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Dolphin and Union Caribou Herd Status and Trend

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ABSTRACT. The Dolphin and Union caribou herd (*Rangifer tarandus groenlandicus*) is of great importance for Inuit subsistence and cultural needs. This herd is somewhat particular in that it relies on the seasonal connectivity of the sea ice between Victoria Island and the mainland to undertake its fall and spring migrations to and from its wintering ground on the mainland. While the herd may have numbered in the order of 100 000 animals in the past, it experienced a dramatic decline in the early 1900s and stopped its migration to the mainland. It resumed its migration only as it started to increase during the 1980s and 1990s, and in October 1997, the caribou gathered on the southern coast (prior to crossing to the mainland) were estimated to number 27 948 ± 3367 SE. In October 2007, using the same method and covering approximately the same area as during the 1997 survey, we estimated 21 753 ± 2343 SE caribou within our study area. The method used in 1997 and 2007 assumes that most of the herd is located within a narrow strip along the southern coast of Victoria Island, but also acknowledges that some caribou are outside that area. Therefore, we undertook a correction of both 1997 and 2007 estimates for the Dolphin and Union caribou herd based on available data from radio-tracking of female caribou. The corrected estimate for the Dolphin and Union caribou herd in 2007 was 27 787 ± 3613 SE. Both the study area estimates and the corrected herd estimates for 1997 and 2007 indicate that the herd trend in the intervening decade was at best stable.

Key words: caribou, *Rangifer*, migration, population size estimate, population trends, Dolphin and Union herd, Canada, Nunavut, Northwest Territories

RÉSUMÉ. Le troupeau de caribous Dolphin et Union (*Rangifer tarandus groenlandicus*) revêt une grande importance pour la subsistance et la culture des Inuits. Ce troupeau a la particularité d'utiliser la banquise pour migrer en automne et au printemps entre son aire d'estivage, sur l'île Victoria, et son aire d'hivernage sur le continent. Bien que ce troupeau ait été estimé aux alentours de 100 000 individus par le passé, il a connu un déclin dramatique au début du XX^{e} siècle et interrompu sa migration vers le continent. C'est seulement dans les années 1980 et 1990 que le troupeau a commencé à augmenter et à reprendre sa migration. En octobre 1997, les caribous assemblés le long de la côte sud, avant leur traversée vers le continent, étaient estimés à 27 948 ± 3 367 (± erreur type). En octobre 2007, utilisant la même méthode, nous avons estimé 21 753 ± 2 343 (ET) caribous dans à peu près la même aire d'étude qu'en 1997. La méthodologie employée en 1997 et en 2007 présume que la majorité du troupeau se regroupe dans une bande étroite le long de la côte sud de l'île Victoria, mais reconnaît aussi qu'un certain nombre de caribous se trouve en dehors de cette zone. Par conséquent, nous avons effectué une correction des estimés de 1997 et de 2007 pour obtenir un estimé du troupeau tout entier grâce aux données de télémétrie disponibles pour les caribous femelles. Cette correction nous a permis d'estimer le troupeau Dolphin et Union à 27 787 ± 3 613 (ET) caribous en 2007. Entre 1997 et 2007, tant les estimés dans l'aire d'étude que les estimés corrigés témoignent d'un troupeau au mieux stable pour la décennie concernée.

Mots clés : caribou, *Rangifer*, migration, estimé de taille de population, tendance de population, troupeau Dolphin et Union, Canada, Nunavut, Territoires du Nord-Ouest

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INTRODUCTION

The Dolphin and Union caribou herd (*Rangifer tarandus groenlandicus*) is the most genetically differentiated of the barren-ground caribou (Zittlau, 2004). Local Inuit hunters distinguish it from other caribou by its phenotype, its behavior, and the taste of its meat.

This herd is distinctive in that it relies on the seasonal connectivity of the sea ice between Victoria Island and the mainland to undertake its fall and spring migrations to and from its wintering ground on the mainland (Poole et al., 2010). The herd calves and mates on the island and spends the winter on the nearby mainland.

Conservation concerns were raised by the Kitikmeot Hunters and Trappers Association in 1997 and consultation to initiate a management plan was undertaken by the government of the Northwest Territories (GNWT-RWED, 1998), but the management plan was never drafted. Also,

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because of this herd's small size, its vulnerability to harvest, and the potential future impacts of natural or anthropogenic alteration of the sea ice, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed these caribou as a species of special concern (COSEWIC, 2004). The herd is listed under Schedule 1, Part 4, of the Species at Risk Act in Canada (Canada Gazette, 2011), and it has been investigated by the U.S. Fish and Wildlife Service to be listed under the Endangered Species Act (Federal Register, 2011).

After a period of very low densities reported from observational studies (see Gunn, 1990) and traditional knowledge (M. Angohiatok, unpubl. data), the herd started to increase in the late 1970s to early 1980s, and it resumed its migration to the mainland during the late 1980s and early 1990s (Gunn and Nishi, 1998; Gunn and Fournier, 2000). Until 1997, the herd was increasing, with a conservative estimate of 27 948 ± 3367 (± SE) animals in October 1997 (Nishi and Gunn, 2004), but the status and trend of this herd since that year are unknown**.** However, surveys conducted in 1998, 2001, and 2005 on a small portion (< 5%) of the herd in the northwest part of Victoria Island showed a significant (250%) increase of caribou in that area from 1998 to 2001 and then no significant trend ($p > 0.05$) between 2001 and 2005 (Nagy et al., 2006).

Subsistence harvest levels are unknown and have fluctuated mainly in relation to availability of alternative caribou herds for mainland communities. Local hunters are reporting more animals in poor physical condition or with signs of disease (Dumond et al., 2007). Moreover, local knowledge indicates an increase of predators on the Island (Dumond et al., 2007) and increasing human activity (mining and mining exploration, Distant Early Warning line sites, maritime traffic) could affect both summer and winter ranges and migratory routes (COSEWIC, 2004; Poole et al., 2010; Dumond et al., 2013). Because of the risk of negative cumulative effects on the Dolphin and Union caribou herd and its importance to communities for subsistence, the Department of Environment, Government of Nunavut, conducted an aerial survey to estimate the herd's abundance. The survey was conducted during the fall staging of caribou on the southern coast of Victoria Island. In this paper, we examine survey results and trends since previous surveys to provide an updated status of this caribou herd.

STUDY AREA

The range of the Dolphin and Union caribou herd extends to most of Victoria Island (70˚ 55′ N; 109˚ 59′ W) and to the nearby mainland (Poole et al., 2010; Nagy et al., 2011; Fig. 1). The island has a fairly low topography, with elevations rising to only 655 m. The island has two settlements: Cambridge Bay, Nunavut, and Holman, Northwest Territories). Cambridge Bay (69˚ 06′ N 105˚ 08′ W) has a low average annual precipitation (138.8 mm) and mean temperatures ranging from 8.4 ± 1.6˚C SD in summer to -33.0 ± 3.2˚C SD in winter. Snow usually covers the area from late September to early July, giving a snow-free period of only three months (Environment Canada, 2013).

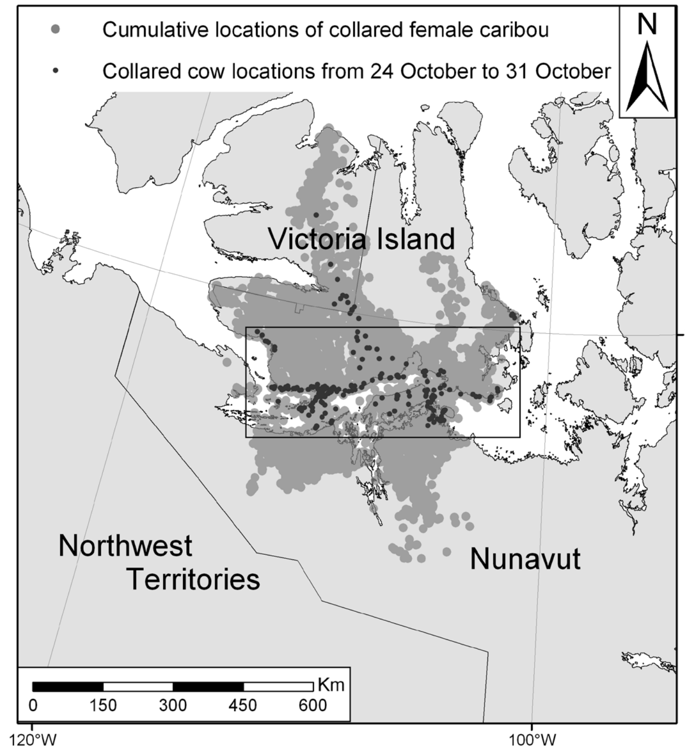

FIG. 1. General study area. Grey area shows cumulative annual distribution of Dolphin and Union caribou derived from satellite collar locations for 1999–2005. Black dots indicate cumulative locations on 24 to 31 October. Note that during our 2007 survey, caribou were unlikely to be offshore on the sea ice or on the mainland because freeze-up was late that year.

The island is characterized by mesic and dry habitats dominated by prostrate shrubs with patches of wet sedge-moss tundra in the north. The southern coast supports a relatively higher biomass with vegetation similar to that on the mainland: erect dwarf-shrub tundra dominated by *Carex* spp. and *Salix lanata*, with some *Oxytropis* spp. (Gould et al., 2002).

Caribou share this environment with only a few mammal species: muskox (*Ovibos moschatus*), lemmings (*Lemmus trimucronatus* and *Dicrostonyx* spp.), Arctic hare (*Lepus arcticus*), Arctic fox (*Alopex lagopus*), red fox (*Vulpes vulpes*), wolf (*Canis lupus*), wolverines (*Gulo gulo*), and low densities of grizzly (*Ursus arctos horribilis*) and polar bears (*Ursus maritimus*).

Over the past 2.5 decades, later fall freeze-up of sea ice (delayed by more than three days per decade) has delayed the fall migration of the herd from the island to the mainland (Poole et al., 2010).

METHODS

The survey technique, based on the method developed by Nishi and Gunn (2004), aimed to survey most of the herd on the southern coast of Victoria Island during its fall staging

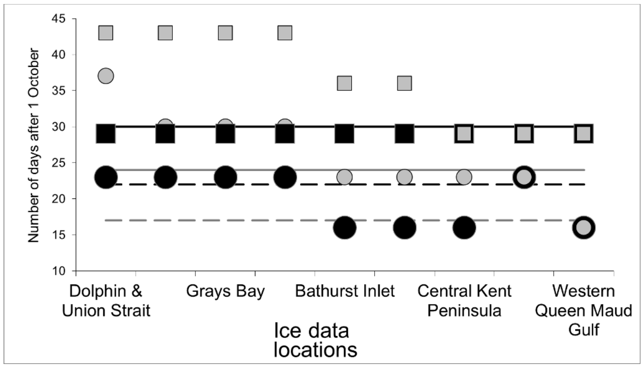

FIG. 2. Number of days from 1 October for the formation of new ice (black) and grey ice (grey) in 1997 (circles) and 2007 (squares) at various locations from west to east between Victoria Island and the Nunavut mainland (see Poole et al., 2010 for details). The lines represent the beginning and end of the surveys in 1997 (broken line) and 2007 (solid line).

period, when caribou wait for the ice to form to allow them to migrate to the wintering grounds on the mainland.

To pinpoint the start of the survey, we monitored sea ice formation patterns and caribou aggregation on the southern coast of Victoria Island using Environment Canada weather data and local observations from hunters and conservation officers. We plotted the dates for the formation of new ice (< 10 cm thick) and grey ice (10 to 30 cm thick) at various locations in 2007 (see Poole et al., 2010) and compared this plot with the 1997 ice formation pattern (Fig. 2). Like the 1997 survey, our survey was conducted one to 13 days before the formation of grey ice between Victoria Island and the mainland (Fig. 2).

We used a fixed-wing aircraft, Helio-Courier H-295, on wheel skis to conduct an aerial reconnaissance survey on 24 October 2007 (between Read Island and Cambridge Bay) and on 26 October 2007 (west and east of Cambridge Bay, Fig. 3a) and determine the distribution of the caribou along the southern coast of Victoria Island. Flight lines were oriented mainly parallel to the coast, with some inland lines to identify any gradient of distribution. All observations during the reconnaissance and the survey itself were recorded on a Global Positioning System (GPS), and the number of caribou was recorded on the observation sheet along with the date, time, and waypoint number for each observation. The aerial reconnaissance survey was used to stratify the survey according to densities observed and to ensure that the majority of the herd was gathered along the coast. The reconnaissance was done by the pilot and the principal investigator alone on 24 October and with two additional observers on 26 October 2007.

We conducted the aerial stratified strip transect survey using the same aircraft, flying at an altitude of 100 m above the ground and an average speed of 160 km/h (Nishi and Gunn, 2004). In addition to the pilot (left) and the navigator (right), the survey crew consisted of a right and a left observer or only a left observer during one day (the navigator covering the right side). Observers were local residents from the community of Cambridge Bay. The first transect was randomly placed and then each sequential line was evenly spaced at a set interval within each stratum. All transects were oriented perpendicular to the coast. We set up markers to aid in delineating a 500 m strip on each side of the aircraft when it was 100 m above ground and recorded all caribou within those strips. Most transects were 10 km or less in length because very few caribou were observed more than 7 km from the coast (average distance from the coast = 2.9 km ± 2.8 SD). The survey was conducted on 29 and 30 October 2007 and covered 651 km of transects, representing an area of 651 km^2 (0.5 km width on each side of the transect line). The total survey area was 3757 km^2 divided into five strata (Fig. 3b) covered at 11% to 20% (mean coverage of the study area = 17.3%).

During the flights we recorded dead caribou and classified each one as drowned (when caribou had broken through the ice), killed (when seen on the ice or on the land with blood visible) or unknown (when no blood was visible and drowning was rejected). We also recorded any muskoxen, wolves, and other carnivores observed during the survey. For each observation, a waypoint was added onto a GPS, and the airplane flight track was recorded during all reconnaissance and survey flights.

Survey Area Caribou Estimate

To estimate the total number of caribou within the study area, we used only the individuals observed within the 1 km wide transect strips. Caribou observed outside the 1 km wide strip were recorded to inform the distribution.

We calculated the caribou population estimate within each stratum using Jolly's Method 2 for unequal sample sizes (Jolly, 1969 in Norton-Griffiths, 1978). All sexes and ages were pooled, as it was difficult to classify individuals during the survey. Lake areas, being frozen at the time of the survey, were not subtracted from the total area used in density calculations (statistical analysis adapted from Campbell and Setterington, 2001).

The estimate of the Dolphin and Union caribou within our survey area was produced from the sum of the estimates in each stratum. We also created a stratum for islands where caribou had gathered at the edge of the freezing sea ice. This stratum was surveyed by aerial photography (Canon Rebel digital camera, 10 megapixels); all the caribou were counted visually or from the photographs, and the count was added to the survey estimate. The photographs were overlapping, and landmarks were used to avoid double counts or missed individuals. Photographs were imported as maps in OziExplorer (version 5.95.4q), and a waypoint was created for each caribou (J. Nagy, pers. comm. 2006).

Total Caribou Herd Estimate

Although we were confident that the core of the herd was within our study area, we acknowledged that some caribou might not have reached the study area and therefore were not included in the estimate. In an attempt to account for these caribou and provide a more accurate picture of the

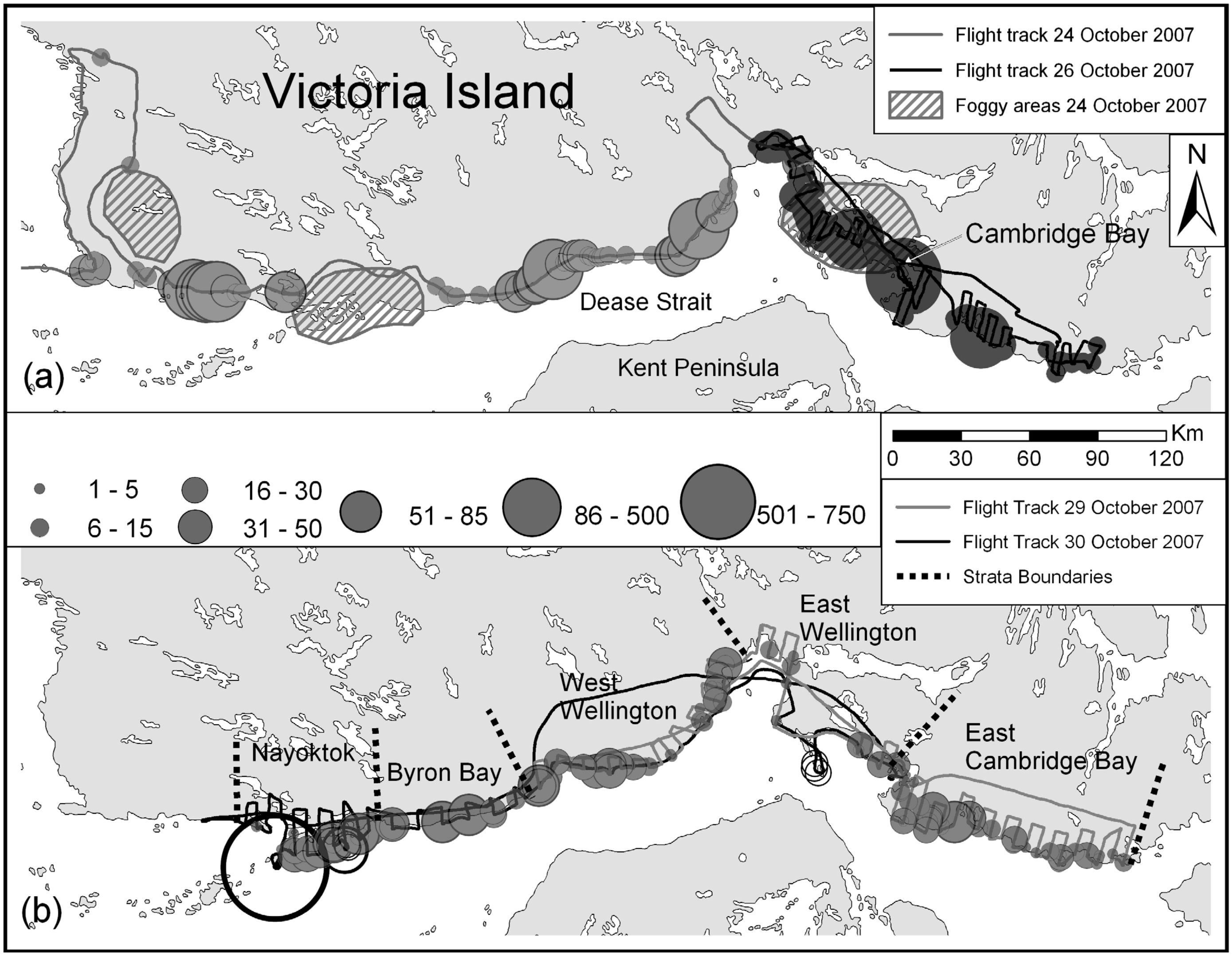

FIG. 3. Dolphin and Union Caribou herd 2007 survey area and caribou observations on the southern coast of Victoria Island, Nunavut. (a) Caribou observed during the aerial reconnaissance survey on 24 and 26 October. (b) Distribution and abundance of caribou observed on transect during the systematic aerial survey on 29 and 30 October. Names of strata and their boundaries (dotted lines) are also shown.

herd status (abundance and trend), we used collar data from previous years (we did not have collared caribou during the 2007 survey) to estimate the proportion of caribou that were outside our study area. This method was based on two assumptions: (1) that caribou behaviour and movement patterns were consistent from year to year (Poole et al., 2010), and (2) that the number of non-collared animals associated with each collared animal is similar both within and outside our study area. To estimate p_a (the probability that a caribou would be within the study area), we used SVIC99-06 satellite collar data sets (one location per day from October 26 to October 30, n = 34 caribou•year) for 2000, 2001, and 2002, the three most recent years with sufficient collar data. We discarded data from subsequent years (2003–05) because the number of collared caribou decreased from seven in 2003 to only two in 2004 and 2005, and these were distributed mainly in the eastern portion of the herd range. All spatial data were analyzed using ArcGIS 9.0. Only females were fitted with radio-collars, but because the period considered here followed the rut, we assume that these data are a fair representation of both male and female distribution.

We assigned a probability for each collared caribou to be within our study area during the time of our survey. Poole et al. (2010) showed that the duration of staging along the coast was not influenced by sea ice formation; however, the start of the fall migration to the southern coast of Victoria Island had a weak correlation with new and grey ice formation ($r^2 = 0.07$, $p = 0.044$ and $r^2 = 0.10$, $p = 0.017$, respectively). During our survey, the ice was not strong enough to allow movements to the mainland; therefore, when examining the 26–30 October data from 2000 to 2002, we included in the study area collar locations of caribou that were on the sea ice or had crossed to the mainland. This choice may have resulted in a slightly conservative population estimate if late ice formation actually delayed the fall staging on the coast. We then used the following formula to calculate the probability for a caribou to be "available" within the study area during the survey (p_a):

$$p_a = \sum p_y / N_{years}$$

where p_y = the probability of a caribou being in the study area between 26 October and 30 October for a given year (mean p_{xy} for year y), p_{xy} = the probability for a given caribou (x) to be within the study area between 26 October and 30 October in a given year (y) calculated as the count of a given caribou (x) locations within the study area/n_{xy}, n_{xy} = the number of collar locations from 26 October to 30 October of year y for caribou x, and N_{years} = the number of years of data.

We adjusted the Dolphin and Union caribou herd estimate by adapting equations 14 and 15 in Innes et al. (2002), where $N^{**} = N^{*}/p_a$, N^{**} = the corrected estimate, and N^{*} = the estimate based on caribou within the study area ("available" during the survey). The use of SVIC99-06 satellite collar data from 2000 to 2002 to obtain p_a for our study area leads to the following calculation for the estimate:

$$N^{**} = [(N^{*})/\ p_a]$$

Variance is then $Var(N^{**}) = (N^{**})^2\ [CV^2(N^{*}) + cv^2(p_a)]$, with $cv^2(N^{*}) = var(N^{*})/(N^{*})^2$ where CV is the coefficient of variation of N*.

We used the same method to adjust the 1997 survey estimate. Available VHF collar data from the 1997 survey (Nishi and Gunn, 2004) indicated that the probability of caribou being in the study area during the survey was $p_{a\ 1997VHF} \geq 0.75$ (some collars were not found, which is why $p_{a\ 1997VHF}$ is a minimum value). Because it was not possible to calculate a variance and CV for $p_{a\ 1997VHF}$, and since the proportion of collared caribou within the 1997 study area was similar to $p_{a2000-2002}$, we corrected the 1997 estimate in the same way as the 2007 estimate, using $p_{a2000-2002}$ and its variance.

We repeated the same process with the 1994 survey (Nishi and Buckland, 2000). The 1994 survey was done in the summer on the western half of Victoria Island, and the proportion of VHF collars within the study area was $p_{a\ 1994VHF} \geq 0.65$.

For the sake of comparison, we also ran our data through the formula to estimate the caribou population size on the basis of post-calving photographic surveys, as presented by Russell et al. (1996), and the Lincoln-Petersen Index applied to radio-telemetry data (White and Garrott, 1990), using the following formula:

$$N = (((M + 1)\bullet(C+1))/(R + 1)) - 1$$

where N = estimate of population size, M = the number of radio-collared animals in the herd, C = the number of caribou observed in post-calving aggregations containing at least one collared animal, and R = the number of collared caribou observed in these aggregations.

The variance for the estimate can then be calculated as:

$$Var(N) = \frac{(M + 1)(C + 1)(M - R)(C - R)}{(R + 1)^2(R + 2)}$$

Because we did not have collar data during the survey, we considered caribou within the study area as one group and calculated M as the average number of collared animals between 2000 and 2002, C as the estimate within the study area, and R as $M \bullet p_a$.

In 2005, a small portion of the herd summering on the northwest part of the island was surveyed in July (Nagy et al., 2006), when the Dolphin and Union caribou herd is spread over most of Victoria Island. These caribou mix with the rest of the herd in the fall, but data from collared caribou suggest that they do not always reach the southern coast of the island at the same time (Poole et al., 2010). Aerial surveys conducted in the area between 1998 and 2005 estimated that the number of these caribou varied between 423 ± 201 (95% Confidence Interval [CI]) and 1357 ± 480 (95% CI) animals. Because of their relatively small numbers and their delay in reaching the study area, we considered this part of the herd negligible in our calculation and did not include these collar data in our calculation of p_a. However, we acknowledge that the unknown portion of these animals that did not reach the survey area should be added to the herd estimate.

Trend Analysis

To determine trend in caribou abundance in the study area, we compared the 2007 population estimate to the 1997 estimate using equation 5.3 of Thompson et al. (1998):

$$z = \frac{Y_{1997} - Y_{2007}}{\sqrt{Var(Y_{1997}) + Var(Y_{2007})}}$$

where Y = the caribou population estimate, z = the z statistic, Y_x = the population estimate for year x, and $Var(Y_x)$ = the variance of the population estimate.

The statistics were based on the hypothesis that the population estimate did not change between surveys; therefore, we used the two-tailed probability of the z statistic.

RESULTS

During the reconnaissance flights on 24 and 26 October 2007, most of the caribou were either static or moving eastward. During the survey, most of the caribou in the East Cambridge Bay and East Wellington strata were static, the caribou in the West Wellington and Byron Bay strata were mainly moving westward along the coast, and the caribou in the Nayoktok stratum were static or moving eastward. The caribou in the Islands stratum were mainly static.

We observed a total of 12 686 caribou during the survey itself (Table 1), including 2669 seen on transect and 4362 counted on small islands. From the analysis in the five strata and the addition of total counts on small islands,

TABLE 1. Estimated population of Dolphin and Union caribou within the aerial survey area along the southern coast of Victoria Island, Nunavut, on 29 and 30 October 2007.

Stratum	Date	Stratum area (km^2)	Number of transects	Study area coverage	Caribou on transect	Total caribou observed (on and off transect)	Estimate within the study area	Standard error	Coefficient of variation
East Cambridge Bay	29 October	1388	24	20%	672	2517	3360	703	0.21
East Wellington	29 October	528	7	12%	529	1199	4348	1577	0.36
West Wellington	29 October	786	20	17%	559	1372	3353	674	0.20
Byron Bay	30 October	349	6	11%	412	1906	3844	1142	0.30
Nayoktok	30 October	706	11	20%	497	1330	2486	865	0.35
Islands	30 October	NA	NA	Count	NA	4362	4362	NA	NA
Total						12 686	21 753	2343	0.13

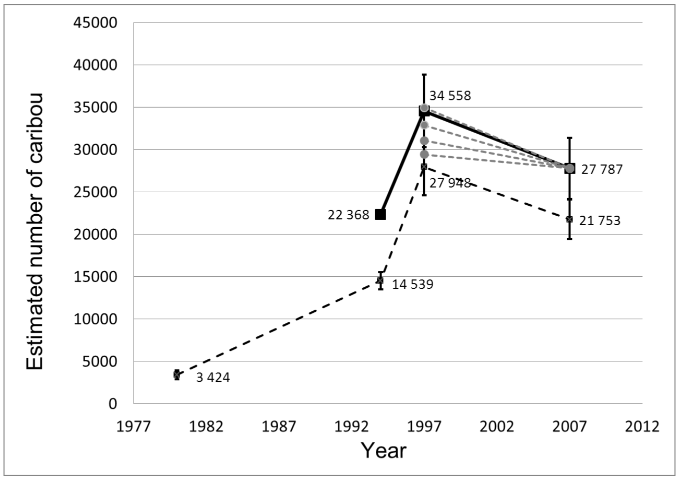

FIG. 4. Variation of the Dolphin and Union caribou herd estimates from 1980 to 2007 (standard error is shown). The dark grey dashed line shows the estimate in the study area, and the black solid line shows the extrapolated estimate for the whole herd. The grey dots represent the 1997 herd estimate calculated with values of p_a ranging from 0.80 to 0.95 (see text for calculation method) and the grey dotted lines, the associated trend. Note that the 1980 (Jakimchuk and Carruthers, 1980) and 1994 (Nishi and Buckland, 2000) surveys were conducted at different times of the year and in different areas.

we estimated 21 753 ± 2343 SE animals from the Dolphin and Union caribou herd within the study area (Table 1). While graphic results (Fig. 4) suggest a lower abundance compared to the 1997 survey estimate of 27 948 ± 3367 SE (Nishi and Gunn, 2004) and are consistent with information gathered through local hunters and conservation officers, there was not a statistical difference between the two survey area point estimates of 1997 and 2007 (z = 1.51, p = 0.13).

Using the correction based on collared caribou data ($p_{a2000\text{-}2002}$ = 0.81), we obtained a 2007 estimate for the whole Dolphin and Union caribou herd of 27 787 ± 3613 SE individuals (Table 2). The 95% confidence interval was ± 7537 and was calculated with a degree of freedom estimated at 20 (based on the formula in Nagy et al., 2006). The Lincoln-Petersen Index method provided a similar result, with a 2007 herd estimate of 26 417 ± 3244 caribou.

The corrected estimate for the Dolphin and Union caribou herd in October 1997 (using $p_{a2000\text{-}2002}$ = 0.81) was at or below 34 558 ± 4283 SE. The 95% confidence interval was ± 6801. The difference between the two corrected estimates (1997 and 2007) was not significant (z = 1.21, p = 0.23). However, because collared caribou that were not confirmed within the study area in 1997 were not located outside the study area, we also graphed trends between point estimates based on a series of p_a ranging from 0.80 to 0.95 in increments of 0.05 (Fig. 4). We did not calculate the variance for the point estimates, as we had no data to estimate the variance of p_a.

The 1994 corrected estimate for the Dolphin and Union herd ($p_{a\ 1994VHF} \geq 0.65$) was then 22 368 or fewer caribou (Fig. 4). We did not calculate the variance for this corrected estimate as we had no data to estimate the variance of $p_{a\ 1994VHF}$.

During the flights, we observed three drowned caribou, 15 kill sites, and two caribou dead from unknown causes. We observed 3752 muskoxen distributed on most of the areas flown and two wolf packs (2 and 9 individuals).

DISCUSSION

The late formation of sea ice and rapid changes in weather prevented coverage of all the areas originally planned in the western and eastern parts of the study area. However, the reconnaissance flight and the 1997 survey results (Nishi and Gunn, 2004) suggested that high caribou densities were included in our survey area. Using caribou satellite collar data from previous years, we produced a corrected estimate for the Dolphin and Union caribou herd on Victoria Island of 27 787 ± 3613 SE animals that accounts for animals outside our study area. This correction, while increasing the estimate for the herd, did not affect the main conclusion regarding the trend of the herd. Our results show that from 1997 to 2007, the Dolphin and Union caribou herd at best remained stable, in contrast to the five- to tenfold increase documented between 1980 and 1997 (Jakimchuk and Carruthers, 1980; Nishi and Buckland, 2000; Nishi and Gunn, 2004). Our findings are consistent with observations by local hunters, who have reported that the herd increase had slowed or stopped, and with trends observed in the northwestern part of Victoria Island during July aerial surveys (increase from 1998 to 2001 and then no significant difference between the 2001 and 2005 estimates; Nagy et al., 2006).

The Lincoln-Petersen Index method and the method developed by Innes et al. (2002) provided similar point

TABLE 2. Dolphin and Union caribou survey results from 1994, 1997, and 2007 and 2007 herd estimate.

	1994 survey estimate[1]	1997 survey estimate[2]	2007 survey estimate[3]	2007 herd estimate[3]
Dates	5–17 June 1994	17–22 October 2005	26–30 October 2007	
Estimate	14 539	27 948	21 753	27 787
Variance	1031115	11339415	5489649	13053349
Standard error	1015	3367	2343	3613
Coefficient of variation CV(N)	0.07	0.12	0.13	0.13
Probability of caribou in study area (p_a)	≥ 0.65	≥ 0.75	0.81	NA
CV(p_a)	NA	NA	0.012	NA

[1] Nishi and Buckland (2000).
[2] Nishi and Gunn (2004).
[3] This study.

estimates and variance. However, we argue that the Innes et al. (2002) method is more appropriate in our case as it is assessing the availability of the animals within the study area using data collected at a different time than the survey. Innes et al. (2002) estimated the probability of marine mammals to be within a strip of water below the surface (where they can be observed from an aircraft) on the basis of multi-year radio-tracking data on frequency and depth of dives, and we estimated the probability that caribou would be within a strip along the coast (where they could be observed during the aerial survey) using multi-year radio-tracking data on the timing and location of caribou use of our study area.

To increase the accuracy of our method, we recommend that satellite/GPS collars be deployed on this herd and monitored during future surveys to better inform the timing of the survey and the calculation of p_a and to verify the underlying assumptions related to this method. Also, the trend toward later sea ice formation in the study area has made it extremely challenging to operate small aircraft safely in October-November, and the survey window is very short. We therefore recommend exploring alternative methods for surveying this herd. For example, if sufficient satellite/GPS collars are active, a variation of the post-calving survey method (with aerial photographs) could be used during the fall staging or spring pre-migration aggregation as an alternative to the October-November surveys. A survey of the calving ground is probably not possible for this herd, as its calving strategy is mainly individualist (Nagy et al., 2011): the females do not aggregate within one or more finite calving grounds, but rather spread over most of Victoria Island during the calving and post-calving periods.

Accurate long-term monitoring of this caribou herd is crucial to its management and conservation. We can only speculate about the factors responsible for the population dynamics observed for 1980–2007, but the six described below seem plausible. First, both the caribou (Nishi and Gunn, 2004) and muskox (Patterson and Gunn, 1999) populations on the Island increased during the 1980s and 1990s. Second, the reduction in winter food supply on Victoria Island when the Dolphin and Union caribou herd resumed its migration to the mainland may have kept the already low carnivore populations on the island from increasing during the first decade. Third, carnivore abundance and distribution in the landscape may have influenced caribou mortality and recruitment and ultimately population dynamics. Fourth, sea ice conditions related to delayed ice formation may have increased caribou mortality during the fall migration (Poole et al., 2010; Allen Niptanatiak, pers. comm. 2010), affecting the population growth rate. Fifth, vegetation status and parasite prevalence may have contributed to intra- and inter-specific density-dependent regulatory mechanisms (Hughes, 2006). Sixth, the cumulative impacts of mineral exploration and mining activities, mainly on the herd's winter ground, have been poorly monitored and remain a source of uncertainty and concerns. Each of these factors may have influenced the Dolphin and Union herd population dynamics independently or cumulatively; they signify the importance of continued and improved monitoring of the population, including telemetry of individuals.

With the limited number of radio collars currently deployed on the herd and the lack of formal and accurate harvest monitoring, it is not possible to model harvest and other forms of mortality. The estimated harvest from the herd likely increased between 2000 and 2007 (Dumond et al., 2007), and especially from 2006 to 2008, as a result of the decreased availability of other barren-ground caribou herds (Dumond et al., 2007). Subsequently, the Kugluktuk Hunters and Trappers Association implemented several initiatives (education and communication to reduce wastage and improve harvest practices; hunting of alternative species) that reduced the caribou harvest and particularly the harvest of the Dolphin and Union caribou herd. Also in fall 2007 and 2008, several hunters reported that a number of Dolphin and Union caribou were very skinny and had signs (ice on the fur and cuts on the legs) that they had fallen through the ice during the fall migration. The relatively low number of dead caribou recorded during the 2007 survey could be the result of ice being formed only along the coast so that many caribou had not yet ventured onto the forming sea ice. Mortality due to ice condition is likely higher during the actual crossing to the mainland. In spring 2010, a few dozen caribou carcasses were found frozen in the ice and on small islands near the mainland, obviously having died in the water or shortly after getting out of the water (Allen Niptanatiak and Dustin Fredlund, pers. comm. 2010;

Mathieu Dumond, pers. obs. 2010). The fall migration is the period of highest natural mortality (Poole et al., 2010). The quantitative assessment of mortality related to ice conditions would require monitoring of both male and female movements and the resources to confirm the cause of death. While hunters' observations are valuable, this mortality occurs when the sea ice is too thin to allow all-terrain vehicle travel and environmental conditions are challenging for aircraft. Maritime traffic, if affecting ice formation, may add to already existing stresses on this herd during spring and fall migration (Dumond et al., 2013). Co-management partners and stakeholders have initiated discussions to address some of the concerns related to the Dolphin and Union caribou herd, including its monitoring and the foundation of a management plan.

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