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Data Summary

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EXECUTIVE SUMMARY

- Over 55 years have elapsed since 23 barren-ground caribou calves (*Rangifer tarandus groenlandicus)* were introduced to Adak Island within the Alaska Maritime National Wildlife Refuge. Originally transplanted at the request of the U.S. Navy, the founding herd grew to a fairly stable population of approximately 300 – 600 animals until the decommissioning of the naval base in the early 1990s. A period of exponential growth quickly ensued subsequent to the release from hunting mortality, whereby the population increased over 300% to at least 2751 animals by 2005. No survey had been conducted since that time, and concerns over a continued irruption resulting in deteriorating habitat conditions and dispersal to neighboring islands have increased.
- We conducted helicopter-based aerial surveys of Adak and neighboring Kagalaska during June 2012. Due to weather conditions and available flight time, a complete survey of Adak was achieved in 3 days (June 19, 20, 25) across 1 week. Two surveys were conducted on Kagalaska on June 18 (complete) and June 25 (partial).
- We observed between 2512 and 2880 animals on Adak depending on our treatment of potentially double-counted groups. In both treatments, over 70% of the total population and calf-adult groups occurred between False Bay and Teardrop Basin on the south-central side of Adak. Observed calf:adult proportions ranged from 0.28 – 0.29, and did not differ from measures obtained from ground-based counts. Less than 4% of the population and no calf:adult groups occurred on the north side of Adak. Low detections of caribou during repeated hikes at Thumb and Scabbard Bay on the north side (an area typically frequented in late summer) indicated low rates of south-to-north animal movements during the survey window.
- We observed a single group of 3 adults and 1 calf (< 3 weeks old) on the southwest side of Kagalaska above Crater Cove on the June 18 survey. The calf likely represents the first known reproduction on Kagalaska. No caribou were detected on the June 25 Kagalaska survey.
- Two plausible (and not necessarily independent) reasons exist for the observed slowing of the Adak population growth trend: 1) post-2005 harvest rates are under-reported and may be substantial enough to limit population growth, 2) the population continued to rapidly grow after the 2005 survey but is now declining owing to deteriorating habitat conditions and episodes of harsh winter weather.
- Future studies that determine 1) indices of caribou occupancy and population trends between intervening aerial surveys by utilizing ground-based measures, 2) inter-island movement rates between Adak and Kagalaska, and 3) relations between caribou demography, movements, and habitat conditions would prove valuable for managing this nonindigenous (and now invasive) herd.

INTRODUCTION

At the request of the U.S. Navy, 23 barren-ground caribou calves were introduced to Adak Island within the Alaska Maritime National Wildlife Refuge (including the former Aleutian Islands NWR) in 1958 and 1959 to provide sport hunting for residents of Naval Air Station, Adak and as an emergency food source for the military personnel (Jones 1966, Williams and Tutiakoff 2005). The resulting population grew to a fairly stable population size of approximately 300 – 600 animals until the naval base was decommissioned in the early 1990s (Fig. 1). During this period, Adak caribou were most likely regulated by hunting that acted as a surrogate for natural predation (Klein 1991). Concomitantly, caribou attained larger body sizes, experienced high calving rates, and reproduced at earlier ages compared to their mainland parent herd (Valkenburg et al. 2000). These findings indicated a lack of resource limitation coupled with a relatively mild climate. The closure of the naval base in 1993 corresponded with dramatic decline in hunter harvest rates, which likely contributed to a tripling of herd size to at least 2800 animals by 2005 (Williams and Tutiakoff 2005) (Fig. 1).

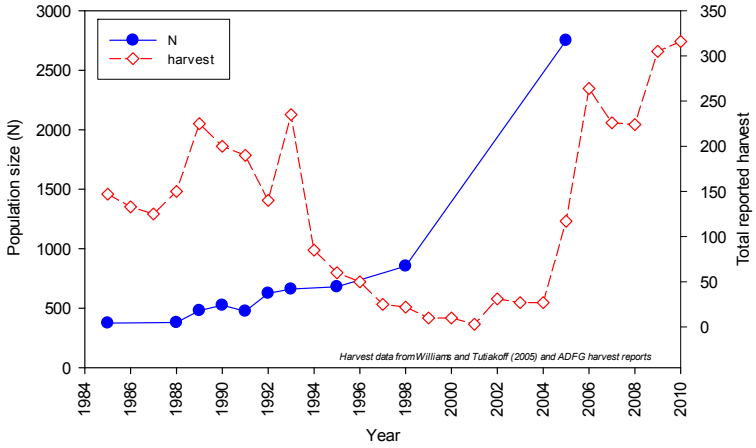


Fig. 1. ***Population size and hunter harvest estimates for Adak Island caribou, 1985 - 2005.***

Uncertainty surrounded the caribou population trend since the 2005 survey for several reasons. First, reported hunter harvest rates returned to or exceeded pre-naval base decommissioning levels beginning in 2005 (Fig. 1) but it is unclear whether these rates are sufficient enough to provide additive mortality necessary to decelerate the apparent exponential rate of caribou population growth. Second, Ricca et al. (2012) recently documented caribou occupancy of Kagalaska Island, but they could not determine population size or reproductive status. Establishment of a reproductively viable resident population on Kagalaska is especially worrisome and could set the stage for a step-wise invasion of additional nearby islands (Ricca et al. 2012). Third, preliminary results from an ongoing study indicate increasing caribou densities are impacting island ecosystem processes (M. Ricca, *unpublished data*).

Herein, we describe results of helicopter and ground based surveys of caribou on Adak and Kagalaska during June 2012. This survey represented a joint effort between the Alaska Maritime National Wildlife Refuge (AMNWR), USGS-Western Ecological Research Center, and Texas State University.

STUDY AREA

Adak is a large (ca. 725 km^2) mountainous island located in the Andreanof group of the central Aleutian archipelago. Kagalaska is the closest large (116 km^2) island to the east and is separated from Adak by Kagalaska Strait, which is roughly 1.0 km wide on average and only 400 m wide at its narrowest

point. Notably, Adak has a mixed land ownership pattern, whereby the northern end is owned by the Aleut Corporation and includes the City of Adak (population < 300) while the remainder of the island lies within the AMNWR (Williams and Tutiakoff 2005). All of Kagalaska is managed by the AMNWR and has no human habitation. The climate and floristic community of the islands are characteristically maritime. Summers are cool (5 – 10 °C), wet, and foggy, whereas cyclonic storms occur frequently during winter but temperatures normally hover near 0 °C. Soils are of volcanic origin.

Plant communities on both islands are compositionally similar to the maritime tundra (or oceanic heath) described by Talbot et al. (2010) and are broadly characterized by graminoid meadows (e.g. *Calamagrostis nutkaensis*, *Carex* sp., *Erigeron peregrinus, Anemone narcissiflora*), evergreen heaths (e.g., *Empetrum nigrum*, *Phyllodoce aleutica, Loiseleuria procumbens*), and deciduous dwarf shrubs (*Vaccinium uliginosum*, *Salix* sp.). Fruiticose lichens (e.g. *Cladonia* sp.), which are a highly preferred winter forage for caribou, are notably less abundant on Adak relative to Kagalaska (M. Ricca, *unpublished data*). The plant growing season is relatively short and occurs primarily from June to September.

METHODS

We used the following methods to maintain consistency with previous surveys (Meehan 1993, Williams and Tutiakoff 2005). Surveys were flown in a Bell Jet Long Ranger 206-L3 helicopter (Maritime Helicopters, Homer AK) operating at 74 -93 km/h (40 - 50 knots) at 90 m AGL, although flight speed and altitude varied with topography. We divided Adak into 10 areas separated by prominent geographic features (e.g., steep ridgelines, large lakes) that would impede large-scale caribou movements from one area to another and help minimize double counting (Fig. 2.). We flew roughly parallel transects separated by ~ 1 – 1.5 km in survey areas with flat topography (e.g., Caribou and Yakak Peninsulas). Transects could not be flown safely in mountainous areas, so we followed landscape contours in these areas to facilitate thorough visual coverage above and below the aircraft.

Three days and four flights (sorties) from June 19 - 25 were necessary to complete an island wide survey of Adak (Fig. 2). Persistent low clouds and fog negated survey attempts of the southwest and central portions of Adak prior to June 25.

- The June 19 survey comprised 2 sorties (flown from 1400 - 1520h, and 1540 - 1740h) covering the north side of the island including Caribou Peninsula, Mt. Reed, Mt. Moffett, and Mt. Adagdak. Attempts to cover Yakak Peninsula and Hatchet Lake were thwarted by fog, and alpine areas (> 500 m) were obscured by cloud cover.
- The June 20 survey comprised 1 sortie (1740 - 1925h) covering Lake Betty to Kagalaska Straits, and the eastern half of Boot Bay (Mandy-Lynn-Camel/Campers Cove survey area). The survey was abbreviated when a thick fog bank quickly covered the western half of Boot Bay.
- Survey conditions on June 25 were excellent with unobscured visibility except for the southwest tip of Yakak Peninsula and southern tips of Turet Pt. and Cape Kagigikak bracketing False Bay. The first sortie (1400 - 1550h) covered Yakak Peninsula, Hatchet Lake-

False Bay, and the western half of Teardrop Basin. The second sortie (1610 - 1730h) covered the eastern half of Teardrop Basin, western half of Boot Bay and Kagalaska Straits (including alpine areas obscured during previous surveys).

- We also conducted two independent surveys of Kagalaska on June 18 (1440 - 1545h) and June 25 (1735 - 1810h) (Fig. 2). Excellent visibility occurred on both surveys, with fog/cloud cover only obscuring intermittent sections of the steep northern coastline and alpine areas along the southern coast. The June 18 survey covered the entire island while the June 25 survey focused on covering the central portion of the island with the remaining flight time.

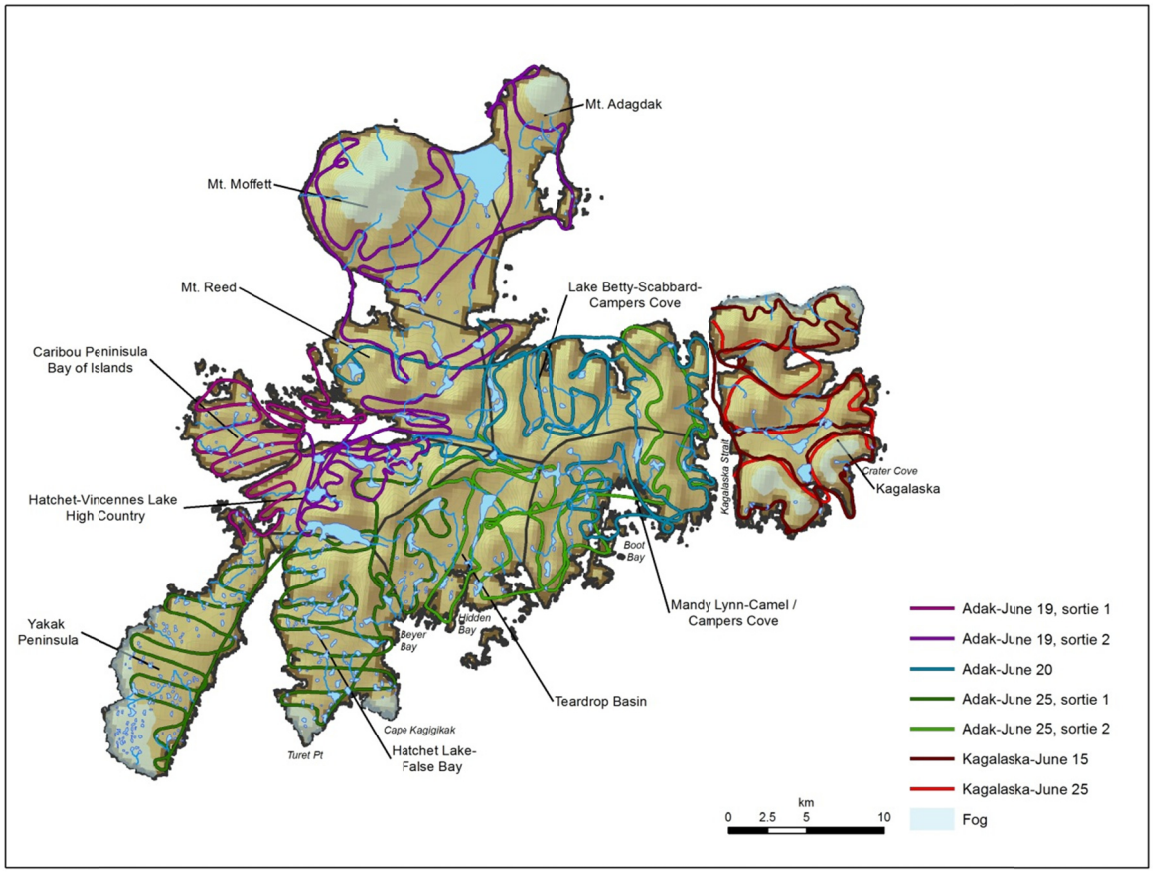


Fig. 2. Survey areas and helicopter flight paths for Adak and Kagalaska caribou surveys, 18-25 June 2012.

For all surveys, the pilot was seated on the front right side of the helicopter and regularly acted as a secondary observer. The front left position was occupied by a secondary observer who acted as navigator and recorded group size, GPS coordinates, and herd composition. Two primary observers were seated in left and right rear of the helicopter. For the June 18 survey, Weckerly and Ricca occupied the front left and rear left positions, respectively. For all other surveys, Ricca occupied the front-left and Weckerly occupied the rear left. Tutiakoff occupied the rear right position June 18, 19 and 25, and Williams occupied the position on June 20.

The multi-flight nature of the Adak survey increased the probability of survey bias owing to animal movements. Therefore, we report low and high counts to account for potential 'double counting'. Low counts represented a 'conservative' estimate whereby we rejected all potential double counts along a flight path in a given day (e.g., identical groups sizes of animals moving in the same direction initially observed on the right side of the helicopter and then observed on the left side during the subsequent pass) and repeat flight paths over the same area in multiple days (e.g., Yakak Peninsula, Boot Bay). High counts used more liberal criteria whereby we accepted double counts in doubt (i.e., groups of similar size, but running in opposite directions; a situation that occurred frequently in high density areas such as Teardrop Basin) and areas that were partially obscured by rapidly approaching fog (i.e., Boot Bay on June 20 and June 25). Counts from all other repeat survey flight paths over the same area were rejected.

Because the survey occurred within ~ 3 weeks post-calving, we were able to identify calves from the air based on differences in size and pelage coloration, and calculated calf:adult proportions as the total number of calves observed divided by the total number of adults observed within only those groups that contained calves. We could not reliably determine gender of adult caribou or distinguish between yearling and adult caribou from the air.

RESULTS AND DISCUSSION

Adak

We estimate between 2512 (low count) and 2880 (high count) caribou on Adak for the 2012 survey (Table 1). In both count types, over 70% of the observed population inhabited relatively low

Table 1. Population size and density of caribou on Adak and Kagalaska islands determined during aerial surveys, 18-25 June 2012. Results from the 2005 survey are provided for comparison; see methods for 'low' and 'high' count descriptions.

	No. caribou			Density (animals/km^2)			% change from 2005	
Survey Area	2005	2012 (Low)	2012 (High)	2005	2012 (Low)	2012 (High)	2012 (Low)	2012 (High)
Mt. Moffett	34	11	11	0.3	0.1	0.1	-68%	-68%
Mt. Adagdak	0	0	0	0.0	0.0	0.0	0%	0%
Mt. Reed	184	16	16	2.6	0.2	0.2	-91%	-91%
Caribou Peninsula-Bay of Islands	85	53	53	2.3	1.4	1.4	-38%	-38%
Yakak Peninsula	301	124	124	3.9	1.6	1.6	-59%	-59%
Hatchet Lake-False Bay	302	383	397	3.8	4.8	5.0	27%	31%
Teardrop Basin	524	1350	1650	6.6	16.9	20.6	158%	215%
Mandy Lynn-Camel Cove-Campers Cove	135	326	380	1.8	4.3	5.0	141%	181%
LakeBetty-Scabbard-Campers Cove	577	81	81	6.2	0.9	0.9	-86%	-86%
Hatchet-Vincennes Lake High Country	609	168	168	9.8	2.7	2.7	-72%	-72%
Kagalaska	1	4	4	0.0	0.0	0.0	400%	400%
Total	2751	2516	2884	3.2	2.9	3.4	-9%	5%

elevation (< 500 m) areas between False Bay and Teardrop Basin on the south-central side Adak (Fig. 3). In particular, caribou densities in Teardrop Basin exceeded 20 animals/km^2 whereas < 5 animals/km^2 occupied all other survey areas. Caribou were notably absent from much of the north side of the island (< 4% of the total population size) and alpine areas across the entire island. Low caribou densities on Mt. Moffett and Mt. Adagdak correspond to patterns observed during prior surveys (Meehan 1993, Williams and Tutiakoff 2005). However, low densities in areas largely comprised of alpine habitat (e.g., Mt. Reed, Hatchet-Vincennes Lake High Country, Lake Betty-Scabbard-Campers Cove) were markedly different from those observed during the 2005 survey (Table 1, Appendix I), although caribou trailing was quite apparent in these areas (Appendix II). Two factors help explain the observed shift in caribou distribution. First, most prior surveys occurred in late summer (late July-August) at or near the peak of plant greenness, so green forage is available in higher elevation habitats for caribou utilize. In contrast, the 2012 survey occurred in early June following a winter characterized by exceptionally heavy snowfall that contributed to persistent snowbeds and brown vegetation throughout high (> 500 m) elevations. This pattern stood in marked contrast to the rapid greening occurring at lower elevations on both islands where most caribou were observed. Second, high densities of caribou in the Teardrop Basin and Mandy Lynn-Camel Cove areas likely represent large post-calving aggregations (see below).

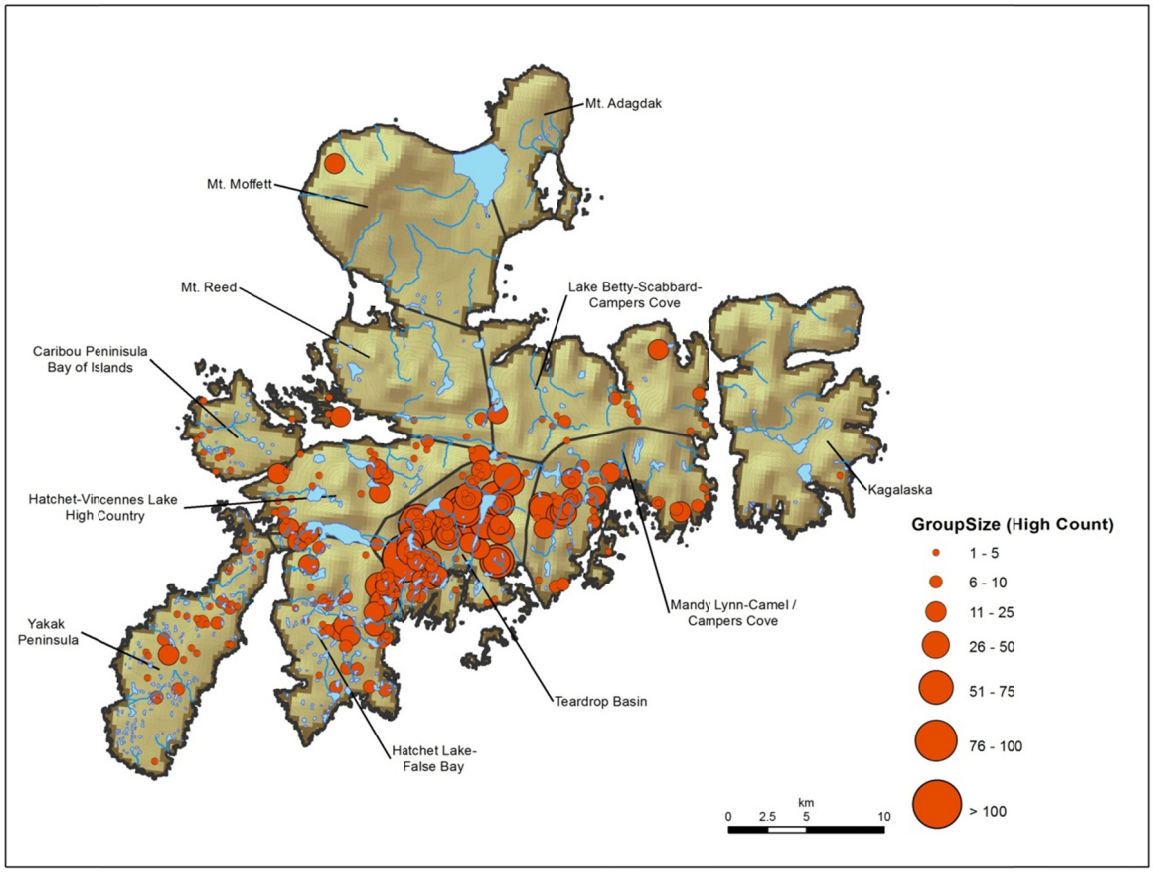


Fig. 3. Distribution of caribou groups on Adak and Kagalaska islands detected during aerial surveys, 18-25 June 2012. Larger dots correspond to larger group sizes. The distribution of 'high counts' (shown) did not differ from 'low counts' (not shown).

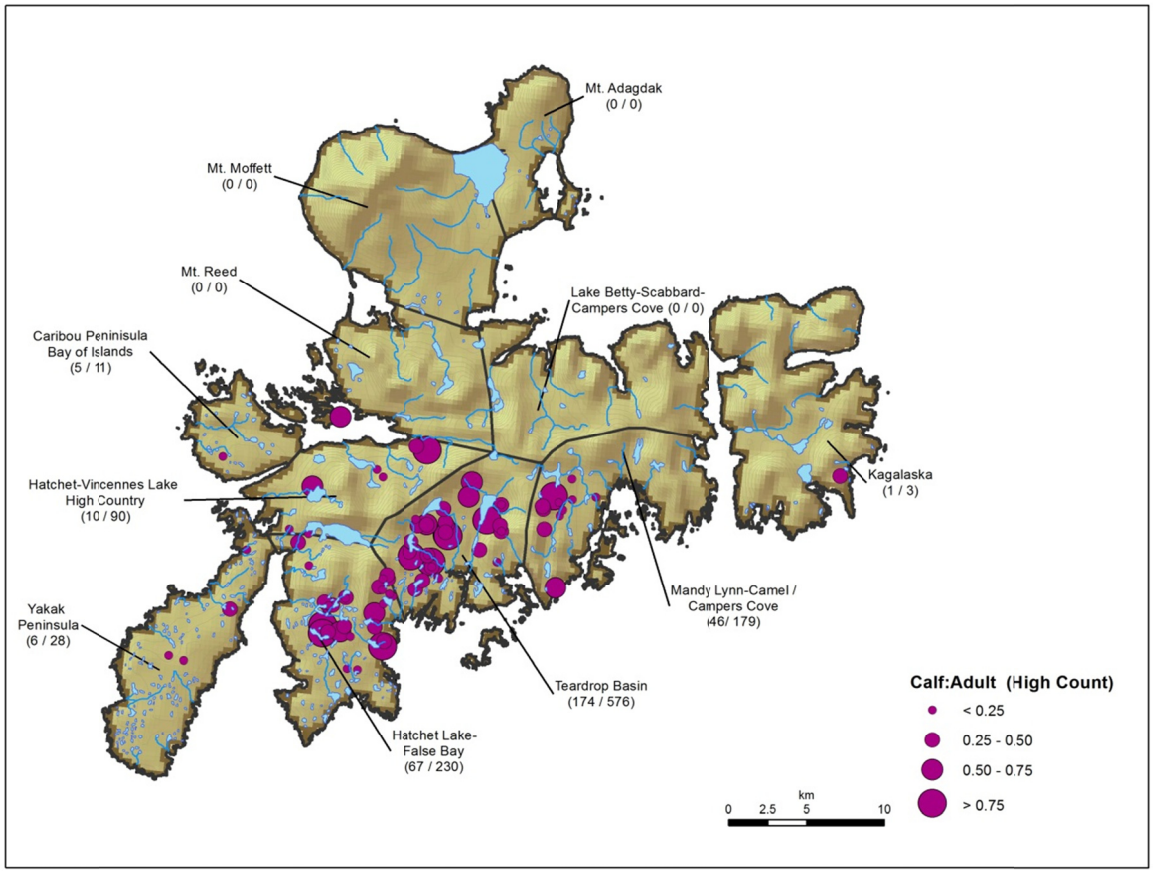
For groups containing calves, we observed 28 – 29 calves per 100 adults island-wide (Table 2), but the distribution of calf-adult groups was highly skewed. The majority (> 85%) of calf:adult groups observed occurred within the Hatchet Lake-False Bay, Teardrop Basin, and Mandy Lynn-Campers Cove survey areas, whereas no calf:adult groups were observed on the north side of the island (Fig. 4). The observed distribution fits the conventional wisdom that concentrated caribou calving occurs on the south-central side of the island, a pattern observed since the early 1980s (Meehan 1993). Hence, Adak caribou appear to show strong long-term site fidelity to calving areas.

Table 2. Numbers of calves to adults determined during aerial surveys, 18-25 June 2012. Low counts are indicated without parentheses, high counts are within parentheses.

	2012 Low (High)			
Survey Area	No. groups with calves	No. calves	No. adults	Calves:100 adults
Mt. Moffett	0 (0)			
Mt. Adagdak	0 (0)			
Mt. Reed	0 (0)			
Caribou Peninsula-Bay of Islands	2 (2)	5 (5)	11 (11)	45 (45)
Yakak Peninsula	4 (4)	6 (6)	28 (28)	21 (21)
Hatchet Lake-False Bay	27 (28)	64 (67)	219 (230)	29 (29)
Teardrop Basin	39 (40)	169 (174)	529 (546)	32 (32)
Mandy Lynn-Camel Cove-Campers Cove	10 (11)	45 (46)	169 (179)	27 (26)
LakeBetty-Scabbard-Campers Cove	0 (0)			
Hatchet-Vincennes Lake High Country	7 (7)	10 (10)	90 (90)	11 (11)
Kagalaska	1 (1)	1 (1)	3 (3)	33 (33)
Total	90 (93)	300 (309)	1049 (1087)	29 (28)

Over- or under-counting animals due to animal movements is a potential source of error associated with our estimates. The multi-day nature of our survey increased the probability that animals could be counted in one area during a preceding survey, then move to an adjacent area and be counted again during a subsequent survey. Similarly, large scale south - north or east - west movements during time intervals between survey days could result in underestimating abundance for a given area. While we cannot easily account for movement errors in adjacent areas of high caribou density (e.g., Teardrop Basin to Hatchet Lake-False Bay), we have evidence indicating that large scale movements that could account for lower than expected counts in more northern areas (Lake Betty-Scabbard-Campers Cove and Mt. Reed) were not frequent during the one week survey period. First, we repeatedly surveyed Lake Betty-Scabbard on foot by hiking extensively and glassing from vantage points on June 15, 16, 18, 22, and 23. On average, we detected 12 caribou per day (range: 0 - 24) and all groups were male. These low ground counts and the absence of calf:adult groups correspond with the aerial survey results. Second, FWW did not detect any caribou during a circumnavigation hike of Mt. Reed on July 17, and few (< 5) animals were observed during repeated fly-overs of the area during outbound and return trips to town.

Obtaining unbiased counts of calves from aerial surveys poses similar difficulties since calves are small and can be obscured when running alongside larger adults. Thus, we conducted ground based age composition counts in Teardrop Basin immediately after completing the aerial survey on June 26-27. We



<u>Fig. 4.</u> Distribution of detected caribou groups partly comprised of calves on Adak and Kagalaska islands during aerial surveys 18-25 June 2012. Larger dots correspond to higher calf:adult proportions within groups.

observed 34 calves per 100 adults across 14 calf:adult groups on the ground compared to 32 calves per 100 adults across 40 groups from the air. The average calf:adult ratio within groups did not differ significantly between aerial and ground counts after accounting for group size effects (ANCOVA: F = 0.02, P = 0.89). We feel confident in our ability to accurately enumerate calves from the air. However, our reported values should be viewed as an approximate measures of productivity since we could not differentiate between young male, yearling (non-parturient) and adult (parturient) females within a calf:adult group.

Kagalaska

On June 18, we detected a single caribou group comprised of 3 adults and 1 calf in a drainage above Crater Cove on the southeast side of Kagalaska (Figs. 3-4). Importantly, the detection of the very young (< 3 week old) calf likely represents the first known calving on Kagalaska (drowning while crossing Kagalaska Strait could easily occur since young calves are not strong swimmers). Notably, a group of four females and one male were observed approximately 3 km to the north one week earlier (S. Ebbert, *pers. commun.*). We did not detect caribou within the Laska Cove and Galas Point drainages that harbored sign or animals during the previous two summers (Ricca et al. 2012).

On June 25, we elected to take advantage of excellent weather conditions to conduct a second (partial) survey of Kagalaska with our remaining flight time in lieu of resurveying the northern part of Adak (which would have reduced potential counting errors associated with the multi-day survey of Adak). No caribou groups were detected. Extensive trailing across the Kagalaska Island landscape was not evident in either survey.

CONCLUSIONS

While within island caribou distribution changed markedly between surveys owing to seasonal differences in plant phenology and caribou life history, overall population size changed relatively little between 2005 and 2012. The high count represents a 9% increase since 2005 and the low count represents a 5% decrease (Fig. 5). These changes are small relative to the ~300% increase in population size from 1993 – 2005. However, we do not know what transpired in the 7 years between 2005 and 2012. Did the herd continue to increase after 2005 and are we now observing the early stages of a decline owing to deteriorating habitat conditions and episodes of harsh winter weather? Or, has the rate of population growth actually slowed due to higher than expected additive mortality from the recent increase in hunting pressure?

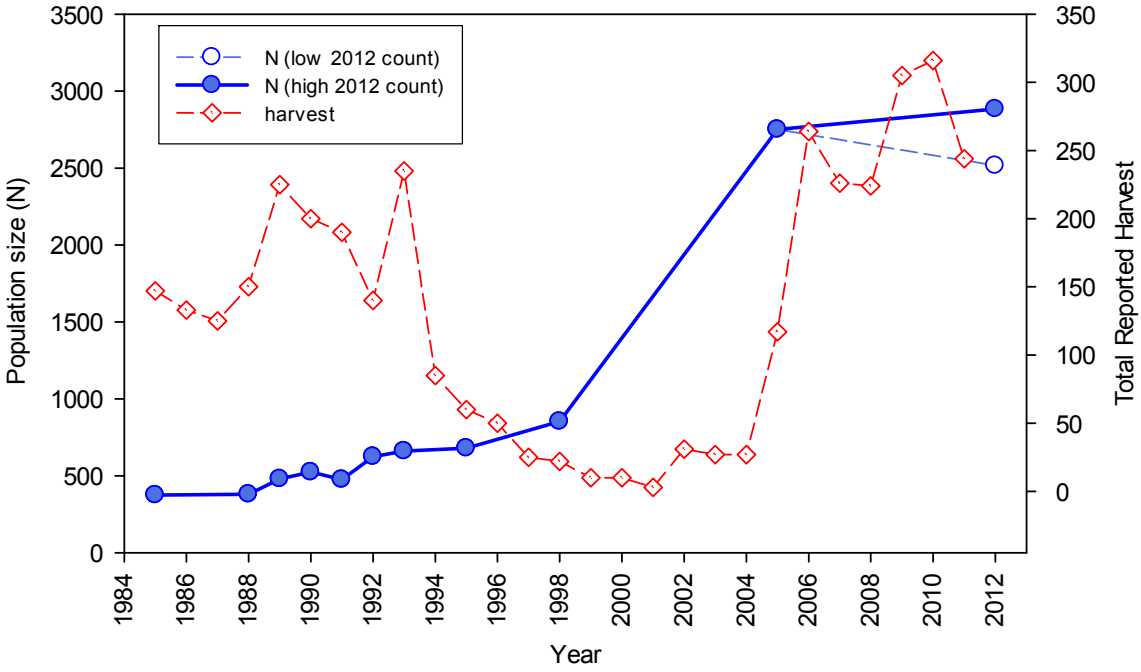


Fig. 5. Current population size and hunter harvest estimates for Adak Island caribou, 1985 - 2012.

First, declining recruitment (i.e., lower calf:adult ratios) and altered habitat conditions are classic signs associated with population crashes following irruptive growth (Leader-Williams 1988). Absolute comparisons of calf:adult ratios among studies is difficult due to differences in reporting (e.g. calves:adults+yearlings vs. calves:adults) and classification errors. With these caveats in mind, however, our ratios are similar to those reported by Meehan (1993) (32 calves : 100 adults) from an aerial survey of the Lake Vincennes to Teardrop Basin during the early irruptive phase for Adak in 1993. Leader-

Williams (1988) reported a similar calf:adult ratio (~35 : 100) during the post irruptive phase for introduced reindeer inhabiting South Georgia Island in the southern ocean. In contrast, (Klein 1968) reported 60 calves : 100 adult cows for St. Matthew immediately preceding the herd's precipitous decline, so current levels of productivity on Adak may not indicate continued irruptive growth. Intensive caribou herbivory can also stimulate increased production of graminoids that can facilitate caribou persistence on islands with fairly mild climates (Leader-Williams 1988, van der Wal 2006). High caribou density areas on Adak are generally associated with higher spatial coverage of graminoids, yet slower nitrogen cycling rates in these areas may also contribute to lower forage quality (M. Ricca, *unpublished data*). Although data on overwinter survivorship is completely lacking, it is plausible that persistent snow cover throughout the extreme winter of 2012 contributed to some unknown additional mortality.

Second, post-2005 hunting pressure increased by as much as 260% (and > 10-fold over the past 10 years) based on reported harvest tickets from Alaska Department of Fish and Game (https://secure.wildlife.alaska.gov/index.cfm?fuseaction=harvest.lookup). The increase was driven largely by liberal hunting regulations for Alaska residents (no limit for females, 2 bull limit), increased public knowledge of trophy bull hunting on the island, and improved island access via commercial airline. If we assume minimal calf mortality until recruitment as adults, a simple 'back of the envelope' comparison of the total number of calves observed during the 2012 survey (N = 310) versus the average yearly reported harvest from 2005 – 2011 (mean = 244) suggests that hunters kill 78% of annual calf production as adults. In addition, the proportion of the reported harvest comprised of female caribou (the segment of the population more strongly linked to growth) has steadily increased from 23% in 2005 to > 60% after 2009. Furthermore, harvest rates are typically underestimated due to imperfect voluntary reporting. This bias may be exacerbated on Adak because until this summer there were no on-site license vendors to dispense harvest tickets used for reporting. Thus, many island residents that hunt for subsistence did not have an easy means of reporting large (> 30) numbers of caribou killed annually (Anonymous, *pers. commum*.). Nevertheless, current hunting pressure appears sufficient to decelerate population growth, and perhaps even limit population size if the actual harvest is higher than reported. Maintaining adequate hunting pressure continues to have strong management implications for this nonindigenous herd.

Continued study of Adak caribou population trends and their associated ecosystem impacts is of importance due to the expansion of the herd to Kagalaska resulting in a multi-island metapopulation. Thus, information gained from the following study designs would aid in caribou management. The extreme expense of chartering helicopter use for long periods while waiting for suitable weather prohibits frequent (e.g., yearly) surveys, but less expensive ground-based measures could yield repeatable indices for population and spatial distribution trends during long time periods between aerial surveys. Such data could be obtained through standard occupancy modeling techniques that quantify caribou sign within fixed plots, and associated data on ecosystem processes (e.g. plant biomass, soil N) impacted by caribou could be efficiently quantified in a subset of plots. In addition, ground based hikes and observations from vantage points within post-calving areas on the south-central side of Adak during early summer would provide time-series data on caribou productivity. Similar efforts were conducted

by AMNWR biologists during the early 1980s (AMNWR, *unpublished reports*) and are used for monitoring remote mainland herds (CARMA 2008). Continued estimates of population size and trend are further needed to know the source pool size of potentially dispersing 'propogules' (i.e., invading caribou) to Kagalaska and possibly neighboring islands to the east. Along these lines, determination of inter-island movement rates between Adak and Kagalaska via GPS-satellite telemetered animals would provide information on the frequency and extent of intra- compared to inter-island movements, and also help identify shoreline crossings where physical intervention (e.g. fencing) could be most efficiently implemented.

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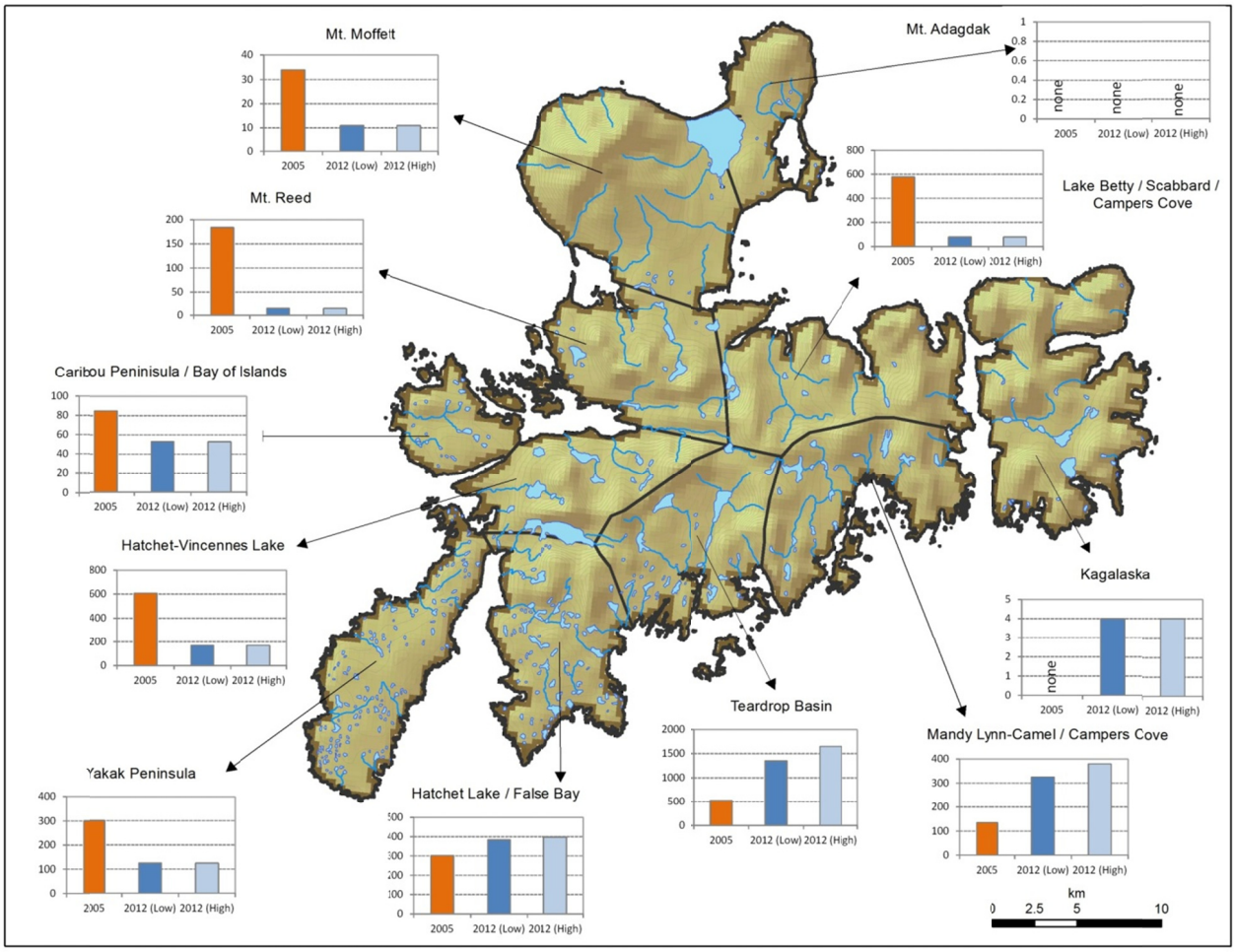
APPENDICES



Appendix I. Caribou counts by area for aerial surveys conducted in August 2005 survey (orange bars) and June 2012 (dark blue bars='low count', light blue bars='high count').

Appendix II. Aerial photo illustrating trailing created by caribou near Hatchet Lake, Adak Island, 19 June 2012.