between 1961 and 1987 (Miller 1990b, COSEWIC 1991). The total number (including calves) on the western Queen Elizabeth Islands dropped from 24 363 in 1961 (Tener 1963) to 2676 in 1974 (Miller *et al.* 1977a). Subsequently, after 1974 and before 1997, Melville Island was only surveyed in 1987 and Prince Patrick Island in 1986 (Miller 1987b, 1988).

More information is available for Bathurst and its satellite islands as the Canadian Wildlife Service undertook research on caribou ecology between 1989-96. Also, aerial surveys were carried out and population sizes were estimated in 1981 (Ferguson 1987: Bathurst Island only), 1985, 1988 and 1993 (Miller 1987a, 1989, 1995b, 1998). Caribou numbers had begun to increase after 1975, seemingly slowly at first, then more rapidly from the mid 1980s until the population reached about an estimated 3000 caribou in summer 1994 (Miller et al. 1977a, Miller 1987a, 1998, 1989: ca. ten-fold increase in 20 years). The Peary caribou population within the Bathurst complex then collapsed during the subsequent two winters and springs of 1994/95 and 1995/96, which respectively experienced the highest and second highest total snowfalls between 1 September and 31 May in 50 years of records at Resolute, Cornwallis Island (Environment Canada, Climate Archives, Resolute 1948-98). The 1996 summer aerial survey estimated 1143 ± 164 SE dead and 452 ± 108 SE live caribou - an 83-85% decline since summers 1993 and 1994 (Miller 1998).

The seriousness of the 1994-96 decline on Bathurst and its satellite islands and the unknown status on the other islands led to this survey in summer 1997, which was designed to cover all the western Queen Elizabeth Islands (Fig. 1). We focused on the western Queen Elizabeth Islands because Tener (1963) reported that most all (94%, including calves) of the estimated Peary caribou in 1961 were on the western Queen Elizabeth Islands, even though those islands are only 22% of the Queen Elizabeth Islands collective island-landmass. Also, financial restraints and logistical reasons prevented us from extending our survey effort to other Queen Elizabeth Islands (or increasing aerial coverage in relatively high-density strata within our 1997 survey area). This report describes the abundance and distributions of Peary caribou on the 15 western Queen Elizabeth Islands surveyed by air in summer 1997 and includes our interpretation of those findings. We also recorded muskox abundance and distribution, which we include in this report.

Study Area

All of the Canadian High Arctic Islands entirely north of *ca.* 74° N latitude are collectively known as the Queen Elizabeth Islands (*ca.* 415 000 km^2). The planned 1997 survey area was to include 16 western Queen Elizabeth Islands with a collective island-landmass of 90 792 km^2: Melville, 42 220 km^2; Bathurst, 16 090 km^2; Prince Patrick, 15 830 km^2; Mackenzie King, 5100 km^2; Borden, 2800 km^2; Eglinton, 1550 km^2; Lougheed, 1300 km^2; Byam Martin, 1160 km^2; Vanier, 1131 km^2; Cameron, 1064 km^2; Brock, 790 km^2; Emerald, 550 km^2; Alexander, 490 km^2; Massey, 441 km^2; Helena, 220 km^2; and Marc, 56 km^2.

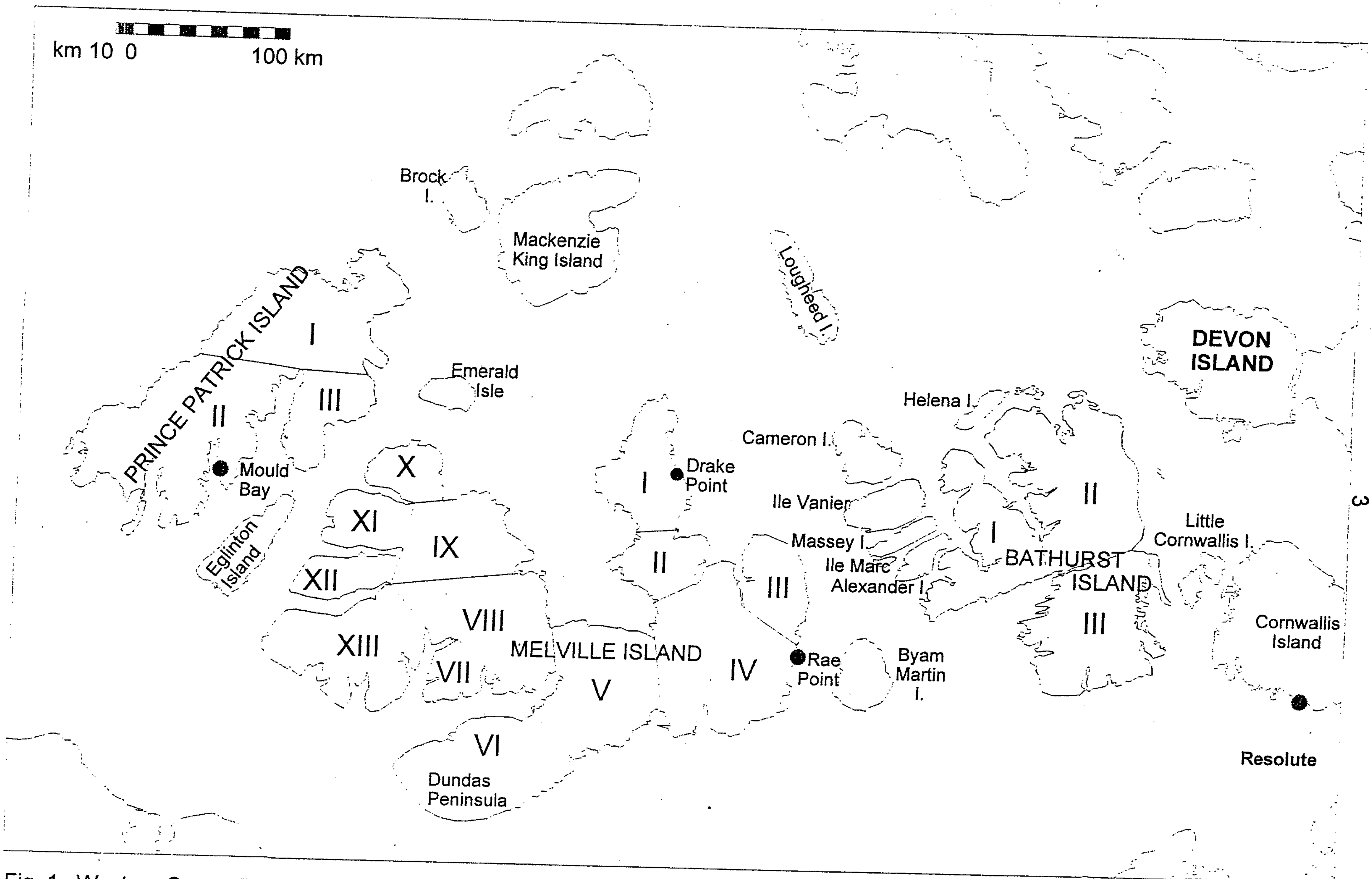

Fig. 1. Western Queen Elizabeth Islands surveyed by air for Peary caribou and muskooxen, Northwest Territories and Nunavut, June-July 1997, showing aerial survey strata

We refer herein to five groupings of islands as follows: (1) Melville-Prince Patrick complex (61 310 km^2) - Melville Prince Patrick, Eglinton, Byam Martin and Emerald islands; (2) Bathurst complex (19 492 km^2) - Bathurst, Vanier, Cameron, Alexander, Massey, Helena and Marc; (3) Prime Minister Group (8690 km^2) - Mackenzie King, Borden and Brock; (4) Governor General Group (3182 km^2) - Vanier, Cameron, Alexander, Massey and Marc; and (5) Lougheed Island. As Borden Island was not surveyed, the size of the resultant study area was 87 992 km^2. The divisions for the Melville-Prince Patrick complex and the Bathurst complex and the subdivisions within those two island-complexes are based on information for relative numbers and sex/age distributions, seasonal movements and seasonal and annual range distributions (Tener 1963, Fischer and Duncan 1976, Miller et al. 1977a, 1977b, Miller 1987a, 1987b, 1988, 1989, 1990a, 1990b, 1995a, 1995b, 1998, Ferguson 1987, Miller and Barry 1992; F.L. Miller, unpubl. VHF radio and satellite location-data). The Melville-Prince Patrick complex and the Bathurst complex are currently recognised as the two major "management units" for the recovery of Peary caribou on the western Queen Elizabeth Islands by the Recovery of Nationally Endangered Wildlife Peary Caribou Recovery Team in their National Strategy Plan.

The Prime Minister Group and the Governor General Group are official geographical names applied to those two respective island groupings. The Prime Minister Group is treated by us as a separate unit because of its remote location in the extreme northwest of the western Queen Elizabeth Islands and their relatively small collective size compared to the Melville-Prince Patrick complex and the Bathurst complex. The Governor General Group is included as the five western major satellite islands within the Bathurst complex along with Helena Island as the major northern satellite island of Bathurst. Lougheed Island is considered separate as it was not included by the Peary Caribou Recovery Team in either the Melville-Prince Patrick complex or the Bathurst complex.

The 15 islands actually surveyed by us in summer 1997 (Borden was not surveyed) is, based on values given in Tener (1963: 87 992 km^2), 21% of the collective island-landmass of the entire Queen Elizabeth Islands. However, those islands held 94% of the 25 845 Peary caribou and 29% of the 7421 muskoxen estimated on the Queen Elizabeth Islands in summer 1961 (Tener 1963).

METHODS

We carried out a systematic, stratified, fixed-strip (0.5 km either side of the transect line) aerial survey design, with planned uniform coverage of *ca*. 20% for the survey strata on Melville, Bathurst and Prince Patrick islands (realised coverage varied due to weather problems). Smaller islands were each delineated as a single stratum. We used the same strata as in 1972-74 (Miller *et al*. 1977a) which were convenient land blocks rather than based on caribou and/or muskox mean densities. We chose uniform coverage at 20%, as we had neither funds nor time to undertake a reconnaissance survey and then assign higher coverage to areas with higher caribou densities. The transect lines ran north-south except on Lougheed Island where they were oriented east-west. Transect strip-width was 1.0-km (0.5-km strip on each side of the aircraft flight path). We calculated where to place a marker for the transect boundary on rope stretched from an eyebolt on the fuselage of the plane to an eyebolt on each wing after Norton-Griffith (1978). The survey altitude was 100 m above ground level and the survey airspeed was about 160 km $\bullet$ h^{-1}.

We counted caribou and muskoxen and recorded them as "on-transect" or "off-transect" but we made no effort to classify them by sex or age classes other than calves as a readily identifiable age class. We also recorded caribou and muskox carcasses but we calculated carcass estimates only for caribou. For caribou we only recorded carcasses that looked like they were caribou that had died the previous winter. Our criteria were that articulated bones (rib cages, limbs) were visible and that the hair patch was conspicuous and not obviously scattered by wind. For muskoxen, we recorded whether the carcass was intact or scavenged and we did not record skeletons.

We flew in a fixed-over-winged, single engine Helio-Courier aircraft on tundra tires. The survey crew consisted of the pilot in the left front seat, a navigator in the right front seat and right and left observers in the two rear seats. The pilot plotted locations on 1:250 000 map sheets while the navigator recorded the observer's sightings of caribou and muskoxen as being "on-transect" or "off-transect". The Environment Canada weather station at Mould Bay, Prince Patrick Island, the Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development, polar bear project's cabin on southwest Melville Island, and Canadian Wildlife Service's cabin on northeast Bathurst Island were used as survey bases.

We used Jolly's (1969) method #2 for unequal-sized sample units to calculate population estimates. Our estimates and those used from the literature are for 1+ yr-old animals only when feasible (unless otherwise identified). When necessary for previous estimates that included calves, we adjusted the estimate by the associated percentage of calves to obtain an estimate of 1+ yr-old animals only. We assessed differences between successive population estimates by calculating their respective confidence intervals: we assumed that pairs of estimates whose confidence intervals overlapped were not ($p > 0.05$) significantly different while those that showed no overlap were significantly different ($p < 0.05$).

RESULTS

We completed the survey between 29 June and 24 July 1997, flying 188 hours at an average aerial coverage of 17% (15 174 km^2) of the 87 992 km^2 survey area to estimate Peary caribou and muskox numbers (Tables 1-9; Figs. 1-8, App. A-E). Survey conditions were generally favourable (App. A). We covered the major islands (Melville, Bathurst and Prince Patrick) and their satellite islands with minimal problems (see App. A and individual islands for details) but fog prevented us from surveying Borden Island.

We estimated 1086 ± 131 SE 1+ yr-old Peary caribou within the 87 992 km^2 survey area with an overall mean density of only 1.2 caribou • 100 km^{-2} (Tables 2, 3, 6, 8). Eighty-seven percent of them were estimated on the three major islands - Melville, Bathurst and Prince Patrick (Tables 2, 3, 6, 8). We saw 188 Peary caribou carcasses, 148 on-transect and 40 off-transect and estimated from on-transect carcasses that 831 ± 86 SE 1+ yr-old Peary caribou had died during winter/spring 1996/97 on the western Queen Elizabeth Islands (Table 1). We saw only 2 calves among the 378 caribou counted, none was on any of the three major islands - Melville, Bathurst and Prince Patrick. Live caribou were seen on only 6 of the 15 islands surveyed but we saw caribou carcasses on 12 islands. We did not find live caribou on Eglinton, Byam Martin, Vanier, Cameron, Brock, Emerald, Alexander, Helena and Marc islands.

We saw 1066 1+ yr-old muskoxen on 4 of the 15 islands surveyed and 57 muskox carcasses on 3 of those 4 islands. Only two muskox calves were seen among all of the muskoxen counted. We estimated 2515 ± 276 SE 1+ yr-old muskoxen within the entire survey area with an overall mean density of about 2.9 muskoxen • 100 km^{-2}

(Tables 4, 5, 7, 9). Ninety-nine percent of them were estimated on the three major islands: Melville Island, 2258 ± 268 SE; Bathurst Island, 124 ± 45 SE; and Prince Patrick Island, 96 ± 42 SE. (Tables 4, 5, 7, 9). No estimate was made for the number of dead muskoxen.

Table 1. Estimated numbers of dead Peary caribou on the western Queen Elizabeth Islands, Northwest Territories and Nunavut, June-July 1997.

Islands[a] by (island-complex)	Carcass counts		Dead caribou estimates	
	On-transect	Off-transect	Mean	± SE
(Melville-Prince Patrick)	(61)	(10)	(371)	(63)
Melville	24	6	150	48
Prince Patrick	30	1	178	37
Byam Martin	5	3	26	11
Emerald	2	0	17	16
(Bathurst complex)	(82)	(23)	(408)	(53)
Bathurst	16	1	82	18
Vanier	20	8	95	26
Cameron	38	12	188	30
Alexander	1	1	5	5
Massey	3	0	13	11
Marc	4	1	25	29
(Prime Minister Group)	(2)	(2)	(24)	(14)
Mackenzie King	2	2	24	14
(Lougheed Island)	(3)	(5)	(28)	19)

[a] No caribou carcasses were seen on Eglinton, Helena and Brock islands

MELVILLE-PRINCE PATRICK COMPLEX

Peary caribou were seen on only two of the five islands within the Melville-Prince Patrick complex (Tables 2, 3, 6). They, however, contributed 80% to the total estimated mean number of Peary caribou on the western Queen Elizabeth Islands in summer 1997. Most, 90%, were estimated for Melville Island and were significantly overrepresented on eastern Melville (St. 1-VI) compared to western Melville (St. VII-XIII) on a relative landmass basis (i.e., eastern Melville, 578 estimated on 23 530 km^2 vs. western Melville, 209 estimated on 18 690 km^2: $\chi^2 = 94.06$, 1 df; $p < 0.005$). The remaining 10% were estimated for Prince Patrick Island. The estimated numbers of Peary caribou on Prince Patrick Island on a relative landmass basis by strata were significantly overrepresented ($\chi^2 = 81.89$, 2 df; $p < 0.005$) on St. III (major east-central Peninsula) and underrepresented on St. I (southern portion of the island) and St. II (northern portion of the island). It is the first time since aerial surveys were initiated in 1961 that there was an apparent total absence of caribou summering on Eglinton, Byam Martin and Emerald islands.

Melville Island

Melville Island was surveyed between 2 and 20 July 1997 at an average 18% (7454 km^2) aerial coverage (Tables 1-5; Figs. 1, 2, 5, 6; App. A, B). Most of Melville was surveyed under favourable viewing conditions (App. A). On northwestern Melville, however, high winds and cloud on high ground prevented us from doing some segments of strata IX, XII and XIII, which reduced coverage on those strata (Fig. 2; App. A). We also had to reduce the coverage on Stratum I (northern Sabine Peninsula) due to coastal fog (Fig. 2-3; App. A).

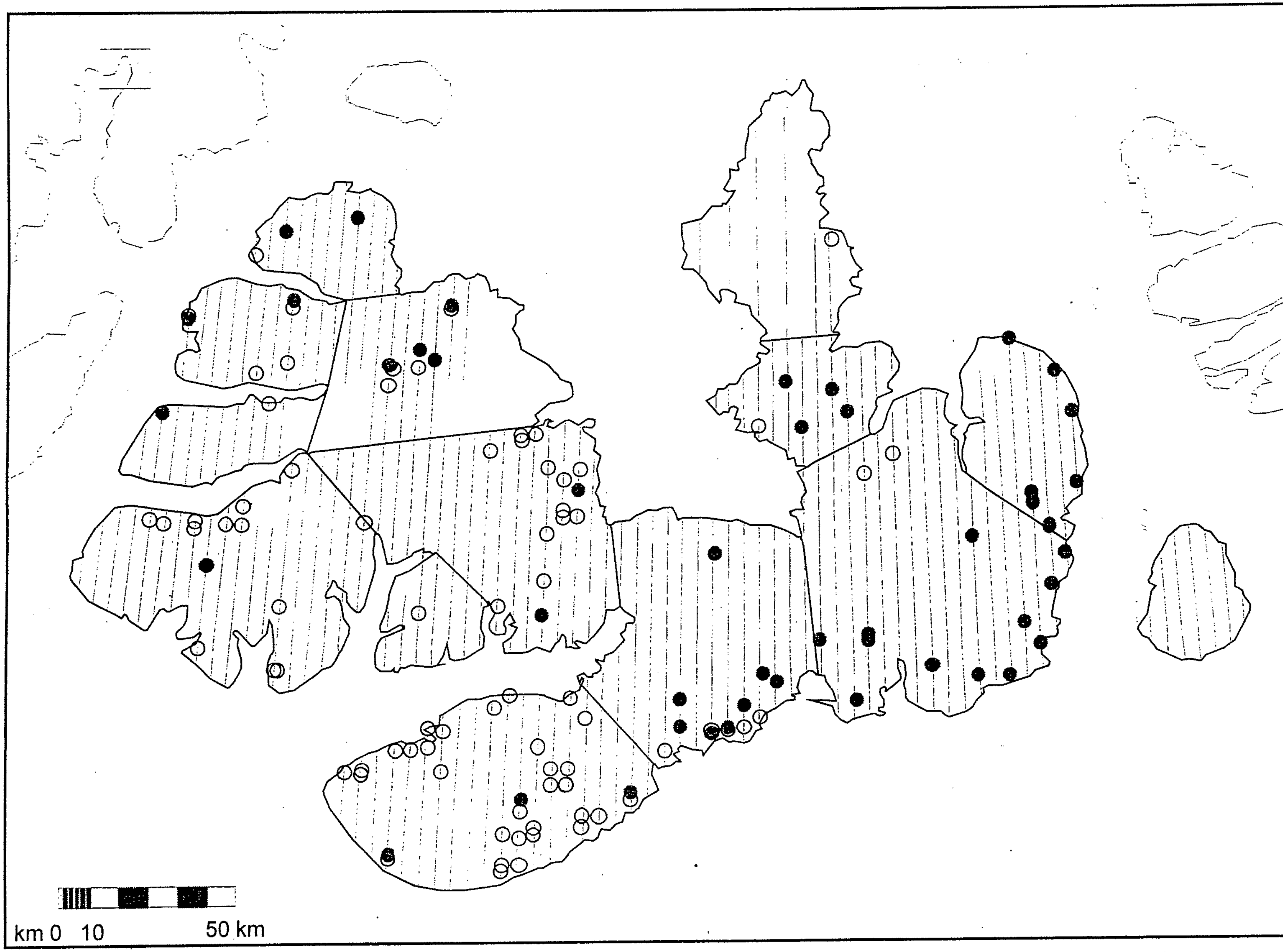

Fig. 2. Locations of transect lines and observations of Peary caribou (●) and muskoxen (○) seen on-transect during an aerial survey of Melville and Byam Martin islands, Northwest Territories and Nunavut, July 1997.

Caribou

We saw 293 caribou, 141 on-transect and 152 off-transect. The on-transect caribou gave an estimate of 787 ± 97 SE 1+ yr-old caribou or, on average, 1.9 caribou • 100 km^{-2} (Tables 2, 3; Fig. 2). On a proportional landmass basis, caribou on 6 of the 13 survey strata contributed at relatively greater rates than expected by chance alone to the overall estimated number of caribou on Melville Island: St. X, III, IV, II, V and IX in descending order of overrepresentation ($\chi^2 = 480.97$, 12 df; $p < 0.005$). Although the estimated number of Peary caribou was collectively overrepresented ($\chi^2 = 94.06$, 1 df; $p < 0.005$) on eastern Melville (St. I-VI) compared to western Melville (St. VII-XIII), there were exceptions on a stratum basis on both the eastern and the western sections of the island. Estimates of Peary caribou on the eastern section were greater ($\chi^2 = 162.51$, 5 df; $p < 0.005$) than expected by chance alone on St. II-V (east-central) but less than expected on St. VI (Dundas Pen.) and none was estimated on St. I (northern Sabine Pen.) of Melville Island. Also, estimates for Peary caribou on the western section were greater ($\chi^2 = 281.22$, 6 df; $p < 0.005$) than expected by chance alone on St. IX (north-central) and St. X (northwest, Marie Heights) but less than expected on St. VII (south-central), St. VIII (west-central) and St. XI-XIII (western) of Melville Island. We saw 30 caribou carcasses (Table 1; Fig. 5). The on-transect carcass count contributed about 18% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). The dead caribou estimate was based on the six strata where caribou carcasses were seen on-transect (Table 1; Fig. 5: 24 590 km^2 or 58% of Melville Island - 8 carcasses on St. II; 1, St. V; 1, St. VI; 5, St. VIII, 8, St. IX; and 1, St. XIII).

Muskoxen

We saw 997 muskoxen, 423 on-transect and 574 off-transect. The on-transect muskoxen gave an estimate of 2258 $\pm$ 268 SE 1+ yr-old muskoxen or, on average, 5.3 muskoxen • 100 km^{-2} (Tables 4, 5, Fig. 2). On a proportional landmass basis, muskoxen on only 3 of the 13 survey strata contributed at relatively greater rates than expected by chance alone to the overall estimated number of muskoxen on Melville Island: St. VI (Dundas Pen.), St. VIII (west-central) and St. XIII (southwest) in descending order of overrepresentation ($\chi^2 = 3053.25$, 12 df; $p < 0.005$). There was no significant difference in the collective number of muskoxen estimated on eastern vs. western Melville Island ($\chi^2 = 0.21$, 1 df; $p > 0.05$). Most, 85%, of the estimated muskoxen on eastern Melville were contributed by those on St. VI ($\chi^2 = 2858.91$, 5 df; $p < 0.005$). On western Melville, most (72%) were contributed by those muskoxen estimated in St. VIII and St. XIII ($\chi^2 = 171.53$, 6 df; $p < 0.005$). We recorded 30 muskox carcasses on-transect and 2 off-transect (no estimate was made for the number of dead muskoxen).

Table 2. Data from an aerial transect survey used to calculate estimates of 1+ yr-old Peary caribou (mean ± SE) on eastern Melville Island, Northwest Territories and Nunavut, July 1997.

Variables	Eastern Melville Island (Stratum)					
	(I)	(II)	(III)	(IV)	(V)	(VI)
Stratum area, km^2	2940	1730	1940	7260	4560	5100
Sample area, km^2	272	362	357	1195	946	946
No. Possible transects	58	59	41	90	26	110
No. Transects flown	6	13	7	18	16	20
No. Caribou counted	0	13	16	40	25	12
Mean density, Caribou • 100 km^{-2}	0.00	3.59	4.48	3.35	2.64	1.27
Population estimate	0	62	87	243	121	65
Standard Error	---	25	28	52	11	36
Variance	---	614	772	2653	132	1271
Coefficient Variation	---	0.40	0.32	0.21	0.10	0.55
% of total area surveyed	9	21	18	16	21	19

Table 3. Data from an aerial transect survey used to calculate estimates of 1+ yr-old Peary caribou (mean ± SE) on western Melville Island, Northwest Territories and Nunavut, July 1997.

Variables	Western Melville Island (Stratum)						
	(VII)	(VIII)	(IX)	(X)	(XI)	(XII)	(XIII)
Stratum area, km^2	1030	5100	3330	1390	1670	1400	4770
Sample area, km^2	204	963	376	295	359	242	937
No. possible transects	36	99	84	49	54	58	100
No. transects flown	7	20	9	11	11	10	19
No. caribou counted	0	6	9	14	3	2	1
Mean density, Caribou • 100 km^{-2}	0.00	0.62	2.39	4.75	0.84	0.83	0.11
Population estimate	0	32	80	66	14	12	5
Standard Error	-	18	35	47	9	10	5
Variance	-	336	1256	2249	90	110	23
Coefficient Variation	-	0.56	0.44	0.71	0.64	0.83	1.00
% of total area surveyed	20	19	11	21	22	17	20

Table 4. Data from an aerial transect survey used to calculate estimates of 1+ yr-old muskoxen (mean ± SE) on eastern Melville Island, Northwest Territories and Nunavut, July 1997.

Variables	Eastern Melville Island (Stratum)					
	(I)	(II)	(III)	(IV)	(V)	(VI)
Stratum area, km^2	2940	1730	1940	7260	4560	5100
Sample area, km^2	272	362	357	1195	946	946
No. possible transects	58	59	41	90	26	110
No. transects flown	6	13	7	18	16	20
No. muskox counted	3	9	0	8	17	212
Mean density, muskoxen • 100 km^{-2}	1.10	2.49	0.00	0.67	1.80	22.41
Population estimate	32	43	0	49	82	1143
Standard Error	29	36	-	27	7	191
Variance	853	1307	-	749	44	34 463
Coefficient Variation	0.91	0.84	-	0.55	0.09	0.17
% of total area surveyed	9	21	18	16	21	19

Table 5. Data from an aerial transect survey used to calculate estimates of 1+ yr-old muskoxen (mean ± SE) on western Melville Island, Northwest Territories and Nunavut, July 1997.

Variables	Western Melville Island (Stratum)						
	(VII)	(VIII)	(IX)	(X)	(XI)	(XII)	(XIII)
Stratum area, km^2	1030	5100	3330	1390	1670	1400	4770
Sample area, km^2	204	963	376	295	359	242	937
No. Possible transects	36	99	84	49	54	58	100
No. Transects flown	7	20	9	11	11	10	19
No. Muskox counted	9	66	7	12	18	2	59
Mean density, muskoxen • 100 km^{-2}	4.41	6.85	1.86	4.07	5.01	0.83	6.30
Population estimate	45	350	61	57	84	12	300
Standard Error	25	116	35	50	43	11	112
Variance	635	13 489	1245	2506	1858	115	12 557
Coefficient Variation	0.56	0.33	0.57	0.88	0.51	0.92	0.37
% of total area surveyed	20	19	11	21	22	17	20

Prince Patrick Island

Prince Patrick Island was surveyed on 29 and 30 June, and 1 July 1997 at an average aerial coverage (2533 km^2) of 16% (Tables 1, 6, 7; Figs. 1, 4, 5, 8; App. A, D). Most of Prince Patrick was surveyed under favourable viewing conditions (App. A). Fog patches caused us to reduced the coverage for Stratum II to 8% (Fig. 4, App. A).

Caribou

We saw only 31 caribou, 15 on-transect and 16 off-transect. The on-transect count gave an estimate of 84 ± 34 SE 1+ yr-old caribou or, on average, only 0.5 caribou • 100 km^{-2} (Table 6, Fig. 4). On a proportional landmass basis, the estimated numbers of Peary caribou were overrepresented ($\chi^2 = 81.89$, 2 df; $p < 0.005$) on St. III (the east-central peninsula where Mould Bay is located) compared to St. II (northern) and St. I (southern) Prince Patrick Island. We saw 31 caribou carcasses (Table 1; Fig. 5). The on-transect carcass count contributed about 21% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). The 30 carcasses found on-transect included 25 on St. I, 4 on St. II and 1 St. III (Fig. 5).

Muskoxen

We saw only 28 muskoxen, 20 on-transect and 8 off-transect. The on-transect muskoxen gave an estimate of 96 ± 42 SE 1+ yr-old muskoxen or, on average, only 0.6 muskoxen • 100 km^{-2} (Table 9, Fig. 4). On a proportional landmass basis, muskoxen were overrepresented ($\chi^2 = 71.33$, 2 df; $p < 0.005$) on St. I (southern), underrepresented on St. III (east-central) and none was estimated for St. II (northern) Prince Patrick Island. We saw 3 muskox carcasses on-transect and none off-transect (no estimate was made for the number of dead muskoxen).

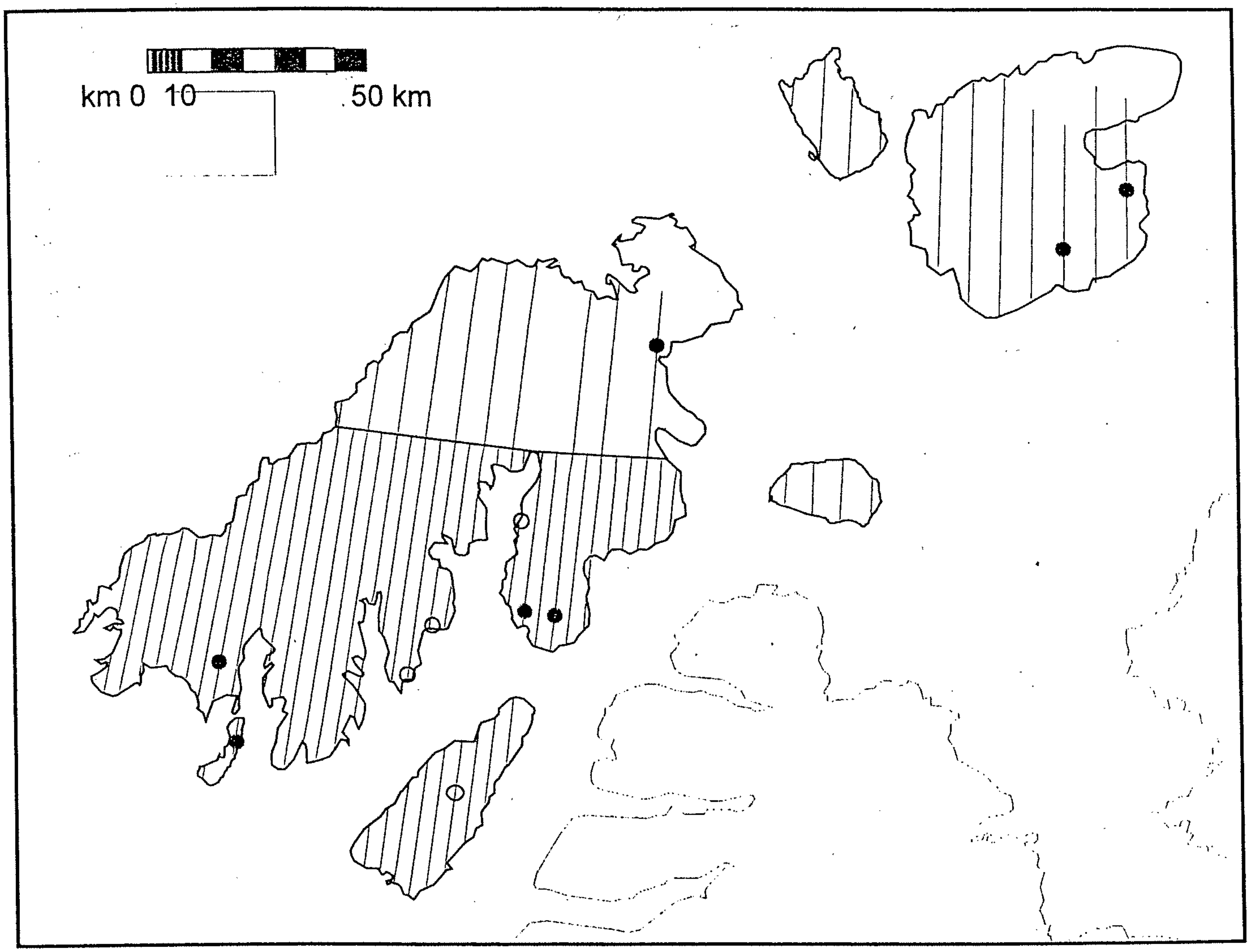

Fig. 3. Locations of transect lines and observations of Peary caribou (●) and muskoxen (○) seen on-transect during an aerial survey of Prince Patrick, Eglington, Emerald, Brock and Mackenzie King islands, Northwest Territories and Nunavut, July 1997.

Table 6. Data from an aerial transect survey used to calculate estimates of 1+ yr-old Peary caribou (mean ± SE) on Prince Patrick Island, Northwest Territories, June-July 1997.

Variables	Prince Patrick Island (Stratum)		
	(I)	(II)	(III)
Stratum area, km^2	7740	5980	2110
Sampling area, km^2	1593	459	481
No. possible transects	108	115	53
No. transects flown	30	10	11
No. caribou counted	4	2	9
Mean density, Caribou •100 km^{-2}	0.25	0.44	1.87
Population estimate	19	26	39
Standard error	10	22	24
Variance	93	481	580
Coefficient Variation	0.53	0.85	0.62
% of total area surveyed	21	8	23

Table 7. Data from an aerial transect survey used to calculate estimates of 1+ yr-old muskoxen (mean ± SE) on Prince Patrick Island, Northwest Territories, June-July1997.

Variables	Prince Patrick Island (Stratum)		
	(I)	(II)	(III)
Stratum area, km^2	7740	5980	2110
Sampling area, km^2	1593	459	481
No. possible transects	108	115	53
No. transects flown	30	10	11
No. muskoxen counted	18	0	2
Mean density, Muskox • 100 km^{-2}	1.13	0.00	0.42
Population estimate	87	0	9
Standard error	41	-	9
Variance	1722	-	78
Coefficient Variation	0.47	-	1.0
% of total area covered	21	8	23

Eglinton Island

Eglinton was surveyed on 2 July 1997 at 19% (292 km^2) aerial coverage (Figs. 1, 4, 5; App. A, E). We did not see any live caribou and we saw no caribou carcasses on-transect or off-transect. We saw a group of 7 muskoxen on-transect but none was seen off-transect. The on-transect muskoxen gave an estimate of 37 ± 21 SE 1+ yr-old muskoxen or, on average, 2.4 muskoxen • 100 km^{-2}. No muskox carcasses were seen.

Byam Martin Island

Byam Martin Island was surveyed on 20 July 1997 at 19% (224 km^2) aerial coverage (Table 1; Figs. 1, 2; App. A, E). We saw no live caribou or live muskoxen. We found 8 caribou carcasses (Table 1). The on-transect carcass count contributed about 3% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). We found no muskox carcasses on-transect but we saw 1 muskox carcass off-transect (no estimate was made).

Emerald Isle

Emerald Isle was surveyed on 19 July 1997 at 12% (64 km^2) aerial coverage (Table 1; Figs. 1, 4; App. A, E). We found no live caribou or live muskoxen. We found 2 caribou carcasses (Table 1). The on-transect carcass count contributed about 2% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). No muskox carcasses were seen.

BATHURST COMPLEX

Bathurst Island

Bathurst Island was surveyed on 21, 22, 23 and 24 July 1997 at an average 20% (3210 km^2) aerial coverage (Tables 1, 8, 9; Figs. 1, 3, 5, 7; App. A, C). Bathurst was surveyed under favourable viewing conditions (App. A).

Caribou

We saw only 30 caribou, 15 on-transect and 15 off-transect. The on-transect caribou gave an estimate of 74 $\pm$ 25 SE 1+ yr-old caribou or, on average, about 0.5 caribou • 100 km^2 (Table 8, Fig. 3). On a proportional landmass basis, the estimated numbers of Peary caribou were overrepresented (χ^2 = 14.86, 2 df; p <0.005) on St. II (northeastern), slightly so or about as expected on St. I (northwestern) and underrepresented on St. III (southern) of Bathurst island. We counted 17 caribou carcasses (Table 1; Fig. 5). The on-transect carcass count contributed about 10% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). The 16 carcasses included 4 on Stratum II and 12 on Stratum III (Fig. 5).

Muskoxen

We saw only 36 muskoxen, 25 on-transect and 11 off-transect. The on-transect muskoxen gave an estimate of 124 $\pm$ 45 SE 1+ yr-old muskoxen or, on average, only 0.8 muskoxen • 100 km^{-2} (Table 9, Fig. 3). On a proportional landmass basis, the estimated numbers of muskoxen were overrepresented (χ^2 = 68.68, 2 df; p < 0.005) on St. II (northeastern) and underrepresented on St. I (northwestern) and St. III (southern) of Bathurst Island. We saw 13 muskox carcasses on-transect and 8 off-transect (no estimate was made for the number of dead muskoxen).

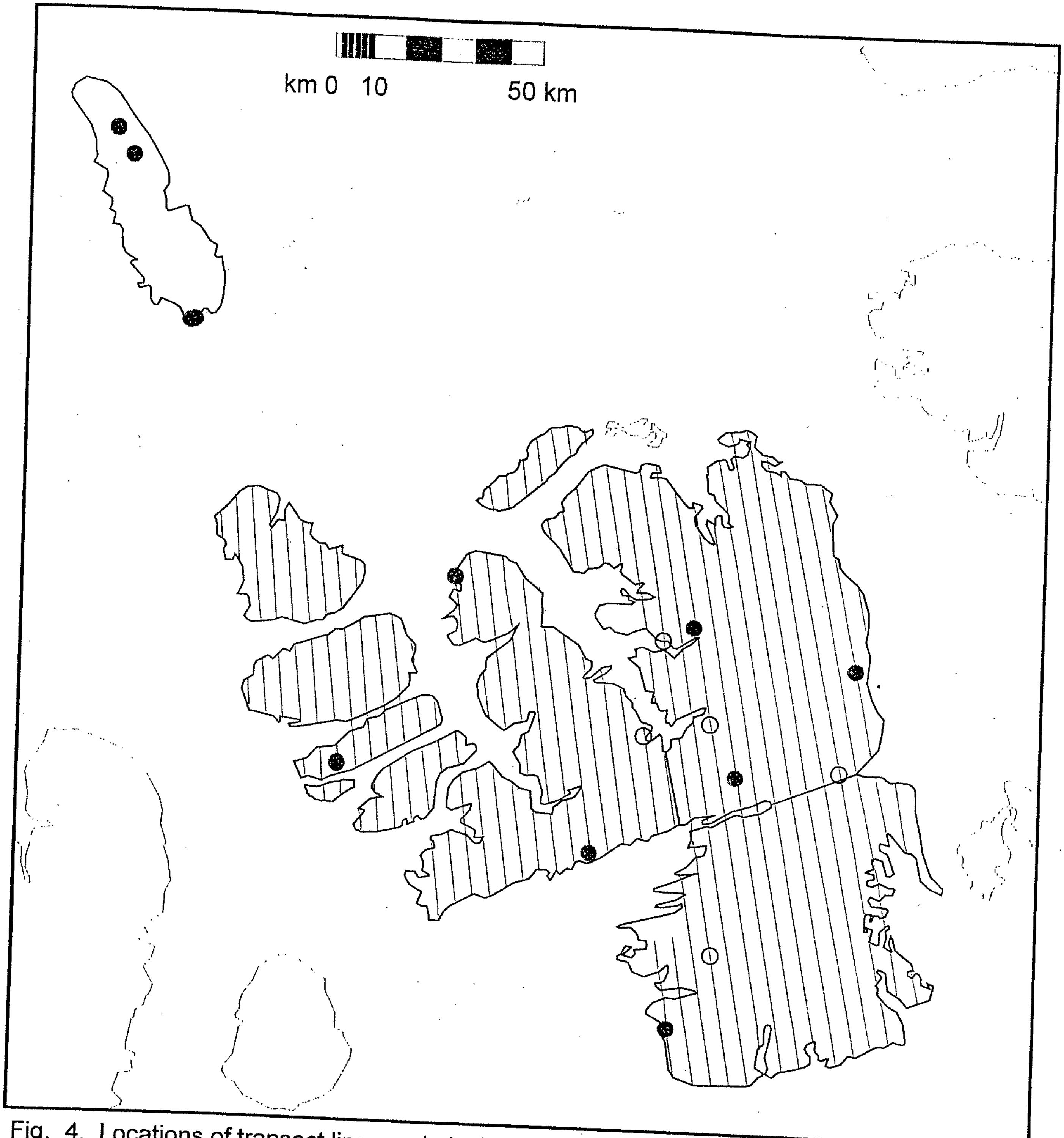

Fig. 4. Locations of transect lines and obsérvations of Peary caribou (●) and muskoxen (○) seen on-transect during an aerial survey of Bathurst, Lougheed and the Governor General Group, Northwest Territories and Nunavut, July 1997.

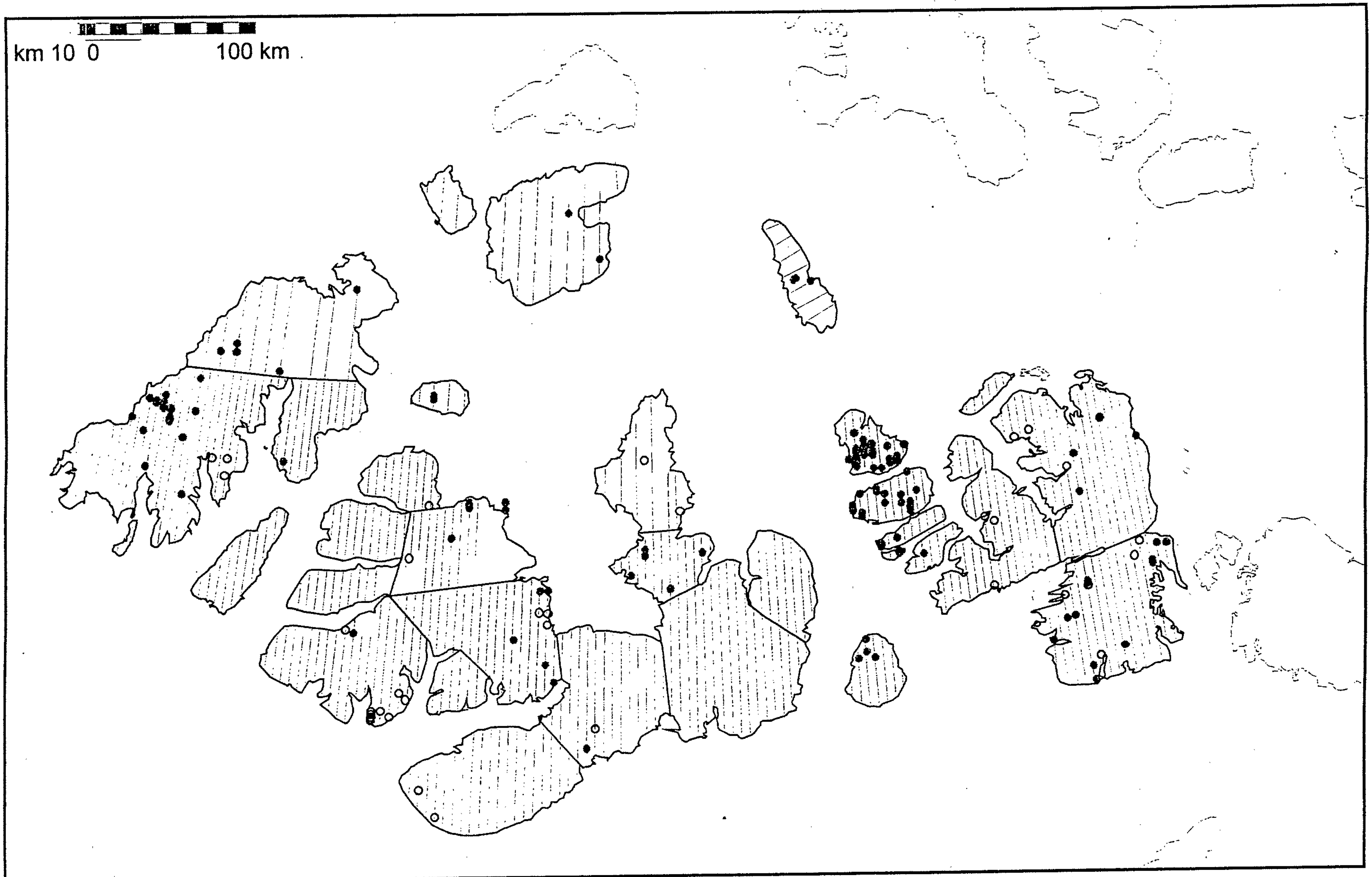

Fig. 5. Locations of transect lines and observations of Peary caribou (●) and muskox (○) carcasses seen on-transect during an aerial survey of the western Queen Elizabeth Islands, Northwest Territories and Nunavut, June-July 1997.

Table 8. Data from an aerial transect survey used to calculate estimates of 1+ yr-old Peary caribou (mean ± SE) on Bathurst Island, Nunavut, July 1997.

Variables	Bathurst Island (Stratum)		
	(I)	(II)	(III)
Stratum area, km^2	4080	6650	5360
Sampling area, km^2	832	1346	1032
No. possible transects	79	86	80
No. transects flown	22	19	16
No. caribou counted	4	9	2
Mean density, Caribou •100 km^{-2}	0.48	0.67	0.19
Population estimate	20	44	10
Standard Error	10	22	9
Variance	94	464	85
Coefficient Variation	0.50	0.50	0.90
% of total area surveyed	20	20	19

Table 9. Data from an aerial transect survey used to calculate estimates of 1+ yr-old muskoxen (mean ± SE) on Bathurst Island, Nunavut, July 1997.

Variables	Bathurst Island (Stratum)		
	(I)	(II)	(III)
Stratum area, km^2	4080	6650	5360
Sampling area, km^2	832	1346	1032
No. possible transects	79	86	80
No. transects flown	22	19	16
No. muskoxen counted	5	19	1
Mean density, Muskoxen •100 km^{-2}	0.60	1.41	0.10
Population estimate	25	94	5
Standard Error	15	42	4
Variance	238	1775	20
Coefficient Variation	0.60	0.45	0.80
% of total area surveyed	20	20	19

Ile Vanier

Ile Vanier was surveyed on 21 July 1997 at 21% (239 km^2) aerial coverage (Table 1; Figs. 1, 3; App. A, E). We saw no live caribou or live muskoxen. We saw 28 caribou carcasses (Table 1). The on-transect carcass count contributed about 11% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). No muskox carcasses were seen.

Cameron Island

Cameron Island was surveyed on 21-22 July 1997 at 20% (215 km^2) aerial coverage (Table 1; Figs. 1, 3; App. A, E). We found no live caribou or live muskoxen. We did, however, count 50 caribou carcasses (Table 1). The on-transect carcass count contributed about 23% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands - the single greatest contribution on an island basis (Table 1). No muskox carcasses were seen.

Alexander Island

Alexander Island was surveyed on 21 July 1997 at 22% (108 km^2) aerial coverage (Table 1, Figs. 1, 3; App. A, E). We saw no live caribou but we saw 2 caribou carcasses (Table 1). The on-transect carcass count contributed < 1% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). No live muskoxen or muskox carcasses were seen.

Massey Island

Massey Island was surveyed on 21 July 1997 at 23% (103 km^2) aerial coverage (Table 1; Figs. 1, 3; App. A, E). We saw only 1 caribou on-transect and none off-transect and estimated only 4 $\pm$ 5 SE 1+ yr-old caribou or, on average, 0.9 caribou •

100 km^{-2}. We saw 3 caribou carcasses (Table 1). The on-transect carcass count contributed < 2% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). No live muskoxen or muskox carcasses were seen.

Helena Island

Helena Island was surveyed on 22 July 1997 at 31% (68 km^2) aerial coverage (Fig. 1; App. A, E). We saw no live caribou or live muskoxen and we found no caribou or muskox carcasses.

Ile Marc

Ile Marc was surveyed on 21 July 1997 at 16% (9 km^2) aerial coverage (Table 1; Figs. 1, 3; App. A, E). We saw no live caribou but we counted 5 caribou carcasses (Table 1). The on-transect carcass count contributed about 3% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). No live muskoxen or muskox carcasses were seen.

PRIME MINISTER GROUP

Mackenzie King Island

Mackenzie King Island was surveyed on 18 July 1997 at 8% (430 km^2) aerial coverage (Table 1; Figs. 1, 4, 5; App. A, E). We saw only 4 caribou on-transect (a cow-calf pair and 2 adults) and 7 caribou off-transect (Fig. 4). The 3 1+ yr-old caribou counted on-transect gave an estimate of 36 ± 22 SE 1+ yr-old caribou or, on average, only 0.7 caribou • 100 km^{-2}. We saw 4 caribou carcasses (Table 1; Fig. 5). The on-transect carcass count contributed about 3% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). No live muskoxen or muskox carcasses were seen.

Borden Island

Not surveyed in summer 1997.

Brock Island

Brock Island was surveyed on 18 July 1997 at 11% (84 km^2) aerial coverage (Figs. 1, 4; App. A, E). We found no live caribou or live muskoxen nor did we find any caribou or muskox carcasses.

Lougheed Island

Lougheed Island was surveyed on 21 July at 11% (141 km^2) aerial coverage (Table 1; Figs. 1, 3; App. A, E). We reduced aerial coverage to 11% as there were fog banks to the north and we wanted to complete the island before the fog blew in. We counted 12 caribou (including one calf) on-transect and no live caribou off-transect. The 11 1+ yr-old caribou seen on-transect gave an estimate of 101 ± 73 SE 1+ yr-old caribou or, on average 7.8 caribou • 100 km^{-2}. We saw 8 caribou carcasses (Table 1). The on-transect carcass count contributed about 3% to the overall estimated number of dead caribou on the western Queen Elizabeth Islands (Table 1). We did not see any live muskoxen or muskox carcasses.

WOLF SIGHTINGS

We counted 9 wolves on transect and 29 wolves including 12 pups off transect. We saw wolves on Prince Patrick Island (single and a pair of wolves), Eglinton (a pack of 3 wolves) and Melville Island (packs of 6 adults and 8 pups, 2 adults and 4 pups, 7 adults, 1 pair and three singles). Most wolves on Melville were on strata VIII and XIII

(29 wolves) with 3 wolves on strata IV and VI. The single wolf on Stratum IV was carrying a medium-sized seal on the shore-fast ice. The pair of wolves on Prince Patrick Island were tunneling in snow where a pair of large caribou antlers protruded.

DISCUSSION

The 1997 estimates of live Peary caribou and carcass estimates document a decline in Peary caribou during winter and spring of 1996/97 across the western Queen Elizabeth Islands. For Bathurst and its satellite islands, our documentation of the decline is based on a comparison with a 1996 aerial survey (Miller 1998). The 1997 abundance of 1086 ± 131 SE live Peary caribou on the western Queen Elizabeth islands is the lowest mean estimate since 1961 when Tener (1963) estimated 19 456 1 + year-old Peary caribou. After 1961, the next surveys were in the early 1970s and documented about an 86% decline (Miller et al. 1977a). Surveys continued to be infrequent but revealed that by 1987, Peary caribou numbers had not increased on the western islands of Prince Patrick and Melville but were increasing on Bathurst Island (Ferguson 1987, Miller 1987b, 1988, 1989). By 1993, Peary caribou on Bathurst and its satellite islands had returned to over 84% of the level in 1961 (Miller 1995b). That recovery was lost through deaths and some movements (where the fate of those individuals is largely unknown) between 1995 and 1997 (Miller 1997, 1998). Muskox numbers have also changed in abundance between 1961 and 1997 and the direction and magnitude of the changes varies across the survey area. In the following sections, we describe the changes in Peary caribou and muskox abundance and possible reasons for them.

Accuracy and precision of the 1997 survey

One of the first factors to consider when evaluating an apparent change in population size is whether there were any technical shortcomings in the survey design or execution. The aerial survey that we carried out was of an accepted design for a standard systematic aerial survey and we executed it according to accepted procedures within the limitations of the available resources to do so. Whatever flaws might exist in this type of aerial survey would be inherent as well in all previous aerial surveys of Peary caribou and muskoxen on the Queen Elizabeth Islands. Therefore, there is no reason to believe that our results are not comparable to findings from the earlier aerial surveys. The precision of the overall estimate for Peary caribou was favourable, with a 12% CV and varied by island and by complex. The precision for the collective number of Peary caribou estimated in the Melville-Prince Patrick and in the Bathurst complexes was high, with a 11% CV for 87% (n = 949) of the overall estimated number of Peary caribou (N = 1086) in summer 1997. Precision for the remaining 13% (n = 137) of the overall estimate was relatively low at 56% for Mackenzie King within the Prime Minister Group and for Lougheed Island. Basically, this later result is the expected outcome for any systematic survey at relatively low coverage of a low-density population where animals are few and many sample units have zero observations (App. B-E). Therefore, given the low-density populations that we were working with, our results are adequate for the purpose intended to assess the current status of Peary caribou and muskoxen on the western Queen Elizabeth Islands.

Failure to detect animals, problems with counting or assigning them on-transect or off-transect would have reduced accuracy. Although we have no measure of those effects, we have no reason to believe that we had any exceptional problems in those areas of concern. Group sizes were small in all observations and total counts were made with ease and the observers and pilot were experienced. We flew the survey at an altitude and with a transect width that are typical for caribou aerial surveys and actually more conservative than most. The representative of the Hunters' and Trappers' Organization's was comfortable with the altitude and transect width for seeing caribou (and muskoxen). We took frequent breaks to reduce fatigue. The caribou were relatively conspicuous as their summer pelage contrasted against the background.

We opted for uniform aerial coverage throughout the entire survey area without any reconnaissance searches because our budget did not permit us to increase the aerial coverage on part or all of the survey area or to resurvey strata where weather caused us to reduce coverage. Therefore, while our planned level of about 20% aerial coverage was dictated by our budget, the realised coverage was determined by the proportional overall length of transects among strata and sometimes additionally by the then prevailing weather conditions. Had funding and weather allowed us to do so, we would have conducted the entire survey at 25% aerial coverage. That level of coverage would have reduced the ratio for observed on-transect animals to extrapolated (estimated minus observed) animals from 1:4 to 1:3. In hindsight, however, we cannot see any aspect of our survey that was of consequence that we would have done differently then we did in the first place. We would have liked to be able to resurvey those few strata where weather conditions resulted in reduced coverage, mainly because it would have provided direct comparisons with the reduced efforts. This desire is especially true for Lougheed Island where the resultant estimate represents 9+ extrapolated caribou for every one caribou actually seen on-transect.

Observer motivation is rarely discussed as a source of bias, probably because to question it, can be thorny and judgmental. However, during our planning for the survey, M. Ferguson (pers. comm. 1996) suggested that the authors could be biased against counting caribou, as we thought that the Peary caribou were in a serious state. All we can state is that the pilot and the observer representing the Resolute HTO (back left seat) were a check on our counting and we were on our guard about any presumption of bias.

During our 1997 survey, we encountered no technical problems. Our only one weather-caused delay was on western Melville: we surveyed the northwest (strata X, XI and XII) and then poor weather delayed us 6 days before we completed the adjacent strata. We knew that Peary caribou move from Prince Patrick and Eglinton going to Melville for the summer (Miller *et al.* 1977a, 1977b), and we saw east-west trails across snow patches on eastern Prince Patrick and northwest Melville. Therefore, we suggest that some Peary caribou had made similar movements in 1997. On 19 July 1997, we counted 17 caribou in a group walking east and their tracks in soft ground indicated that they had come from the west. Possibly during the 6-day delay, Peary caribou that we had already counted moved from either Prince Patrick, Eglinton or Melville strata X-XII into areas that we then surveyed, such double-counting, if it occurred, would have inflated the estimate. We suggest that the converse, Peary caribou moving into areas that we already counted is the least likely possibility given Miller *et al.*'s (1977a, 1977b) findings about seasonal movements from Prince Patrick or Eglinton to Melville Island (no spring movements of caribou from Melville Island to Prince Patrick or Eglinton islands have ever been recorded).

Peary caribou abundance

The Queen Elizabeth Islands were first surveyed in summer 1961 when Tener (1963) estimated 24 320 Peary caribou there (19 456, 1 + year-old animals). When those islands were next surveyed in the early 1970s, Peary caribou numbers had already declined by about 78% and totaled 5244 (includes calves) in July-August 1973 (Miller *et al.* 1977a). Then, in the 1973/74 winter and spring nearly half (49%) of all remaining Peary caribou on the western Queen Elizabeth Islands were lost, representing an overall 89% (includes calves in 1961) or 86% (1+ yr-olds only) decline from 1961. The 1997 estimate of 1086 ± 131 SE Peary caribou is lower than the mean estimate of 2676 (1+ yr olds only) in 1974, which was when all the major islands of the western Queen Elizabeth Islands had been last surveyed prior to 1997 (Miller *et al.* 1977a). The overall 36-year decline on the three major islands of Melville, Prince Patrick and Bathurst from 1961 to 1997 is 96% (including calves) or nearly 95% (1+ yr olds only). And, of equal and warranted consideration is the uniform, essentially range-wide end results for the loss of 1+ yr-old Peary caribou by major island: Bathurst, 97% (1961, 2191 vs. 1997, 74); Prince Patrick, 95% (1961, 1797 vs. 1997, 84); and Melville, 92% (1961, 10 366 vs. 1997, 787).

The subsequent population trend is then uncertain for Melville and Prince Patrick as the islands were surveyed only once in consecutive years (1986 and 1987) before our 1997 survey. Bathurst and its satellite islands were, however, surveyed in 1981, 1985, 1988, 1993 and 1996 (Ferguson 1987, Miller 1987a, 1988, 1989, 1995b, 1998).

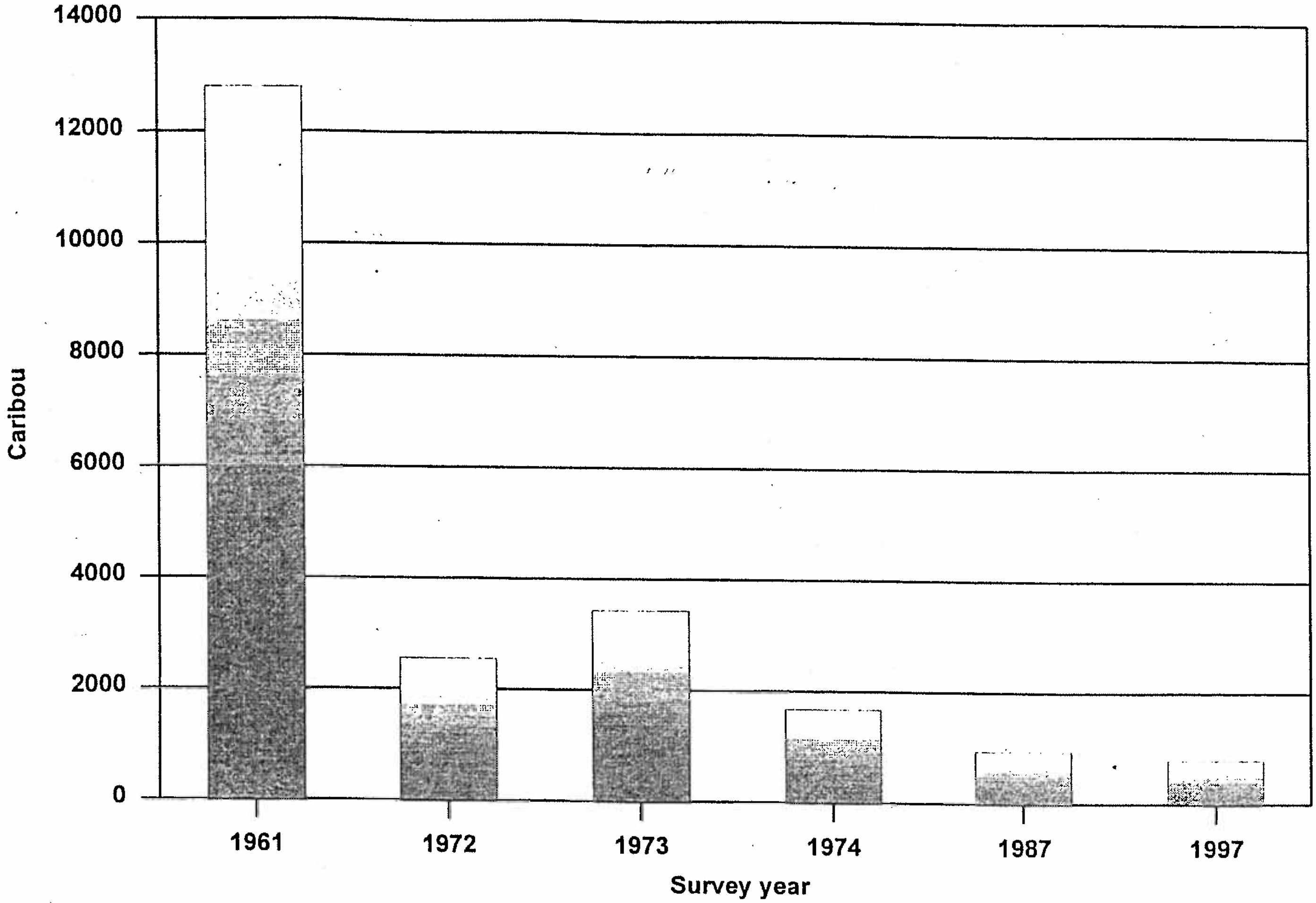

Fig. 6. Peary caribou population trends for Melville Island, Northwest Territories and Nunavut, 1961-97.

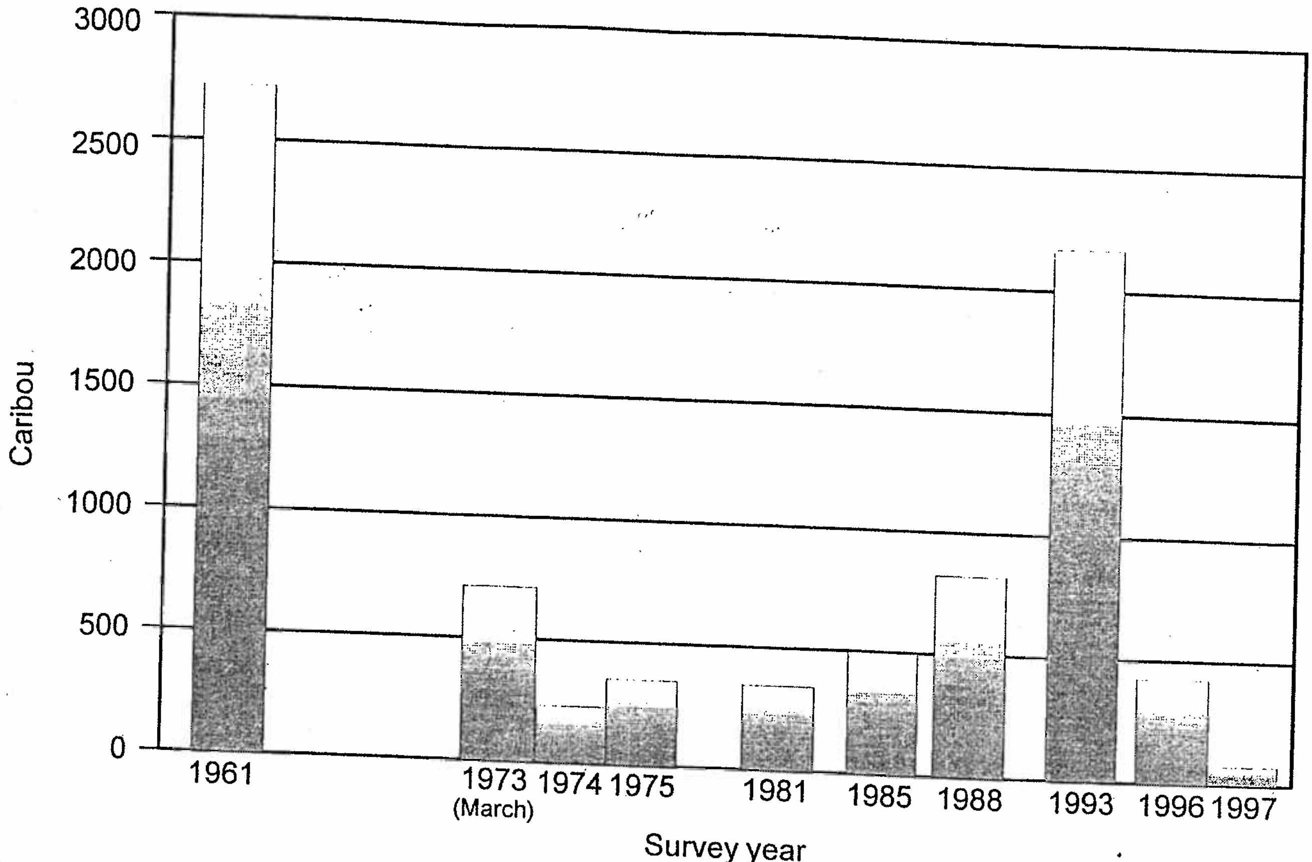

Fig. 7. Peary caribou population trends for Bathurst Island, Northwest Territories and Nunavut, 1961-97.

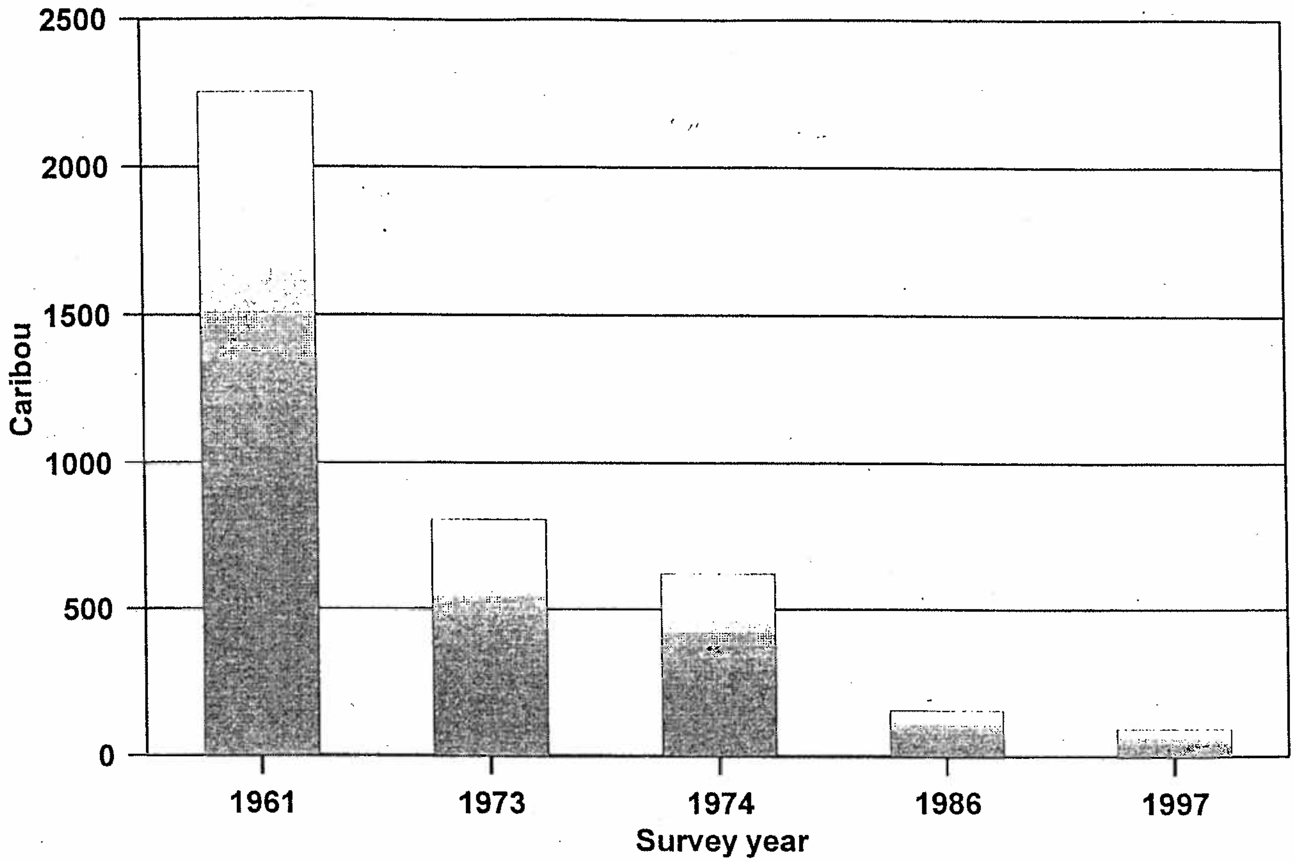

Fig. 8. Peary caribou population trends for Prince Patrick Island, Northwest Territories, 1961-97.

Peary caribou on Bathurst and its satellite islands have fluctuated since 1961: mean numbers declined from an estimated 3565 in 1961 to 256 in 1974; then, recovered over the next 20 years and by 1994 the estimated population had reached about 3000 caribou (including calves). The population then declined to 452 ± 108 SE 1+ yr-old caribou in 1996 (Miller 1998) and further declined to <100 1+ yr-old caribou by July 1997 (Figures 6-8).

We can estimate how deaths contributed to changes in Peary caribou numbers between 1996 and 1997 by comparing numbers of live and dead caribou observed in 1997. Those rates of decline could be biased by scavenging when carcasses are utilized to such an extent that they were too scattered to be readily visible from the air. Alternatively, but less likely, is that scavenging could be light and the carcasses remain for more than a year. We were careful not to include any carcass remains in our counts that were composed solely of scattered bones and/or those where the hair was highly scattered, which we assumed would have been carcasses from caribou that had died more than one winter before.

Dead Peary caribou appeared to represent about 43% of the number of 1+ yr-old caribou that were present in summer 1997 across the western Queen Elizabeth Islands, based on total mean estimates of 831 carcasses/1086 live caribou + 831 dead caribou (the estimate of 831 ± 86 SE dead caribou is based on 148 carcasses counted on-transect). Rates of death varied among the complexes and by island: being highest 408 1+ yr-old caribou, 84%, in the Bathurst complex; followed by 371 1+ yr-old caribou, 30% in the Melville-Prince Patrick complex; 326 1+ yr-old caribou, 99%, in the Governor General Group; 28 1+ yr-old caribou, 22%, on Lougheed island; and 24 1+

yr-old caribou, 40%, in the Prime Minister Group. Interpretation of the losses within the Melville-Prince Patrick complex is somewhat complicated as 68% of the caribou died on Prince Patrick Island but only 16% on Melville Island. The Prince Patrick Island loss, however, most likely includes caribou from Melville Island, as Peary caribou move from summer range on Melville to winter range on Prince Patrick (Miller *et al.* 1977b). Thus, the relatively low rate of deaths for caribou on Melville Island probably simply reflects the timing of the winter/spring die-offs when many animals that summer on Melville were still on winter/spring ranges on Prince Patrick Island.

Evaluating the 1961-97 trends in abundance is possibly hampered by differences in survey methods especially island-by-island coverage (Table 10). In 1961, 1972-74 and 1997 most of the western Queen Elizabeth Islands were covered during one survey. To determine trend in abundance we compare our results in 1997 with those in 1974 when coverage and survey design and methods were the most similar although we flew at a lower altitude. Abundance of 1+ yr-old Peary caribou on the three major western Queen Elizabeth Islands of Melville, Prince Patrick and Bathurst is statistically significantly less in July 1997 (945 $\pm$ 106 SE) than in July-August 1974 (2260 $\pm$ 434 SE) based on no overlap in 95% confidence intervals.

Table 10. Comparison of aircraft, survey altitude, strip width and percent cover used during aerial surveys, western Queen Elizabeth Islands, 1961-97, Northwest Territories and Nunavut.

Year	Aircraft type	Altitude (m, agl)	Strip width (km)	Cover (%)	Source reference
1961	Super Cub	152	0.4	8	Tener 1963
1973	Helio-Courier	150	1.6	25	Miller *et al.* 1977a
1974	Helio-Courier	150	1.6	25	Miller *et al.* 1977a
1981	Cessna 337	122	1.6	27	Ferguson 1987
1985	Bell 206B	90m	1.7	27, 34	Miller 1987a
1986	Bell 206B	90m	1.7	27, 34	Miller 1987b
1987	Bell 206B	90m	1.7	27, 34	Miller 1988
1988	Bell 206B	90m	1.7	27, 34	Miller 1989
1993	Bell 206B	90m	1.7	27, 34	Miller 1994
1997	Helio-Courier	100	1.0		This study

During the 23 years between the 1974 and 1997, there is only information on trends in abundance for surveys in the 1980s, but those surveys did not cover all the western Queen Elizabeth Islands during one survey. In 1985, Miller (1987a) surveyed Bathurst and its satellite islands; then Prince Patrick, Eglinton and Emerald in 1986 (Miller 1987b) and Melville and Byam Martin Islands in 1987 (Miller 1988). Interpretation of trends may be compromised by annual differences in the proportions of Peary caribou seasonally moving between or among islands. Observations of dye-marked caribou, tracks and seasonal distribution in the 1970s (Miller *et al.* 1977b) documented that many caribou that winter on Prince Patrick then move in spring for the summer and autumn to Eglinton, Emerald, Melville and Byam Martin islands.

Even although we know that Peary caribou move between Prince Patrick and

Melville islands, we separate Melville from Prince Patrick and Eglinton to compare the 1997 estimate with those estimates from the late 1980s as we do not know if the same proportions of caribou move each year. The July 1997 estimate of Peary caribou (84 ± 34 SE) is not significantly different ($P > 0.05$)) from the 1986 estimate (181± 59 SE) for Prince Patrick, Eglinton and Emerald islands (Miller 1987b). The July 1997 estimate (787 ± 97 SE) for Melville Island is similar to the 1987 estimate of 729 ± 104 SE Peary caribou (Miller 1988). Alternative explanations for the lack of a difference in the two population estimates 10-11 years apart are either that the population size was stable or that the populations recovered and then declined. The carcasses found in 1997 suggested that the population had declined over, at least, the 1996/97 winter which tends to support recovery between 1987 and 1996 which was then lost during the winter and spring of 1996/97.

Peary caribou seasonally use Bathurst and its satellite islands (Miller 1997, 1998, unpubl. data.) and based on that information, we have treated abundance on Bathurst and its satellite islands as separate from the islands to the west in the Melville-Prince Patrick complex. We know most about Bathurst and its satellite islands as not only has the area been surveyed the most frequently but the Canadian Wildlife Service's ecological studies annually monitored Peary caribou calf production and/or early survival by helicopter searches and surveys from 1989 to 1996 (Miller 1987a, 1988, 1989, 1991, 1992, 1993, 1994, 1995b, 1997, 1998).

In July 1985, Miller (1987a: App. 5) estimated 530 ± 99 SE caribou on Bathurst and four of its western satellite islands (Alexander, Massey, Vanier and Cameron). In July 1988, Miller (1989: Table 6) estimated 780 ± 103 SE caribou on Bathurst and the five satellite islands (the same four islands as in 1985 and Marc). The abundance of the Peary caribou continued to increase and in August 1993, Miller (1995b) estimated about 2667 Peary caribou including calves from a count of 2400. In 1994, Miller (1998) estimated that number had increased to about 3000 Peary caribou, including calves.

After 1994, the trend in abundance of Peary caribou on Bathurst and its satellite islands started to decline. In June 1995, Miller (1997) suggested that 25-30% of the Peary caribou population had died based on his count of 1084 caribou and 56 caribou carcasses during extensive but unsystematic searches (about 50 h) using similar aerial search efforts as in the previous years. The following year, in July 1996, Miller (1998) flew a systematic helicopter survey and he counted 143 caribou carcasses on-transect. Based on those counts, 1143 caribou ± 164 SE had died during the 1995/96 winter. No calves were seen in July 1996 and the number of living caribou was estimated at 452 ± 108 SE from 91 live caribou seen (Miller 1998). In 1997, the number of carcasses estimated for Bathurst and its satellite islands (408 ± 53 SE) indicates that most of the Peary caribou alive there in summer 1996 had died.

We only saw 2 caribou calves among the 378 caribou that we counted, indicating essentially a complete failure of the 1997 calf crop. A second conspicuous finding compared to previous years, indicating the extreme severity of the 3 years of die-offs comes from a small mean group size for caribou (Table 11). Group size was largest on Melville Island, averaging 4.6 (Table 1: range = 2-17) and represented relatively small groups, even when compared to after the 1973-74 severe winter when Miller *et al.* (1977a) reported that mean group size on Melville was 7.2 (range 2-33). In summers 1972 and 1973, mean group size averaged 10.1 (range 2-77) and 8.6 (range 2-60), (Miller *et. al.* 1977a). Mean group sizes for Peary caribou in 1997 were significantly smaller than their respective mean group sizes in 1974: Melville (t = 3.801, 181 df; p <0.001), Prince Patrick (t = 3.568, 25 df; p <0.001) and Bathurst (t = 2,944, 16 df; p <0.005). There were, however, no significant within-year differences among mean group sizes for Melville, Prince Patrick and Bathurst islands in 1974 or in 1997. Therefore, all of the groups in each of those 2 years were combined by year and compared, with the collective mean group size in 1997 being significantly (t = 4.847, 237 df; p <0.001) smaller than the collective mean group size in 1974. This condition, plus the general lack of large groups in 1997 relative to 1974, seemingly, supports the probability that some level of above average mortality also occurred in 1994/95 and/or 1995/96 in the Melville-Prince Patrick complex as well as in the Bathurst complex.

When combined samples of group sizes from Melville, Prince Patrick and Bathurst islands are grouped in classes 2-5, 6-9 and 10+ and collectively compared between 1974 (n = 213: immediately after the 1973/74 die-offs) and 1997 (n = 76: immediately after the 1994/95 to 1996/97 die-offs) groups of 6-9 and 10+ are significantly underrepresented in 1997 compared to 1974 (χ^2 = 16.80, 2 df; p < 0.005). This most likely results because both the level of proportional losses of individuals within groups and the relative number of groups experiencing losses, particularly higher losses, would have been greater in the subsequent 2 years of the 3 years (1994-97) of die-offs, as the proportion dying increased annually. The resultant pattern of mortality within these three group classes is variable and complex and likely includes at least nine variations: a high level of total losses of groups in the 2-5 class with a relatively few of those group sizes only losing some animals; most of the groups in the 6-9 class would slip into the 2-5 class, while some relatively few could go to zero and some remain in the 6-9 class; and most of the groups in the 10+ class would slip into the 6-9 class, while others could plummet into the 2-5 class, some few could go to zero and a few remain in the 10+ class. Thus, the lower average group size and especially the lack of larger groups in summer 1997 compared to summer 1974 (immediately after each of the two die-off periods) most likely simply reflects the outcome of multi-year vs. single-year die-offs. For example, within the Bathurst complex between 1994 and 1997, the probability that an individual caribou would be lost in 1995/96 was 2.5 times and in 1996/97 2.7 times greater than in 1994/95.

Table 11. Descriptive statistics for Peary caribou groups (excluding solitary individuals) observed in the summer after major die-offs on the western Queen Elizabeth Islands, Northwest Territories and Nunavut, 1974 and 1997

Island by year	Groups of 2+ individuals			Number of singletons
	Mean ± SE	Number of caribou (number of groups)	Range	
1974[a] (after 1-year of die-offs, 1973/74)				
Melville	7.2 ± 0.54	879 (123)	2-33	7
Prince Patrick	5.9 ± 0.45	455 (77)	2-18	14
Bathurst	6.4 ± 0.97	83 (13)	2-15	1
All groups***	6.7 ± 0.36	1417 (213)	2-33	22
1997 (after 3 consecutive years of die-offs, 1994/95 to 1996/97)				
Melville	4.6 ± 0.42	276 (60)	2-17	17
Prince Patrick	3.5 ± 0.50	28 (8)	2-5	3
Bathurst	3.3 ± 0.41	26 (8)	2-5	4
All groups***	4.3 ± 0.34	330 (76)	2-17	23

[a] Data sources for 1974 from Miller et al. (1977a) and Miller, unpublished data.
*** Mean group size in summer 1997 after 3 consecutive years of die-offs is significantly smaller ($t = 4.847$, 237 df; $p < 0.001$) than the mean group size in summer 1974 after the 1-year of die-offs. This significant reduction in the mean group size in 1997 comes from the significantly smaller proportional contribution by groups of 6+ in 1997 compared to the 1974 contribution of 6+ groups ($\chi^2 = 16.87$, 2 df; $p < 0.005$).

Peary caribou distribution

In July 1997, we did not find caribou on six of the smaller islands that held caribou in July 1961 (Tener 1963). Those islands cover 8% of the landmass of the western Queen Elizabeth Islands. Compared to summer 1974 (Miller *et al.* 1977a) we did not find caribou on Byam Martin or Eglinton islands. On the larger islands of Melville and Bathurst, distributions were mostly similar to the earlier summer surveys. In July 1997, more than half the Peary caribou (57%) were on eastern and central Melville (strata III, IV and V), which held 34% of the caribou in 1987 and 74% in 1974

(Miller *et al.* 1977a, Miller 1988). Only 8% and 15% of the estimated caribou were on Dundas Peninsula (Stratum VI) in 1997 and 1987, respectively, in contrast to 38% in 1974. Differences within stratum representation of Peary caribou among surveys may simply reflect differences in timing of surveys relative to summer movements in response to annual variation in plant phenology and/or varying social dynamics.

Distribution on Bathurst Island in July 1997 was similar to 1974, 1988 and 1993 summers (Miller *et al.* 1977a, Miller 1989, 1995b), with the highest proportion (59%) on northeast Bathurst Island (Stratum II) but in 1985, the highest proportion was in the northwest (Stratum I, 45%, Miller 1987a). On Prince Patrick Island, 46% of the caribou were estimated to be on the eastern stratum (Stratum III) in contrast to 1974 and 1987 when 64% of the caribou occurred on Stratum I (Miller *et al.* 1977a, Miller 1988). Again, the observed variation in Peary caribou distribution by survey stratum probably reflects differences in timing of the surveys relative to summer movements in response to annual variation in plant phenology and/or varying social dynamics. The existing evidence strongly supports northeastern Bathurst Island as the ongoing most important range for Peary caribou on Bathurst Island.

Trends in muskox abundance 1996-97

We estimated 2515 ± 276 SE muskoxen on Melville, Bathurst, Prince Patrick and Eglinton islands, which were the only islands where we saw muskoxen. Muskox numbers have risen and fallen between 1961 and 1997 and the changes vary within and among the island complexes. But only on Bathurst Island, do we have information to determine the trend in muskox abundance between 1996 and 1997. Miller (1998) estimated that there were 425 ± 136 SE in July 1996, which declined significantly (p <

0.05) to 124 ± 45 SE muskoxen in July 1997. Between 1994 and 1997, muskox numbers dropped from 1400 muskoxen–a decline of 91%. We recorded no live or dead muskoxen in the Governor General Group. On Bathurst Island, we counted 13 carcasses on-transect and 8 carcasses off-transect but we have not used a comparison between live and dead muskoxen to estimate mortality between 1996 and 1997. Scavengers had apparently less effect disassembling adult muskox carcasses but they can reduce smaller-bodied muskoxen (yearlings) to scattered hair and bones during a single winter. At the Walker River cabin in July 1997, there was a muskox yearling scattered skeleton and hair patch that had not been there in July 1996. The decline is not completely explained by mortality based on the carcasses seen between 1996 and 1997. Muskoxen are known to make desperation moves across sea ice – Miller (pers. comm.) observed 36 muskox carcasses on sea-ice just offshore in 1996.

Trends in muskox abundance 1961-97

On Melville Island, Miller *et al.* (1977a) estimated 2390 ± 412 SE muskoxen and they suggested that Tener's (1963) extrapolation of 1000 muskoxen in 1961 appeared overly conservative and it was more likely that the muskoxen numbered about 4000 at that time, based on the extrapolation of Tener's data. By 1987, muskoxen had increased to 4761 ± 372 SE on Melville Island (Miller 1988). Ten years later, muskox numbers had significantly declined to 2258 ± 268 SE ($p < 0.05$).

On the northwestern edge of their range (Prince Patrick Island) muskoxen were present in the early 1950s but had disappeared by 1961 (Tener 1963). Muskoxen recolonised Prince Patrick Island between 1961 and 1972 (Miller *et al.* 1977a). The estimates for muskoxen on Prince Patrick and Eglinton islands in July 1973 (178 ± 103

SE, calves included), July 1974 (130 ± 64 SE, no calves), July 1986 (154 ± 33 SE, calves included) and July 1997 (133 ± 47 SE, no calves) did not significantly differ.

We know more about changes in muskox abundance on Bathurst and its satellite islands as the complex has been surveyed more frequently and numbers, distributions and percentages of calves were recorded during Canadian Wildlife Service's 1989-96 ecological studies of Peary caribou. Muskox numbers were relatively high in 1961 (1211, Tener 1963) but declined about 86% by 1974 when 164 ± 70 SE were estimated. Gray (1973) recorded that muskox calf production was low to none in the late 1960s. Muskox numbers then increased to an estimated 423 ± 83 SE muskoxen between 1974 and 1988 and an estimated 1200 based on a count of 730 I + yr-old muskoxen in August 1993 and 1400 muskoxen in summer 1994 (Miller 1995b, 1998, App. 7).

In the 3 years following 1994, muskox numbers declined on Bathurst Island. Hunters' concerns about dead muskoxen found on Cornwallis Island during the 1995/96 winter prompted Miller (1997) to investigate the status of muskoxen on Bathurst and its satellite islands in June-July 1995. Miller (1997) estimated 980 live muskoxen from a count of 832 I + yr-old muskoxen and 50 carcasses in 1995. In summer 1996, Miller (1998) flew a systematic helicopter survey and counted 72 muskox carcasses on transect which extrapolated to an estimated 625 ± 241 SE muskoxen that had died during the 1995/96 winter leaving an estimated 425 ± 136 SE muskoxen alive. In 1997, we estimated 124 ± 45 SE live muskoxen and saw 21 carcasses. We did not ascribe the carcasses to only the previous winter so we have not extrapolated the sightings to an estimate.

Muskox distribution

Distribution had contracted in 1997 as muskoxen were not found on five of the smaller islands occupied in 1974 (Miller et al. 1977a: Mackenzie King, Byam Martin, Vanier, Cameron and Alexander). The islands cover 10% of the area of the western Queen Elizabeth. On Melville Island, the highest proportion (51%) of muskoxen among the strata was on VI (Dundas Peninsula), which is similar to 1987 when Miller (1988) recorded 31% compared to 16% in 1974. However, we counted only one muskox herd on Bailey Point which previously was a high-density 'hotspot' (*cf.* Thomas *et al.* 1981). Bailey Point is in Stratum XIII, which in 1974 had 38% of estimated muskoxen, 23% in 1987 and 13% in 1997.

Causes of declines in Peary caribou and muskox abundance

Peary caribou deaths

The 1996/97 decline on Bathurst and its satellite islands was mostly caused by deaths and not movements. This is supported by the estimate of Peary caribou carcasses (408 ± 53 SE) and live caribou (74 ± 25 SE) in the Bathurst complex being similar to the estimate of live caribou in 1996 (452 ± 108 SE, Miller 1998). The 1996/97 decline was a continuation of a decline with observed deaths, low calf survival to no calf production documented following the 1994/95 and 1995/96 winters (Miller 1997, 1998). Our 1997 results indicate that most of the caribou which had survived two consecutive exceptionally severe winters, died during the third such winter.

We lack 1996 estimates for the islands within the Melville-Prince Patrick complex. Therefore, we can only report the proportion of Peary caribou that died in

1996/97 based on carcasses, not an overall decline that would reveal if caribou had moved away from the island. We also lack information to discriminate between whether deaths, movements or reproductive failure caused the decline in Peary caribou in the Melville-Prince Patrick complex between 1986 and 1997. We estimate that 371 ± 63 SE 1+ yr-old caribou died in winter and spring 1997 (Table 1), which indicates that at least a major part (30%) of the decline was due directly to deaths.

Movements

Declines in populations potentially may be explained by movements to other areas (Miller 1990a, Tyler and Øritsland 1989), which are dissimilar to seasonal migrations (Miller *et al.* 1982). Movements of caribou from Bathurst Island during a severe winter was recorded in 1973/74 even although Inuit hunters and biologists did not agree whether the caribou moved because of snow and ice conditions (Miller and Gunn 1978) or seismic activities (Freeman 1975). Some caribou moved from Bathurst Island to Cornwallis Island in winters 1994/95 and 1995/96 and were documented through observations of hunters and the movements of a satellite-collared cow (Miller 1998). Some few caribou likely move annually back and forth between Bathurst and Cornwallis islands and/or Little Cornwallis and adjacent smaller islands, as they do among the western satellite islands (Miller 1995a, 1998, unpubl. data). Therefore, Cornwallis Island is a likely destination for some caribou in years when extreme environmental stress occurs on Bathurst Island but not necessarily a favourable one, as the same environmental pressures would likely be in place on Cornwallis and its surrounding satellite islands. Miller (1998) considers Cornwallis and the small islands between Cornwallis and Bathurst as part of the entire Bathurst Island complex.

The seven Peary caribou fitted with satellite-collars within the Bathurst complex in 1994 had died by February 1997 (Miller 1998, unpubl. data). Three bulls and two cows increased their movements during the 1994/95 and 1995/96 winters but still died on their seasonal winter ranges between February and April of those years (Miller 1998, unpubl. data). One cow left her 1993/94 winter range on Bathurst Island in December 1994 and island-hopped between and among Cornwallis, Little Cornwallis and adjacent smaller islands until returning to her original winter range on Bathurst Island where she died (February 1997). Only one of the seven collared caribou made a long-distance movement away from her 1993/94 winter range in late October 1995 to Borden Island and died there in December 1995.

On Bathurst and its satellite islands, in summer 1995, the number of carcasses indicated that about 30% of the Peary caribou died during the1994/95 winter leaving an estimated 2100 caribou alive (Miller 1997). In summer 1996, the number of carcasses revealed that a further 1260 caribou had died and the live caribou count reflected that about 450 had survived, which left about 400 caribou unaccounted for by deaths. Many or all of those caribou likely left Bathurst Island based on hunters' observations of caribou appearing on neighbouring Cornwallis Island and long distance movement of one satellite collared cow who moved to Borden Island (F. L. Miller, pers. comm.1998). In October/November 1995, hunters reported that caribou moved to Cornwallis Island where between 50 and 100 caribou were killed (Miller 1997, 1998).

While there is evidence for a small proportion of Peary caribou and muskoxen to make long-distance movements during times of forage unavailability, there is no evidence to determine whether those caribou survived and either returned or remain away. Anatomical and genetic differences between Peary caribou and arctic-island caribou on the islands south of the western Queen Elizabeth Islands (Manning 1960, Banfield 1961, Thomas and Everson 1982; K. Zittslau, J. Nagy and N. Larter, unpubl. data) argue against major shifts of Peary caribou south of the western Queen Elizabeth Islands having survived and bred there. Lack of samples prevents determining whether Peary caribou from the western Queen Elizabeth Islands have shifted and bred with Peary caribou on Devon or other islands in the eastern Queen Elizabeth Islands.

Causes of death

In 1997, we did not examine carcasses to determine the cause(s) of death. In July 1996, Miller (1998) examined six caribou carcasses on Bathurst Island and recorded that their femoral marrow appearance was consistent with prolonged malnourishment. The Western College of Veterinary Medicine recorded signs of malnourishment also from muskoxen found dead on Cornwallis in 1995 (Miller 1997). Parker *et al.* (1975) report evidence for malnourishment in Peary caribou and muskoxen dying during the 1973-74 winter.

Hunters from Resolute collected samples from 7 Peary caribou and 6 muskoxen on Cornwallis Island in September 1995. The caribou had class 2 marrow fat reserves based on classifying marrow fat into three classes and the muskoxen were more variable with one individual in class 3, two in class 2 and 3 in class 1 (M. Ferguson pers. comm. 1996). The three visual classes overlap and cover a relatively wide spread of fat content: at least in caribou from south Baffin Island: class 1 is 5-40% fat; class 2 is 15-50% and class 3 is 25-90% 1 (M. Ferguson pers. comm. 1996).

The likely explanation for deaths from malnourishment is forage unavailability. The simplest explanation consistent with the evidence is that winter and spring snow and ice conditions caused widespread relative unavailability of forage. The weather records suggest that winter and spring conditions were severe enough to prevent foraging on many sites and to increase the range-wide energetic costs of foraging for Peary caribou and muskoxen and many of those animals could not sustain those additional costs. The only measures that we have for how snow conditions affect foraging energetic costs are for Alaskan barren-ground caribou (Fancy and White 1985). Cratering through the snow to reach forage increases energetic costs some 30% higher than just walking on bare ground and a crust on the snow that would almost support the caribou's weight before collapsing raised the cost of walking by about 570% (Fancy and White 1985). Fancy and White (1985) commented on the greater effort needed to pound through hard snow than paw (sweep) snow away.

Winter weather

The Peary caribou and muskox deaths on Bathurst and its satellite islands during 1995-97 occurred during the three winters with significantly greater than average total snowfall between September-May and with the highest annual snowfall recorded at Resolute (Table 12). The recorded die-offs on Bathurst Island were during winters with snowfall exceeding at least ≥ 110 cm. However, snow depth is notoriously difficult to measure due to the local effects of wind blowing the snow (Maxwell 1980, Jacobs 1989) and redistributing it. It would be too simplistic to assume that snowfall is the only factor or that snow depth per se is necessarily always the most important factor. As well, snowfall varies locally and regionally (Figure 9).

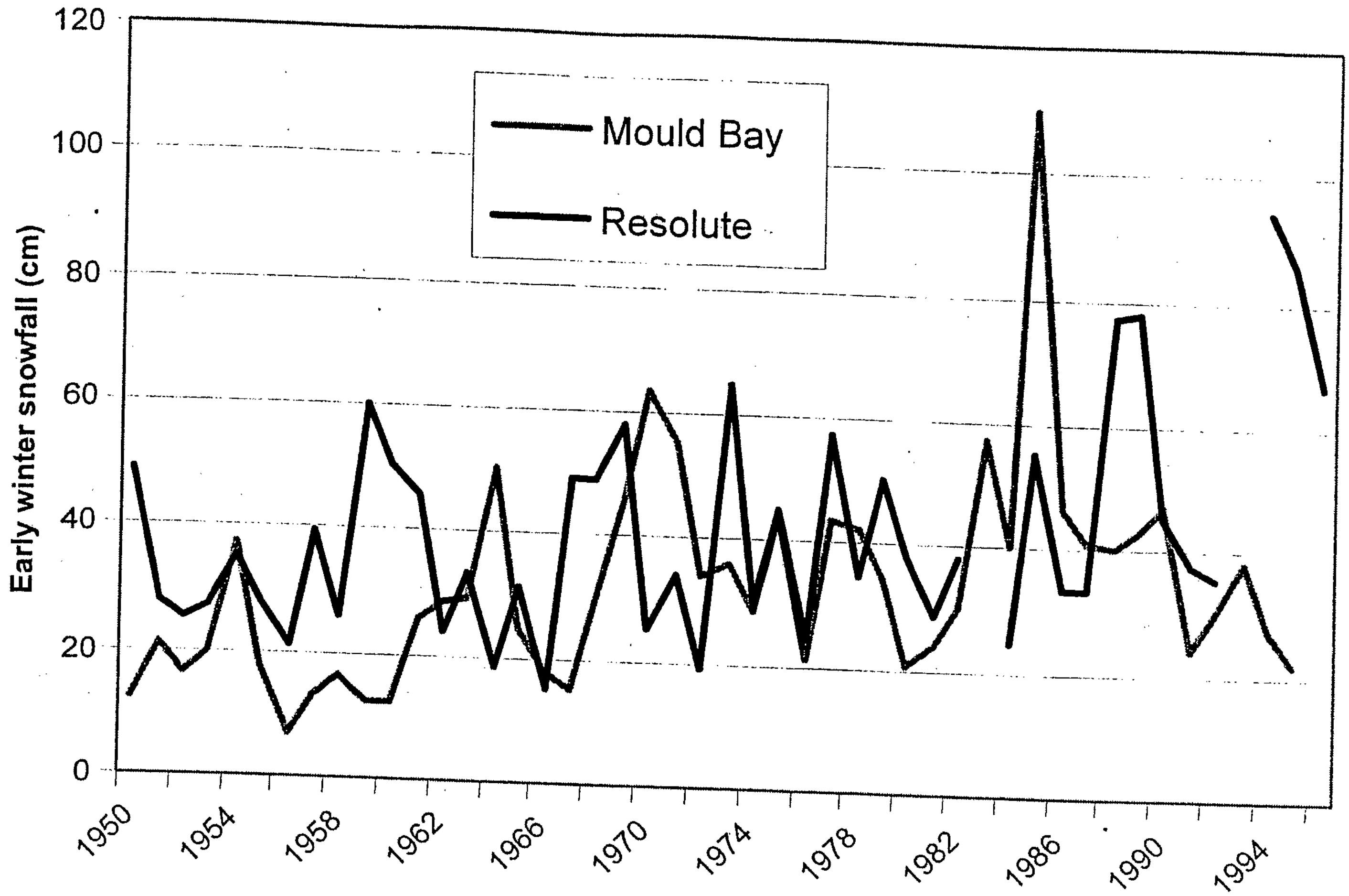

Fig. 9. Early winter snowfall for Mould Bay, Prince Patrick Island, and Resolute, Cornwallis Island, Northwest Territories and Nunavut, 1950-96.

Freezing rain in autumn that causes ground-fast ice to form before snow cover accumulates, ice layering in the snow cover, crusting of the snow, and the formation of ground-fast ice in spring, compound the stress of forage unavailability. However, detailed range-wide information on type of snow cover and the incidence of ground-fast ice or ice layering is generally unavailable for the High Arctic (F. L. Miller, pers. comm.1998). Late winter snowfall, extending into June adds stress to animals and in June 1996, 40 cm of snow fell at Resolute, which is 30% of the average total winter snowfall from September to May.

Table 12. Ranking of winter (September-May) and winter plus spring (September-June) annual total snowfall, Resolute, Northwest Territories and Nunavut, 1949-97 (data sources: Environment Canada, Climate Archives, Resolute; Miller et al. 1977a, Miller 1992, 1997, 1998; Miller, unpubl. data; this study).

Winter/ spring time period[a]	Winter (Sep-May) Snowfall (cm)	Winter/spring (Sep-Jun) snowfall (cm)	Ranking 1949-97		Effect on Bathurst complex Peary caribou
			Relative severity of winter only	Relative Severity of winter plus spring	
1995/96	126.0	165.4	2nd	1st	Die-off
1994/95	149.0	156.6	1st	2nd	Die-off
1996/97	125.9	138.5	3rd	3rd	Die-off
1989/90	119.2	137.9	4th	4th	40% calf loss[b]
1973/74	110.2	125.1	6th	5th	Die-off[c]
Average total winter (Sep-May) snowfall 1949-97: 76 ± 4 SE cm.					
Average total winter/spring (Sep-Jun) snowfall 1949-97: 84 ± 4 SE cm.					

[a] Total annual winter and winter/spring snowfall for each of these 5 years exceeded their respective long-term average by < 1 SD.
[b] Latest calving period recorded between 1989 and 1995.
[c] Probably more intensive, wide-ranging ice cover and prolonged ground fast ice in June

The weather records are from the Resolute weather station which is *ca.* 160 km to the east of the Canadian Wildlife Service's Walker River field camp on northeastern Bathurst Island. A comparison of weather data from two remote automatic weather stations at the Walker River camp (1991-96) with weather records from Resolute, indicates that weather records for Resolute are representative (F. L. Miller pers. comm. 1998).

The winter of 1996/97 started with a severe winter storm. On, at least, Prince Patrick Island: high winds and 14.0 cm snowfall was recorded at the Mould Bay weather station on 13 September 1996. A few days later temperatures rose to above zero with a small amount of freezing rain, 0.2 mm. Snowfall recorded at Mould Bay had been high in August (34 cm) and snow depth on the ground was still on 7 cm on 1 September 1996 (Environment Canada, Climate Archives, Mould Bay). Snowfall in September totalled 46.6 cm (1950-89 mean is 14.9 ± 10.3 SD). An incomplete snowfall record exists for the remainder of the winter, with 69.5 cm recorded compared to a long-term average of 65 cm–but data are missing for December 1996, April 1997, May 1997 and June (spring) 1997 and no data are available for snow depth on the ground, as the station was closing down and switching to automation.

The September storm in 1996 likely created or at least initiated the conditions that led to the 31 caribou and 3 muskox carcasses that we observed in July 1997 and the virtual lack of caribou and muskox calves on Prince Patrick Island. Most (n = 25, St. 1) of the 31 caribou carcasses were in an area of about 250 km^2 on the winter range identified in 1973-74 (Miller *et al.* 1977a). The four antlered carcasses from prime bulls indicate that their deaths occurred in early winter during late rut or immediately or shortly after the rut.

Evidence for the causes of the decline between 1974 and 1986/87, when the estimated number of Peary caribou in the Melville-Prince Patrick complex changed significantly from 2324 to 981, is scanty. Equally, to determine how and if conditions changed to foster either a recovery or no further decline is tenuous. Using snowfall measured at Mould Bay, Prince Patrick Island, as a crude index to winter severity (in terms of relative forage availability) suggests that winter forage availability may have been restricted by snow in the 1985/86 winter and spring periods. The evidence for this is two-fold. The first is the low proportion of solitary muskox bulls and low bull to cow ratio at Bailey Point on western Melville Island following the period 1976-82 when five of six winters had above average snow depths in late winter (Gunn *et al.* 1989). The second line of evidence that snowfall was restricting forage availability is that winter 1985/86 had the heaviest snowfall on record since the opening of the weather station at Mould Bay in1948 (136 cm compared to the average snowfall 1950-1996: 64 ± 28 SD cm) and the most days with freezing rain in early winter. In September 1985, freezing rain fell on 15 days compared to the 1949-90 mean of 2.7 ± 3.3 SD days. Those conditions probably caused muskoxen to move from Prince Patrick to Eglinton Island where their calves survived, although at a low rate, whereas the remaining muskoxen on Prince Patrick had no calves (Miller 1987b). Peary caribou calving was initially successful but during the first 2 weeks of July 1986, 30-40% of the calves disappeared presumably having died (Miller 1987b). The reasons were unknown but most likely the cows were nutritionally stressed during the 1985/86 winter, and the calves were undersized and nonviable.

The evidence on the relationship between winter weather and relative forage availability leading to major die-offs is based on a significant correlation between those three winters being the most severe in terms of total snowfall for the 49-year period of record. We recognise that snowfall is not the only factor as temperature and wind determine variations in snow depths and snow cover characteristics (e.g., density, hardness, granular structure) on the ground (Gunn *et al.* 1989, Forchhammer and Boertmann 1993). In 1996/97, caribou and muskox carcass distribution was over at least 90 000 km^2: and spatial correlation in population fluctuations argues for an environmental factor (Grenfell *et al.* 1998).

Forage quantity and herbivore densities

Peary caribou and muskox numbers had increased on Bathurst and its satellite islands before the 1995-97 die-off. This increase has raised the question of whether these caribou densities reached a level that their foraging reduced plant biomass, which subsequently contributed to their mortality during a severe winter (M. Ferguson, Departmental workshop Yellowknife, December 1997).

The question of how density-dependent or density independent factors interact together depends on the system being considered (Caughley and Gunn 1993, Choquenot 1998). Caughley and Gunn (1993) characterized the High Arctic as having high levels of environmental stochasticity, which over-rides the vegetation-herbivore feedback loop. In more temperate climates, density-independent effects are more conspicuous when densities are higher (Grenfell *et al.* 1998). For example, Portier *et al.* (1998) found that for bighorn sheep, *Ovis canadensis,* density-dependence increased the effects of cooler dry springs, which reduced newborn lamb survival, while winter lamb survival was density-dependent. The interaction between intrinsic and extrinsic factors also varied with sex and age – weather had a greater effect on adult Soay sheep ewes compared to density having a greater effect on lambs and rams (Milner *et al.* 1999). A complication to describing effects of weather is that they may not always be conspicuous but instead effects on reproduction and growth may accumulate over several years (e.g., Albon *et al.* 1987, Mech *et al.* 1987, Post and Stenseth 1999).

While we do not have detailed information for Peary caribou on the relationship between intrinsic and extrinsic factors, there is indirect evidence to suggest that the dominating if not the sole cause of the 1995-97 decline was winter weather. Firstly, the weather was exceptional within the half century of weather records – the highest snowfall combined with warmer temperatures and high winds. The examples of how the effects of intrinsic and extrinsic factors interact do not include exceptional weather, which is one end of the continuum of factors affecting population persistence (Caughley 1994). For example, although Portier *et al.* (1998) did not present the weather data, it seems that their 13 years of study data did not include significant departures from "normal" conditions. The authors wrote (p.277) "Northern ungulates have numerous adaptations to harsh winter weather . . . We suggest that only exceptionally long and cold winters, worse than any encountered during our study, may affect the survival of mountain sheep."

We have three other points of indirect evidence to suggest that reduced Peary caribou densities were not due to the amount of forage available. Firstly, the deaths occurred in two species across a wide geographic region. The second and third points are that, at least on Bathurst and its satellite islands, neither movement patterns nor productivity changed prior to the severe winters although both are attributes influenced by forage availability.

The Peary caribou and muskox deaths during the 1996/97 winters were across several islands, which have different regional climatic and vegetation patterns. The arctic climate is strongly regionalised with maritime and continental influences on climate (Maxwell 1981), which in turn impose patterns in vegetation (Edlund 1983, 1990, Edlund and Alt 1989). The western Queen Elizabeth Islands are in three regional subdivisions of the Northwestern climatic region (Maxwell 1981). The subregions differ in the duration of summer (mean daily temperatures > 0°C) and annual precipitation, which increases from < 100 mm in the west, to 125-150 mm in the Bathurst-Prince of Wales Islands subregion. The severity of the arctic climate limits plant growth and nutrient recycling – for example, the mean annual total of growing degree-days (> 5°C) is < 25 days in the west, to 37 days in the eastern section of the western Queen Elizabeth Islands (Maxwell 1981). Plant cover and production are correspondingly low compared to the mid and low arctic (Bliss *et al.* 1984).

Such spatial heterogeneity likely imposes spatial variation in birth and death rates which is counter-acted by either dispersal (for example Coulson *et al.* 1999) and/or widespread extrinsic events (Grenfell *et al.* 1998). The Peary caribou and muskox deaths were occurring at dissimilar densities within and among the islands across the western Queen Elizabeth Islands. Such regional variation reduces the likelihood of whether both Peary caribou and muskox densities reached the levels to reduce forage availability at the same time and to the same relative degree to cause similarly high proportional losses of both species. However, the severity of the 1996-97 winter was widespread across the western High Arctic.

Foraging behaviour between the two species is mostly independent on the western Queen Elizabeth Islands (Thomas and Edmonds 1984) but possibly the winter foraging conditions could have driven muskoxen onto caribou range and caused or exacerbated forage shortages for Peary caribou. However direct evidence is lacking.

Reproductive success was not reduced before the die-offs in either Peary caribou or muskoxen in the Melville-Prince Patrick and Bathurst complexes before the 1973/74 die-offs (Miller *et al 1977)* and in the Bathurst complex before the 3 consecutive years of die-offs began in 1994/95 (no measure is available for the Melville-

Prince Patrick complex in 1994). Declining reproductive success is frequently used as evidence for density-dependence but both muskox and caribou calf production was high within the Melville-Prince Patrick complex and the Bathurst complex preceding the 1973/74 die-offs and the 1995 to 1997 die-offs in the Bathurst complex. Miller (1997) recorded that the highest levels of initial calf production and early calf survival occurred in 1993 and that in 1994; calving was early and initially successful at 26% calves among all Peary caribou seen by 12 June 1994 (Table 13). After the 1994/95 severe winter, calf production was 9% calves among all caribou seen by 24 June 1995 which also suggests that summer range was sufficient for at least some cows to regain condition enough to conceive (Miller 1997). Caribou depend on the high quality forage during the plant-growing season to rebuild body reserves to the level necessary to conceive (Thomas 1982).

Table 13. Calving dates, percentage of breeding cows with calves and early mortality of calves in summer 1988-94, Bathurst complex, Northwest Territories and Nunavut (data sources: Miller 1989, 1991, 1992, 1993, 1994, 1995, 1997).

Flight date interval(s)		Peak spread of calving	Breeding cows with calves (%)		Minimum Early mortality of calves (%)
1988	08-18 Jun 11-21 Jul	end of 3rd wk of Jun & later	18 Jun 21 Jul	36 86	14
1989	07-27 Jun 16-23 Jul	mid 3rd to 4th wk of Jun	16 Jun 27 Jun 23 Jul	19 91 73	27
1990	31 May- 10 Jul	mid 4th wk of Jun into early Jul	10 Jul	73	40
1991	07 Jun- 07 Jul	mid 3rd wk of Jun into early Jul	07 Jul	91	10
1992	13 Jun- 08 Jul	2nd-3rd of Jun into early Jul	08 Jul	94	6
1993	25-26 Jul 16-24 Aug	(no data)	24 Aug	97	3
1994	01-12 Jun 13 Jul-10 Aug	1st-2nd wk of Jun	12 Jun 10 Aug	85 60	40
1995	17-24 Jun 07-11 Jul	4th wk of Jun to mid 1st wk of Jul	24 Jun 11 Jul	35 48	52

Unlike other areas where caribou are suspected to have reduced mainly or solely the lichen component of their winter forage biomass and shifted their winter ranges (for example, Fleischman 1990, Ferguson and Messier 2000), most Peary caribou did not abandon their rut and early winter ranges in 1996/97. Based on the distribution of

Peary caribou carcasses, many caribou had returned in the autumn of 1996 to typical winter ranges as used the previous years (west coast of Prince Patrick Island, Cameron Island, Miller *et al.* 1977a, Miller and Barry 1992, Miller 1998, unpubl. data).

Our understanding of Peary caribou foraging dynamics is incomplete. Lichens are often considered a key forage and a decline in lichen use is evidence for over-utilization of ranges with the implied assumption that caribou then decline. However, caribou are seemingly more flexible in their foraging strategies – for example on Svalbard, repatriated reindeer *R. t. platyrhynchus* preferentially foraged on the highest quality plants but did not decline when their foraging had reduced those plants (Staaland *et al.* 1993). Thomas *et al.* (1999) suggested a higher use of lichens on eastern Melville Island than expected from their sparse cover. The proportion of lichens was higher (but still only 11% of identified plant fragments in the rumen samples) in the winter following the 1973/74 die-off when snow conditions were favorable although not the subsequent two winters. This suggests that densities prior to the 1973/74 die-off had not depleted at least lichens, and that the relationship between lichen use and availability relative to snow cover is complex.

Other factors affecting abundance in Peary caribou and muskoxen

Peary caribou and muskoxen within the Melville-Prince Patrick complex are not hunted. Bathurst Island, being close to Resolute was hunted until 1975 (Bissett 1968, Freeman 1975) when people from the community voluntarily stopped hunting caribou after the 1973/74 die-off (Freeman 1975, Ferguson 1987). Hunting resumed in 1990, but numbers taken were low (less then 30 between 1990 and 1992, Miller 1995b).

The incidence of wolf predation is unknown although wolves are present throughout the western Queen Elizabeth Islands (Miller and Reintjes 1994). Wolves are a generalist predator taking caribou, muskoxen, arctic hares, birds and their eggs and lemmings which means it is difficult to determine the effects of predation on any one species of prey (Holt and Lawton 1994).

In conclusion, the available evidence is that the 40% decline in Peary caribou across the western Queen Elizabeth Islands during 1996/97 was caused by caribou dying during the third consecutive unusually severe winter within the Bathurst complex and a severe winter on Prince Patrick Island that started with a storm in September 1996. During exceptionally severe winters and springs deep snow, freezing rain (causing icing) and the formation of ground fast ice resulted in widespread forage unavailability which leads to severe and prolonged malnourishment and subsequently high levels of death among both Peary caribou and muskoxen. The regional differences in climate (Maxwell 1981) and plant growth (Edlund 1983, Edlund 1990, Edlund and Alt 1989) would likely impose regional differences in herbivore demography across the western Queen Elizabeth Islands. Yet the 1996/97 high rates of death in Peary caribou and muskoxen were across the entire western Queen Elizabeth Islands, as were the high rates of death among Peary caribou and muskoxen across the western Queen Elizabeth Islands in 1973/74. We suggest that only extreme environmental episodes (such as the extremely severe 1996/97 winter and spring periods, and also in 1973/74) could cause such a degree of spatially and temporally correlated deaths in two species with markedly different seasonal and annual site-use patterns on the same range.

Our results have implications for Peary conservation. We documented that

Peary caribou have declined from an estimated 2660 in 1974 to 1100 caribou in 1997 following three of the most severe winters recorded. The decline has raised questions about whether those winters were part of a trend or were within 'normal' climate variability and what either mean for the future of Peary caribou.

If the threats to Peary caribou were simply the consequences of the naturally high variation in weather in an extreme environment (on the edge of the range for plant growth and thus herbivory), then the need for recovery actions would be less as the caribou numbers would likely recover. However, recent trends in arctic weather are consistent with the predictions for global climate change (Maxwell 1987, Tynan and Demaster 1997) and the balance of opinion is that human activity has contributed to global climate change. If the Peary decline is a consequence of human activity, then we have a greater conservation obligation and in addition, the past is not then, necessarily an accurate guide to the future and recovery to population sizes that will sustain meaningful levels of harvest, will be slow at best.

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APPENDIX A. Weather and light conditions during an aerial survey on the western Queen Elizabeth Islands, Northwest Territories and Nunavut, June-July 1997.

Date	Transects flown (Stratum)	Light and weather conditions
Prince Patrick Island		
29 June	15 (northern segment) (I) 16-20 (I)	Scattered high cloud, winds <10 kt, visibility good. Snow cover: 50-100%
30 June	15 (southern segment) (I) 2–14, 22–29 (I) (1 dropped)	Scattered to broken high cloud, winds <5 kt, visibility good. Snow cover: central and west 60-100%, east coast 20-60%
1 July	30-32 (I) 33-44(III) 45, 47, 49, 51, 53, 55, 57, 61, 64, 68 (partial) (II) (46,48, 50, 52, 54, 56, 58-60, 62-63, 65-67, 69-76 dropped)	Scattered cloud, winds <5 kt, visibility good. Fog building throughout day. Snow cover: low level land, central and east coast 100%, east coast 20-40%. Fog building on II. Drop lines to complete geographic coverage.
Melville, Eglinton, Mackenzie King, Brock, Emerald and Byam Martin islands		
2 July	77-85 (Eglinton Island) 98-101 (XI) 128-136 (XII) (137-138 not flown) (127 dropped)	Fog on X and thin, scattered fog north end of Eglinton. Snow cover: Eglington 20-30%, X and XI 30-100%. Fog on lines 137-138.
3 July	86-96 (X) 102-108 (XI) 110 (partial), 112 (partial), 114, 116 (IX)	Broken to overcast cloud, winds 10-15 kt, 5° C, visibility variable bright to dull. Variable, scattered fog patches. Snow cover 20-60%. Lines 110 & 112 broken in fog.
3 – 8 July		Too foggy to survey
9 July	202-216 (VI)	Broken cloud, 2000' with occasional showers, winds <10 kt, 3° C, visibility good with occas. dull light. Snow cover: Central Dundas (VI) 50%, otherwise 10-20%.

APPENDIX A. (CONT'D)

Date	Transects flown (Stratum)	Light and weather conditions
10 July	217-221 (VI) 186-201 (V) 222-223 (IV)	Broken to overcast cloud with occasional showers, winds 10 kt, 3° C, visibility variable bright to dull. Snow cover: northern sections of lines 60-80%, southern sections with snowbanks.
11 July	224-226 (southern sections) 254, 256, 258, 260, 262 (partial), 264 (I) (253, 255, 257, 259, 261, 263, 265 dropped)	Broken to overcast cloud, 1000-2000', visibility variable bright to dull in fog patches. Snow cover: variable, mostly <20%. Northern sections of 224-226 in fog. Coverage dropped as low densities in 1972-74.
12 July		Too foggy to survey
13 July	227-229 (southern sections) (IV) 272 (partial), 273 (III) 230-239 (IV)	Broken, 1000-2000', winds NW 25kt, visibility variable bright to dull in fog patches. Snow cover variable, mostly <20%. Northern segments of 227-229 in fog.
14 July	267-268 (partial) 269-272 (III) 240-252 (II) 224-228 (northern sections) 266 dropped	Fog patches, winds N 20 kt, visibility variable, mostly bright, occasionally dull in fog patches. Snow cover: variable, mostly <10%, north end of II 60-80%. North ends of 267 & 268 in fog. 266 in fog.
15 July	139-144 (XIII) 152-157 (partial) (XIII) 159-162 (VIII)	Broken to overcast cloud, winds SE 35 kt, visibility good to dull, mostly bright. Snow cover: variable, 60-80% on higher ground. Turbulence on lines 152-157.
16 July	171-172 (VIII)	Overcast cloud, winds <5 – 30kt.
17 July	145-150, 151 (partial) 163-170 173-178 (VIII)	Broken to overcast, mid-level occasionally lower, winds SW 10-15 kt, Snow cover: 30-50% on higher ground of XIII. Fog on line 151 and 173.

APPENDIX A. (CONT'D)

Date	Transects flown (Stratum)	Light and weather conditions
18 July	380-382, 383-386 (partial) (387 dropped) (Mackenzie King Is) 376-378 (Brock Island)	Clear except upslope fog patches, visibility variable. Snow cover: Mackenzie King 100% except northest portion 30-40%, Brock 40-50%. North ends of line 383-386 broken in fog. 387 dropped.
19 July	388-391 (Emerald Island) 111-117, 118-119 (north segments) (IX) (120-126 not flown)	Scattered to broken cloud, winds SE 5 – 25 kt, visibility good, bright light. Snow cover: <10%. Southern segments of 118-119 and 120-126 not flown due to turbulence.
20 July	179-180 (partial), 181-185 (VII) 400-406 (Byam Martin Island)	Broken cloud, fog patches, winds SW 35 kt, Snow cover: VII <20%, Byam Martin <20%. North ends of 179-180 not flown due to tubulance.

<u>Bathurst, Alexander, Massey, Vanier, Laugheed, Cameron islands</u>

21 July	335-339 (I) 310-317 (Alexander Island) 302a-303a (Ile Marc) 301-309 (Massey Island) 290-300 (Vanier Island) 392-399 (Lougheed Island 282-284 (Cameron Island)	Broken to overcast, winds < 5kt, visibility mostly good, dull on Lougheed. Snow cover: Alexander <10%, Massey 20-30%, Vanier, 20-50%, Lougheed <10%.
22 July	285-289 (Cameron Island) 400a-405a, (406a not flown) (Helena Island) 219-334 (I)	Scattered cloud, winds < 5kt, visibility excellent except dull in a few fog patches on Cameron and Helena islands. Snow cover: I 60% in north otherwise <10%.
23 July	364-375 (II) 357-363 (northern segments) (II)	Scattered becoming overcast, winds NW <5 – 20 kt, visibility excellent then ceiling dropped with fog and rain.
24 July	362-363 (southern segments)(II) 341-342 (partial) (III) 343-356 (II)	Broken to overcast, mid to low level, winds 5-20 kt, 10° C; visibility variable good to dull in fog patches. Snow cover: 10-20%. Lines 341-342 broken in fog

APPENDIX B. Peary caribou, muskoxen and wolves observed during an aerial survey on the western Queen Elizabeth Islands, Northwest Territories and Nunavut, June-July, 1997.

Prince Patrick Island, Stratum I

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
1	not flown							
2	40							
3	52							
4	49							
5	46							
6	44							
7	48							
8	61					1 /		
9	72	3						
10	76		5			6 /		
11	6							
12	57					3 /		1 /
13	13	1	1					
14	82					5 /		
15	86		2			6 /		
16	112							
17	102					1 /		
18	108					3 /		
19	104							
20	55							
22	65						1 /	
23	80							
24	78		8	6	1		2 /	
25	34							
26	23			12	5			
27	35							
28	16							
29	32							
30	6							
31	8					/ 1		
32	3							
Total	**1593**	**4**	**16**	**18**	**6**	**25 / 1**	**3 / 0**	**1 / 0**

APPENDIX B. (CONT'D)

Prince Patrick Island, Stratum II

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
45	9							
46	not flown							
47	22							
48	not flown							
49	37					1 /		/ 2
50	not flown							
51	55					2 /		
52	not flown							
53	59							
54	not flown							
55	60							
56	not flown							
57	62					1 /		
58	not flown							
59	not flown							
60	not flown							
61	53							
62	not flown							
63	not flown							
64	52							
65	not flown							
66	not flown							
67	not flown							
68	50	2						
69	not flown							
70	not flown							
71	not flown							
72	not flown							
73	not flown							
74	not flown							
75	not flown							
76	not flown							
Total	**459**	**2**	**0**	**0**	**0**	**4 / 0**	**0 / 0**	**0 / 2**

APPENDIX B. (CONT'D)

Prince Patrick Island, Stratum III

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
33	34			2				
34	57	4						
35	63					1 /		
36	65	5						
37	62							
38/39	57							
40	33							
41	30							
42	30							
43	28							
44	22				2			
Total	**481**	**9**	**0**	**2**	**2**	**1 / 0**	**0 / 0**	**0 / 0**

Eglinton Island

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
77	14							
78	21							
79	33							
80	44							
81	45							/ 1
82	43			7				
83	39							/ 1
84	30							
85	23							/ 1
Total	**292**	**0**	**0**	**7**	**0**	**0 / 0**	**0 / 0**	**0 / 3**

Emerald Island

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
388	11							
389	19							
390	20					2 /		
391	14							
Total	**64**	**0**	**0**	**0**	**0**	**2 / 0**	**0 / 0**	**0 / 0**

APPENDIX B. (CONT'D)

Byam Martin Island

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
400	13							
401	35					2 /	/ 1	
402	44					3 / 2		
403	47					/ 1		
404	41							
405	34							
406	10							
Total	**224**	**0**	**0**	**0**	**0**	**5 / 3**	**0 / 1**	**0 / 0**

Melville Island, Stratum I

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
253	not flown							
254	19							
255	not flown							
256	30							
257	not flown							
258	68						1 /	
259	not flown							
260	83		3					
261	not flown							
262	36							
263	not flown							
264	36			3	4			
265	not flown							
Total	**272**	**0**	**3**	**3**	**4**	**0 / 0**	**1 / 0**	**0 / 0**

Melville Island, Stratum II

Transect number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
240	5							
241	9							
242	20					1 /		
243	30			9				
244	35					5 / 1		
245	41	2	3					

APPENDIX B. (CONT'D)

Melville Island, Stratum II (cont'd)

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
246	44	6						
247	42							
248	40	1				1 /		
249	34	4						
250	31							
251	20				15			
252	11		1			1 /		
Total	**362**	**13**	**4**	**9**	**15**	**8 / 1**	**0 / 0**	**0 / 0**

Melville Island, Stratum III

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
266	not flown							
267	42							
268	39							
269	58	5	2					
270	59	5						
271	61	2	4					
272	61	1						
273	37	3	13					
Total	**357**	**16**	**19**	**0**	**0**	**0 / 0**	**0 / 0**	**0 / 0**

Melville Island, Stratm IV

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
222	28							
223	73	3	3					
224	90							/ 1
225	93	2			3			
226	94	3		6				
227	88							
228	94			2				
229	57		2					

APPENDIX B. (CONT'D)

Melville Island, Stratm IV cont'd

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
230	60	5						
231	82							
232	74							
233	74	8						
234	67		7		4			
235	62	3	9					
236	57	4	4					
237	50	3	10					
238	37	5			7			
239	15	4	19					
Total	**1195**	**40**	**54**	**8**	**14**	**0 / 0**	**0 / 0**	**0 / 1**

Melville Island, Stratum V

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
186	5							
187	17							
188	29							
189	28							
190	77							
191	85							
192	88			5		1 /	1 /	
193	78	5	2					
194	79							
195	77	11		5				
196	75	1		2	6			
197	75	1		2				
198	69	3		3				
199	62	4						
200	57							
201	45							
Total	**946**	**25**	**2**	**17**	**6**	**1 / 0**	**1 / 0**	**0 / 0**

APPENDIX B. (CONT'D)

Melville Island, Stratum VI

Transect	Transect	Caribou on	Caribou off	Muskox on	Muskox off	Caribou carcass	Muskox carcass	Wolf on / off

number	Area	Transect	transect	transect	transect	on / off transect	on / off transect	transect
202	20			2		1 /		
203	29			13	4		3 /	
204	36						1 / 1	
205	44	6		8	6			
206	47			11	23		2 /	
207	53			20	9		1 /	
208	60			26				
209	64				4		1 /	
210	65				2			
211	65			1	7		/ 1	/ 1
212	65		8	21	25			/ 1
213	62	3		19	32			
214	60			20+1	19			
215	56			11	11		1 /	
216	55			24	30			
217	51			23	19			
218	43			7	8			
219	34				13			
220	24	3		6	22+1			
221	13				13			
Total	**946**	**12**	**8**	**212+1**	**247+1**	**1 / 0**	**9 / 1**	**0 / 2**

Melville Island, Stratm VII

Transect number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
179	25							
180	33							
181	37			9	3			
182	38							
183	27							
184	26							
185	18				12			
Total	**204**	**0**	**0**	**9**	**15**	**0 / 0**	**0 / 0**	**0 / 0**

APPENDIX B. (CONT'D)

Melville Island, Stratm VIII

Transect number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
159	7							
160	13							
161	19							
162	25							
163	31							
164	41							
165	40							
166	40							
167	40							
168	45				4			
169	51				2			
170	56			3				1 / 6+8
171	69			4				
172	76		13	15	11			
173	77		9	6	33	1 /		
174	80	4		6	32			
175	78			27	17			
176	76	2		5	7	1 /	2 /	
177	68				31	2 /	2 /	
178	31				8	1 /		
Total	**963**	**6**	**22**	**66**	**145**	**5 / 0**	**4 / 0**	**1 / 6+8**

Melville Island, Stratum IX

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
111	30				20		1 /	
112	29		20					
113	51				7		2 /	
114	51	4		4				
115	51							
116	51	2		2		1 /		
117	53	1				3 /		
118	32	2	3	1		4 / 3		
119	28					/ 1		
120	not flown							

APPENDIX B. (CONT'D)

Melville Island, Stratum IX (cont'd)

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
121	not flown							
122	not flown							
123	not flown							
124	not flown							
125	not flown							
126	not flown							
Total	**376**	**9**	**23**	**7**	**27**	**8 / 4**	**3 / 0**	**0 / 0**

Melville Island, Stratm X

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
86	11			12				
87	19		1					
88	25	12						
89	25				11			
90	29							
91	35							
92	39				4			
93	36	2			4			
94	35							
95	32		11				/ 1	
96	9							
Total	**295**	**14**	**12**	**12**	**19**	**0 / 0**	**0 / 1**	**0 / 0**

Melville Island, Stratum XI

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
98	26	1	5	7				
99	33							
100	36							
101	37							
102	35							
103	34			4				
104	35							
105	34	2		7	5			
106	31					/ 1		

APPENDIX B. (CONT'D)

Melville Island, Stratum XI (Cont'd)

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
107	29				3			
108	29				10			
Total	**359**	**3**	**5**	**18**	**18**	**0 / 1**	**0 / 0**	**0 / 0**

Melville Island, Stratm XII

Transect Number	Transect Area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
127	not flown							
128	20							
129	26	2						
130	27							
131	27							
132	27							
133	25							
134	24							
135	21							
135a	23			2				
136	22							
137	not flown							
138	not flown							
Total	**242**	**2**	**0**	**2**	**0**	**0 / 0**	**0 / 0**	**0 / 0**

Melville Island, Stratm XIII

Transect Number	Transect Area	Caribou on transect	Caribou off Transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
139	16							
140	28							
141	35							
142	37							
143	40			6				
144	37			6				
145	33				11			
146	43			4	14			7 /
147	51	1		3				
148	59			3	5		1 /	/ 2+4
149	66			6	12	1 /		
150	53							

APPENDIX B. (CONT'D)

Melville Island, Stratm XIII (Cont'd)

Transect	Transect	Caribou on	Caribou off	Muskox on	Muskox off	Caribou carcass	Muskox carcass	Wolf on / off

Number	area	Transect	Transect	transect	transect	on / off transect	on / off transect	transect
151	53				11		1 /	
152	78			24			6 /	
153	80						1 /	
154	72				6		1 /	
155	62						1 /	/ 1
156	62				4		1 /	
157	32			7				
Total	**937**	**1**	**0**	**59**	**63**	**1 / 0**	**12 / 0**	**7 / 3+4**

Bathurst Island, Stratum I

Transect Number	Transect area	Caribou on Transect	Caribou off Transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
319	25							
320	21							
321	37							
322	38							
323	37							
324	29							
325	22	3						
326	26							
326b	14							
327	52							
328	49							
329	11							
330	25		2				3 /	
331	72							
332	17						1 /	
333	71		1					
334	68	1						
335	61							
336	52							
337	45				3		/ 1	
338	33			5				
339	27							
Total	**832**	**4**	**3**	**5**	**3**	**0 / 0**	**4 / 1**	**0 / 0**

APPENDIX B. (CONT'D)

Bathurst Island, Stratum II

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
357	6							
358	20							
359	24						1 /	

Bathurst Island, Stratum II (Cont'd)

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
360	28							
361	32						1 /	
362	64				4			
363	101			4	4			
364	104		1					
365	97	4	5	9			1 /	
366	93	1	4			2 /		
367	85							

Bathurst Island, Stratum II

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
368	102							
369	109							
370	108		2			1 /		
371	98							
372	91			6				
373	87							
374	82	4				1 /		
375	15							
Total	**1346**	**9**	**12**	**19**	**8**	**4 / 0**	**3 / 0**	**0 / 0**

Bathurst Island, Stratum III

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
341	40	2				1 /		
342	50						/ 1	
343	64					1 /		
344	77			1		1 / 1	1 /	
345	78					2 /	/ 2	

APPENDIX B. (CONT'D)

Bathurst Island, Stratum III (Cont'd)

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
346	69					2 /	2 / 2	
347	77						/ 2	
348	78							
349	72					1 /		
350	80							
351	80							
352	79						1 /	
353	80						1 /	
354	66					2 /	1 /	
355	21					1 /		
356	21					1 /		
Total	**1032**	**2**	**0**	**1**	**0**	**12 / 1**	**6 / 7**	**0 / 0**

Vanier Island

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
290	9					4 / 2		
291	17					4 /		
292	19							
293	24					2 /		

Vanier Island

Transect number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
294	25					3 /		
295	26					/ 1		
296	29					2 / 3		
297	29					4 / 1		
298	27					1 /		
299	25					/ 1		
300	9							
Total	**239**	**0**	**0**	**0**	**0**	**20 / 8**	**0 / 0**	**0 / 0**

APPENDIX B. (CONT'D)

Cameron Island

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off Transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
281	8							
282	19					2 /		
283	39					14 / 2		
284	38					5 / 2		
285	33					6 / 2		
286	30					3 / 1		
287	21					5 / 2		
288	18					2 /		
289	9					1 / 3		
Total	**215**	**0**	**0**	**0**	**0**	**38 / 12**	**0 / 0**	**0 / 0**

Alexander Island

Transect Number	Transect area	Caribou on Transect	Caribou off transect	Muskox on transect	Muskox off Transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
310	7							
311	14							
312	21					1 / 1		
313	22							
314	21							
315	11							
317	12							
Total	**108**	**0**	**0**	**0**	**0**	**1 / 1**	**0 / 0**	**0 / 0**

Massey Island

Transect Number	Transect area	Caribou on transect	Caribou off transect	Muskox on transect	Muskox off Transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
301	5							
302	9					3 /		
303	9	1						
304	13							
305	13							
306	15							
307	15							
308	13							
309	11							
Total	**103**	**1**	**0**	**0**	**0**	**3 / 0**	**0 / 0**	**0 / 0**

APPENDIX B. (CONT'D)

Helena Island

Transect	Transect	Caribou on	Caribou off	Muskox on	Muskox off	Caribou carcass	Muskox carcass	Wolf on / off

number	area	transect	transect	transect	transect	on / off transect	on / off transect	transect
400	10							
401	10							
402	11							
403	14							
404	13							
405	10							
406	not flown							
Total	**68**	**0**	**0**	**0**	**0**	**0 / 0**	**0 / 0**	**0 / 0**

Marc Island

Transect number	Transect area	Caribou on transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
302	5					/ 1		
303	4					4 /		
Total	**9**	**0**	**0**	**0**	**0**	**4 / 1**	**0 / 0**	**0 / 0**

Brock Island

Transect number	Transect area	Caribou on transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
376	9							
377	33							
378	31							
379	11							
Total	**84**	**0**	**0**	**0**	**0**	**0 / 0**	**0 / 0**	**0 / 0**

Mackenzie King Island

Transect number	Transect area	Caribou on transect	Caribou off transect	Muskox on transect	Muskox off transect	Caribou carcass on / off transect	Muskox carcass on / off transect	Wolf on / off transect
380	53							
381	70		7					
382	78							
383	63							
384	51	1+1				1 / 2		
385	63							
386	52	2				1 /		
387	not flown							
Total	**430**	**3+1**	**7**	**0**	**0**	**2 / 2**	**0 / 0**	**0 / 0**