PROJECT TITLE: DYNAMICS OF THE DENALI CARIBOU HERD, DENALI NATIONAL PARK, ALASKA: PROGRESS REPORT (OCTOBER 2012 - SEPTEMBER 2013)

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Population dynamics of the Denali Caribou Herd have been investigated continuously at Denali National Park since 1984. Denali National Park, totaling 18,800 km^2, encompasses nearly the entire range of the Denali Herd, providing a unique opportunity to investigate caribou population dynamics where ungulate populations (caribou, moose, and Dall's sheep) and the large carnivores that prey on them (wolves, grizzly bears, and American black bears) are driven primarily by natural processes. To date, much has been learned about the interactions between predation and weather that drive the dynamics of the Denali Caribou Herd. In the mid-1980s, the Denali Herd was increasing at about 7%/year during a long period of relatively mild winters. Survival of caribou cows was high (96%/year) and about 50% of the calves produced were recruited. With the onset of a period of severe winters in 1988, caribou numbers leveled off at 3,200 by fall 1989, and then declined by nearly a third to 2,300 caribou over just 3 years**.** During the decline, adult cow survival dropped substantially, to an average of 85%/year, and calf recruitment fell to about 10%. During 1993-2003, with a return to moderate winter snowfall, the caribou herd continued to decline, but a much slower rate of about 2% annually. Adult cow survival was comparable to the period of herd growth in the mid-1980s, but fall calf recruitment continued to be low, averaging 15%. With low calf recruitment during 1990-2003, the female age structure became heavily weighted towards older females, a harbinger of impending population declines regardless of winter snowfall patterns. In May 2002, the proportion of females that were ≥ 13 years old peaked at 24%. As a result of these old females dying, adult female survival was low in the 2002-03 and 2003-04 winters (average = 83%) even though winter snowfalls were substantially below average. These survival rates were comparable to rates measured during the extreme winters of 1990-93.

During the last 10 years (2004-2013), calf survival to fall has improved, averaging 27% annually, allowing for limited growth of the herd at about 2% per year. The age structure is still weighted disproportionately to older females (16% females ≥ 13 years old in May 2012) and therefore susceptible to a sizable decline should the region experience one or more severe winters.

In addition to the basic population monitoring, I have been investigating patterns of growth, survival and seasonal distribution of male caribou since 2007. In general, little is known about the population ecology of male caribou because research and monitoring efforts are commonly focused on adult females and their dependent young given that these sex/age classes tend to drive population trends. Information on male survival patterns is sorely lacking, even though males commonly absorb the majority of

the take in harvested populations. Although prior to these studies little was known about male mortality of Denali caribou, 2 interesting and unexpected patterns arose from investigations of wolf kills in Denali during 1986-93. First, large male caribou showed up in the wolf kill primarily in August and September prior to the annual rut, when caribou bulls should have been in peak condition. High mortality following the rut resulting from the deteriorated nutritional condition of breeding males was expected, but such pre-rut mortality was not. Also, the wolf kill data indicated that mortality of caribou males unexpectedly ended in mid-winter. These patterns have been corroborated with 82% of the observed mortality of adult males occurring during July – November, and no mortalities detected in late winter (February – April).

The current goals of this research are: 1) to document population trends, primary vital rates (calf production, calf recruitment, adult female survival), and other important population characteristics (female age structure, adult sex ratios) that determine the status of the Denali Caribou Herd, and 2) to evaluate growth, survival and seasonal distribution of adult males. This progress report summarizes research and monitoring of the Denali Caribou Herd conducted during October 2012-September 2013 (FY13). During this period, the specific objectives included:

1. Estimate the population size and composition in late September each year;
2. Determine productivity, survival patterns and age structure of adult females;
3. Assess calf production and recruitment;
4. Investigate the patterns of growth, survival, and seasonal distribution of male caribou;
5. Relate caribou population status, trends, and vital rates to climatic variables and predator population characteristics.

METHODS

Capture and Radiocollaring

Female caribou were captured by helicopter darting and radiocollared to monitor their survival, productivity and movements, and to aid in conducting composition surveys and herd counts. I have maintained an age-structured sample of approximately 60 females ≥ 1 year old by recruiting yearling females annually relative to the ratio of female calves to adult females in the herd in the previous September, and by recollaring individuals surviving in the sample every 4 years, prior to exhaustion of radiocollar batteries. Each March, I instrument 12 female calves (10-months-old) to provide recruits for the age-structured sample and to monitor productivity of young age-classes (2 and 3 years of age) that exhibit much of the variation in productivity observed in females overall. Females captured as 10-month-olds but not recruited into the age-structured sample have their collars removed at about 4 years of age to limit the number of radiocollared caribou.

Adult bulls were initially captured in mid-September 2007 to establish a sample of about 50 radiocollared individuals; additional bulls were captured in 2008-2013 as needed to maintain that sample. In addition, 12 10-month-old male calves were radiocollared each year in March 2008-2012 to investigate growth patterns and survival of young bulls. These individuals are recaptured at 4 years of age and subsequently included in the sample of adult bulls. In September 2014 and 2015, radiocollars will be

removed from all the instrumented bulls, bringing this aspect of the caribou research to conclusion.

Caribou captures generally occurred in March for females and calves, and mid-September for adult bulls. Currently, we use a mixture of carfentanil citrate and xylazine hydrochloride for immobilizing caribou, with specific doses for adult females, adult males, and 10-month-olds. A PA-18 Supercub working with the helicopter located caribou for darting, monitored darted caribou during induction, and checked on caribou captured on previous days. Once a caribou was immobilized, it was fitted with a mortality-sensing radiocollar, standard body measurements were taken, and a blood sample was drawn for disease screening. All caribou were weighed to the nearest 0.5 kg. A canine tooth was extracted for age determination from all adults on their first capture. Once processing was completed, caribou were given naltrexone hydrochloride and yohimbine hydrochloride to antagonize the effects of carfentanil and xylazine, respectively. Each radiocollared caribou was relocated within 1-3 days following capture to assess their post-capture condition.

Radiotelemetry: survival and seasonal distribution

All radiocollared caribou were relocated by aerial radiotracking from fixed wing aircraft approximately every 2 months throughout the year to determine their distribution and survival. In addition, caribou were located to assess natality (mid-May at approximately the peak of calving), and to aid in composition surveys and the annual census (early June, late September). Thus the annual radiotracking schedule is as follows: mid-May (natality assessment by observing calves at heel or distended udders); early June (post-calving composition survey and census); late July; late September (fall composition survey); late November; late-January; mid-March; and end of April. In addition, all radioed males were monitored every 2 weeks during August – November to refine estimates of the timing of adult male mortality. We attempted to observe mortalities from the radiotracking aircraft during monitoring flights and investigate by helicopter as soon as practical. Survival rates were calculated using Kaplan-Meier staggered-entry methods.

Pregnancy assessment

In mid-May, near the peak of the annual calving period, all radiocollared cows ≥ 2-years-old were located by radiotracking from a helicopter and observed to assess their pregnancy status based on a calf at heel, udder distension, or hard antler presence. During these surveys, the helicopter crew worked with a Supercub that radiolocated caribou in advance of the helicopter to increase efficiency of the overall effort.

Composition surveys

I conducted 2 helicopter surveys to assess the age/sex structure of the herd annually. During these surveys, a predetermined search area, based on the distribution of radiocollared caribou immediately prior to the survey, was intensively searched and all caribou encountered were approached at close range with a helicopter and classified into a small hand-held tape recorder. In early June following the calving season,

caribou were classified as calves, cows, and bulls to determine a calf:cow ratio as an assessment of early calf survival. As mentioned below, this survey also serves as the basis for population estimates. The fall composition survey was conducted near the end of September at about the peak of the rut, to determine calf:cow ratios, calf sex ratios, bull:cow ratios. During this survey, calves were differentiated by sex and bulls are classified into 3 size classes (small, medium, and large; Table 1) based on body size and antler development.

Population estimation

Annual herd size was estimated based on an estimate of the number of adult cows in the population determined from the postcalving survey results. Prior to that survey, the distribution of radiocollared adult females was assessed and a survey area delineated that ideally included > 50% of the marked females surrounded by a reasonable buffer defined by identifiable topographic features. The survey area usually consisted of 2 to 4 large blocks of mountainous terrain along the main Alaska Range that take 1-2 days to fully survey. From a helicopter, we intensively searched each survey block without the aid of radiotelemetry. Caribou groups encountered were counted and classified, and we determined the occurrence of marked individuals within groups via radiotelemetry. Simultaneously, a Supercub crew located all radiocollared females in or adjacent to the survey block. Periodically through the survey as portions of a survey block are completed, we compared notes among the 2 aircraft crews to determine marked groups that were missed by the helicopter; those groups were then relocated by the helicopter and counted. In addition to adding these caribou to the totals counted, this information provided an assessment of sightability relative to group size during the survey. Because most cows and calves tend to be in large groups at this time of the year, sightability has generally been very high.

With the information collected, an estimate of the total number of cows in the herd was derived by dividing the number of adult females observed during the survey by the proportion of radiocollared adult females that were in the survey blocks. In addition to the estimate for a given year (t), I used available information on seasonal adult female survival from radiotelemetry, and calf sex ratios and calf recruitment from fall composition surveys to derive estimates based on counts of adult females in the previous (t-1) and subsequent (t+1) years, then used the mean of the 3 estimates as the estimated number of adult females for year t. Finally, I determined a fall population estimate by applying the adult female survival rate from radiotelemetry for June-September to estimate fall cow numbers and using the fall herd composition to account for bulls and calves.

RESULTS

On 1 October 2012, a total of 165 caribou were carrying functioning radiocollars, including 79 females and 86 males. During the ensuing year, 24 caribou died of natural causes (11 females, 13 males), we experienced 3 dropped collars on bulls and 2 radiofailures (1 female, 1 male), and removed radiocollars from 5 females. During the year, we instrumented 12 10-month-old female calves and added 10 adult males to the

radioed sample. Thus, we were monitoring 153 radioed caribou (74 females, 79 males) at the end of the reporting period on 30 September 2013.

Herd Size

I derived a preliminary herd size estimate of 2,230 caribou for September 2013 (Table 1, Fig. 1); that number will be adjusted based on results of the 2014 census as described above. This population estimate is consistent with continued slow growth of the Denali Herd at about 2% per year since 2003.

Adult Sex Ratio

Our efforts to conduct an adequate late September composition survey were hampered by inclement weather on the north side of the Alaska Range and the government shutdown that commenced as of 1 October 2013. We classified 295 caribou on ranges south of the Alaska Range on 28 September 2013, but did not get workable weather conditions to the north on the 3 remaining days of the month. Our annual goal has been to classify > 1,000 caribou and has been met in all but 4 years since 1984 (713, 670, 997, and 295 in 1984, 2002, 2007, and this year, respectively).

I estimated an adult sex ratio of 42 bulls:100 cows, similar to the last 3 years (Table 1, Fig. 2b). Adult sex ratios declined from an average of 56:100 during 1984-1989 to a low of 29:100 during 1997-98 as a result of increased mortality of males during severe winters in the late 1980s and early 1990s along with limited recruitment of male calves. Bull:cow ratios have increased slowly since 1998 but are a still well below levels at the beginning of the study.

Calf Production and Survival

Productivity of cows ≥ 1 year old was estimated at 80% in mid-May 2013, based on 66 radiocollared females in the age-structured sample (Table 2). Of the 13 non-parturient females in the sample, 11 were ≤ 2 years-old (8 yearlings, 3 2-year-olds); the remaining 2 females were 4 and 15 years old. The herd natality rate has varied from 59% in 1990 to 92% in 1994 and is primarily influenced by the proportion of the population consisting of yearlings and the variable productivity of the 2-year-old cohort.

During the mid-June 2013 postcalving composition survey, we noted 33 calves:100 cows (Table 3). By the late September composition count, that ratio had declined to 18:100 (Table 1, Fig. 2A), again based on a relatively low sample size of caribou in 2013 compared to other years. Based on these ratios and accounting for adult female mortality between mid-May and late September, I estimated 21% survival to fall for the 2013 cohort. Calf survival has averaged 27% over the last 10 years, compared to 42% and 15% during 1987-1990 and 1991-2003, respectively.

Female Survival and Age Structure

During October 2012 – September 2013, 8 females from the age-structured sampled died for an annual mortality rate of 12%, equal to the long-term study average (range of annual values = 2-23%). The female age structure in May 2013 (Fig. 4) exhibited the effects of improved recruitment over the last 9 cohorts, although the

proportion of females that were ≥ 13 years old remained high (Fig. 5). With continued moderate recruitment, the proportion consisting of older females will likely decline over the next few years because of the paucity of females 10-12 years old, representing the 2001-2003 cohorts that are the last from the period of low recruitment (Fig. 3).

The adult female mortality rate has varied from an average of 7% during 1986-89 when the herd was growing at 8%/year to 19% on average during 1989-93, the period of severe winters and marked herd decline of 10%/year. Since about 2000, mortality rates for adult females have averaged 12% in spite of mild to average winter conditions. This higher mortality in the last decade has in part been due to an age structure skewed toward older females and the expected higher losses of those older females. Given the current age structure, annual mortality rates will likely decline from current levels as the cows ≥ 13 years old die off, and those age classes are replaced by the weak 2001-2003 cohorts (Fig. 4).

Based on data collected from radiocollared caribou since September 1986, age-specific survival rates of females are high during 2-7 years of age, averaging 0.94, then decline slowly during 8-13 years of age prior to declining markedly as individuals become senescent (Fig. 6). The 2 oldest caribou females we have monitored died in May as they turned an estimated 20 years old.

Adult Bull Survival

During September 2007- September 2013, we radiocollared and monitored 198 male caribou, including 137 captured as adults (≥ 1 year old) in mid-September, and 61 captured as 10-month-old calves (12-13 each March 2008-2012). We have experienced some difficulties with premature failure of radiocollars (*n* = 18) or loss of radiocollars (*n* = 21). In Fall 2010, we began deploying transmitters that were fully cast in urethane resin to protect the electronic components from shock during rutting fights. That appears to have taken care of the failure issue, although we continue to experience occasional failures with radiotransmitters deployed prior to September 2010. Many of the dropped collars (*n* = 13 of 21) also resulted from the rut in that they were torn off during rutting fights; the remainder (*n* = 8) were due to premature failure of the elastic expansion sections in the collars. In addition to 4 capture-related deaths, we noted 76 deaths to date attributed to the following causes, including wolves (36), bear (13), accidents (2), unknown large predator (8), unknown (16), and unknown-not predation (1).

Age-specific survival rates of males appeared to be high and possibly increasing through 4 years of age (Fig. 7). Survival then declined as individuals become active in the rut through 7 years of age, then dropped off markedly for males > 7 years old. Very few caribou bulls survive to 10 years of age; the oldest bull we monitored died in May as he turned an estimated 13 years old and is the only collared bull to survive beyond 11 years of age. Bulls ≥ 3 years old died predominantly during July – November (82% of annual mortality; Fig. 8). Of this mortality, over half (43% of annual mortality, occurred prior to the onset of the rut around mid-September.

Bull Growth Patterns

In September 2007-2013, we weighed 158 bulls ≥ 1 year old, at their initial captures and recaptures to replace radiocollars prior to battery exhaustion. In mid-September bull caribou should be at their maximum body for the year in preparation for the rut and ensuing winter. Overall, body masses of these males ranged from 93 to 278 kg. Body masses increased markedly with age from 1 to 6 years of age, gaining an average of 24.5 kg each year, and plateaued at 231.4 kg on average for bulls ≥ 6 years of age (Fig. 9). Antler size was strongly correlated with body mass ($r^2 = 0.90$, $F_{1,155} = 1377.61$, $P < 0.001$), thus mean antler length showed a similar pattern to body mass, increasing by 14.3 cm/year for bulls 1 – 6 years of age, and averaging 123.5 cm for bulls ≥ 6 years of age. The bull size classes we use for composition surveys (Table 1, 4) differed significantly in body mass ($F_{2,155} = 326.4$, $P <0.001$) and antler length ($F_{2,167} = 366.3$, $P <0.001$). However, there was substantial overlap among classes in that the M class included a broad range of ages that were included in the other 2 classes (Table 4).

Seasonal Distribution of Bulls

We have been regularly radiotracking bull caribou on the same schedule as the females, averaging about 7 location/individual/year. To date, we have not analyzed this data.

PLANNED ACTIVITIES (OCTOBER 2013 - SEPTEMBER 2014)

In the upcoming year, we will continue efforts to assess population dynamics of the DCH and begin bring studies of survival, growth, and seasonal distribution of bulls to completion. Specifically, objectives for the year include:

1. Capture and radiocollar caribou females as needed to maintain an age-structured sample of approximately 60 individuals for estimation of calf production, age structure, survival patterns and seasonal distribution, and to aid in population monitoring.
2. Capture and remove radiocollars from approximately half of the instrumented bull in the herd in mid-September 2014; all individuals will be fully processed during capture to add to datasets on growth patterns of males. Remaining bulls will be captured for collar removal in September 2015.
3. Locate all instrumented caribou in late November, late January, mid-March, late April, mid-May, early June, late July, and late September, or as needed to meet study objectives.
4. Conduct the post-calving census and composition survey and the fall composition survey to determine herd size, calf recruitment, and adult sex ratio.

Table 1. Results of helicopter composition surveys in late September and fall population estimates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska, 1984-2013.

	Fall Survey Results											
				Ratios (:100 Cows)		Calf Sex Ratio	Bulls%[b]			Fall	Estimated Fall Herd Composition		
Date	Cows[a]	Calves	Bulls	Calves	Bulls	(m:100f)	S	M	L	Herd Size	Cows	Calves	Bulls
9/27/1984	375	154	184	41	49	--	--	--	--	2,200	1,158	475	567
9/25-26/1985	654	183	368	28	56	72	--	--	--	-	-	-	-
9/27/1986	547	210	305	38	56	--	--	--	--	2,470	1,272	488	709
9/25/1987	631	234	356	37	56	73	28	39	33	2,430	1,256	466	709
9/27-28/1988	678	221	451	33	67	70	27	34	39	2,950	1,482	483	986
9/28/1989	830	246	428	30	52	84	34	34	32	3,210	1,771	525	913
9/26-27/1990	777	130	387	17	50	59	39	28	33	3,100	1,861	311	927
9/26/1991	1,067	72	409	6.7	38	112	32	39	29	2,610	1,799	121	690
9/25/1992	643	103	282	16	44	66	31	40	29	2,340	1,464	234	642
9/27/1993	849	54	336	6.4	40	74	26	46	28	1,970	1,350	86	534
9/27-28/1994	648	128	253	20	39	88	21	38	41	2,140	1,348	266	526
9/25/1995	685	131	204	19	30	75	29	29	42	2,170	1,457	279	434
9/29/1996	820	103	243	13	30	69	32	26	42	2,060	1,449	182	429
9/26/1997	777	124	228	16	29	110	38	28	34	2,070	1,425	227	418
9/26/1998	718	87	205	12	29	98	41	27	32	1,790	1,272	154	363
9/29/1999	667	92	261	14	39	51	30	34	36	1,760	1,151	159	450
9/24-26/2000	730	52	257	7.1	35	86	32	31	37	1,930	1,356	97	477
9/27/2001	778	90	248	12	32	64	22	38	40	1,840	1,283	148	409
9/29/2002	453	72	145	16	32	76	22	17	61	2,050	1,386	220	444
9/30/2003	743	58	264	7.8	36	71	23	23	54	1,880	1,312	102	466
9/27/2004	774	214	309	28	40	69	19	30	50	2,120	1,265	350	505
9/26/2005	848	163	279	19	33	52	32	27	41	1,930	1,269	244	417
9/28/2006	691	145	269	21	39	59	30	29	41	2,090	1,307	274	509
9/28/2007	628	142	227	23	36	84	31	37	33	2,060	1,298	293	469

Table 1. Continued.

	Fall Survey Results										Estimated Fall Herd Composition		
				Ratios (:100 Cows)		Calf Sex Ratio	Bulls%[b]			Fall			
Date	Cows[a]	Calves	Bulls	Calves	Bulls	(m:100f)	S	M	L	Herd Size	Cows	Calves	Bulls
9/29/2008	677	152	222	22	33	85	32	30	38	2,070	1,333	299	437
9/28-29/2009	764	174	272	23	36	81	38	25	37	2,130	1,345	306	479
9/27-28/2010	935	186	396	20	42	100	36	30	35	2,100	1,294	257	548
9/27-28/2011	840	187	352	22	42	83	39	30	32	2,270	1,383	308	579
9/27,30/2012	940	224	383	24	41	85	33	28	39	2,350	1,429	340	581
9/28/2013[c]	184	33	78	18	42	136	29	38	32	2,230[d]	1,391[d]	249[d]	590[d]

[a] Cows ≥ 1 year old.

[b] S = small: antlers indistinguishable from those of adult cows, body size comparable to cows.
M= medium: antlers larger than adult cows, but having smaller beam diameter, fewer points, and/or shorter antler length than the large bull class.
L = large: antlers fully developed with large diameter beams, many points, and long antler length.

[c] Limited survey conducted only south of Alaska Range due to persistent inclement weather on northern ranges and the partial shutdown of the Federal government that began 1 October 2013.

[d] 2013 herd size estimate and composition are tentative.

Table 2. Estimated natality rates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska during 1987-2013. Rates are based on calving season observations of a sample of radiocollared females $\geq$ 1 year old designed to approximate the age structure of the population.

Year	*n*	Pregnant	Not Pregnant	Natality Rate %	95% Cl
1987	37	26	11	70.3	53.0 - 84.1
1988	46	33	13	71.7	56.5 - 84.0
1989	55	37	18	67.3	53.3 - 79.3
1990	49	29	20	59.2	44.2 - 73.0
1991	44	29	15	65.9	50.1 - 79.5
1992	46	41	5	89.1	76.4 - 96.4
1993	41	27	14	65.9	49.4 - 79.9
1994	47	43	4	91.5	79.6 - 97-6
1995	50	43	7	86.0	73.3 - 94.2
1996	53	46	7	86.8	74.7 - 94.5
1997	53	42	11	79.3	65.9 - 89.2
1998	46	39	7	84.8	71.1 - 93.7
1999	48	43	5	89.6	77.3 - 96.5
2000	55	46	9	84.6	71.2 - 92.2
2001	52	43	9	82.7	69.7 - 91.8
2002	45	38	7	84.4	70.5 - 93.5
2003	42	31	10	73.8	58.0 - 86.1
2004	53	45	8	84.9	72.4 - 93.3
2005	57	43	14	75.4	62.2 - 85.9
2006	62	44	18	71.0	58.1 - 81.8
2007	65	47	18	72.3	59.8 - 82.7
2008	68	53	15	77.9	66.2 - 87.1
2009	71	52	19	73.2	61.4 - 83.1
2010	66	49	17	74.2	62.0 - 84.2
2011	63	53	9	85.5	74.2 - 93.1
2012	65	52	13	80.0	68.2 - 88.9
2013	66	53	13	80.3	68.3 – 88.7

Table 3. Results of post-calving composition surveys of the Denali Caribou Herd, Alaska, 1984-2013.

Date	Cows > 1 YO	Calves	Calf:Cow Ratio
5/30-31,6/3/1984	519	201	39:100
1985		NO SURVEY	
5/28/1986	335	134	40:100
5/29-30/1987	1124	487	43:100
5/27-29/1988	1002	435	43:100
5/30/1989	1263	500	40:100
6/1/1990	1402	512	37:100
6/4-5/1991	1213	220	18:100
6/1/1992	909	278	31:100
6/2-3/1993	822	177	22:100
6/1-2/1994	985	376	38:100
5/30/1995	693	238	34:100
5/29/1996	682	139	20:100
5/31/1997	759	101	13:100
5/29-30/1998	624	141	23:100
5/29/1999	522	108	21:100
6/7/2000	665	68	10:100
6/6/2001	736	140	19:100
6/8/2002	431	120	28:100
6/8/2003	613	104	17:100
6/6/2004	673	236	35:100
6/8-9/2005	798	193	24:100
6/9,11/2006	576	218	38:100
6/8-9/2007	953	321	34:100
6/7-9/2008	910	275	30:100
6/7-8/2009	1036	359	35:100
6/9-10/2010	1038	316	30:100
6/8-9/2011	1141	377	33:100
6/15/2012	702	260	37:100
6/14-15/2013	981	325	33:100

Table 4. Breakdown of age, body mass, and antler length by size class for male caribou in the Denali Caribou Herd, Denali National Park and Preserve, Alaska during 2007-2013.

	Age (yr)	Mass (kg) mean (*n*; range)	Antler Length (cm) mean (*n*; range)
Small	1 – 3	116 (30; 93-156)	56.0 (32; 29.1-75.2)
Medium	1 – 5	165 (56; 108-213)	84.2 (62; 62.0-118.8)
Large	≥ 4	225 (72; 163-278)	119.1 (76; 88.6-150.5)

Small: antlers indistinguishable from those of adult cows, body size comparable to cows.

Medium: antlers larger than adult cows, but having smaller beam diameter, fewer points, and shorter antler length than the large bull class.

Large: antlers fully developed with large diameter beams, many points, and long antler length.

Fig. 1. Population estimates for the Denali Caribou Herd, Denali National Park, Alaska, late September, 1986-2013 (2013 estimate is preliminary).

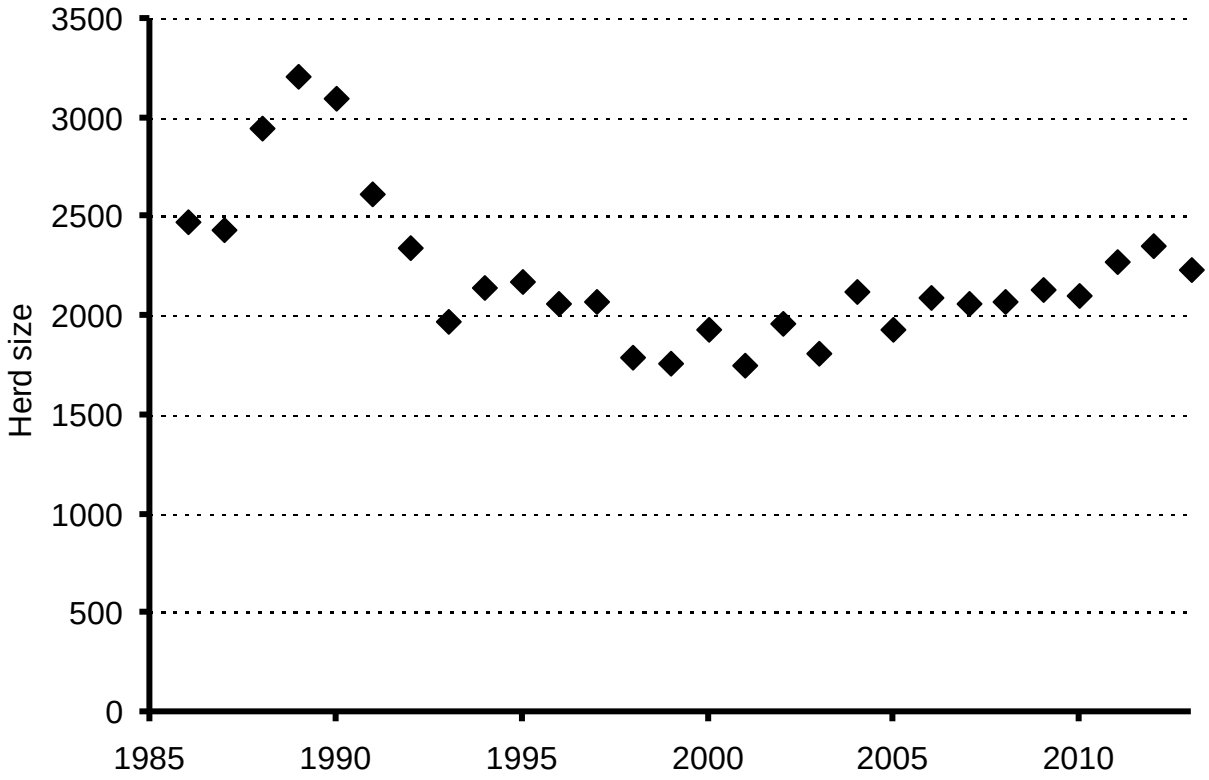


Fig. 2. Calf:cow ratios (A) and bull:cow ratios (B) for the Denali Caribou Herd, Denali National Park, Alaska, late September, 1984-2013.

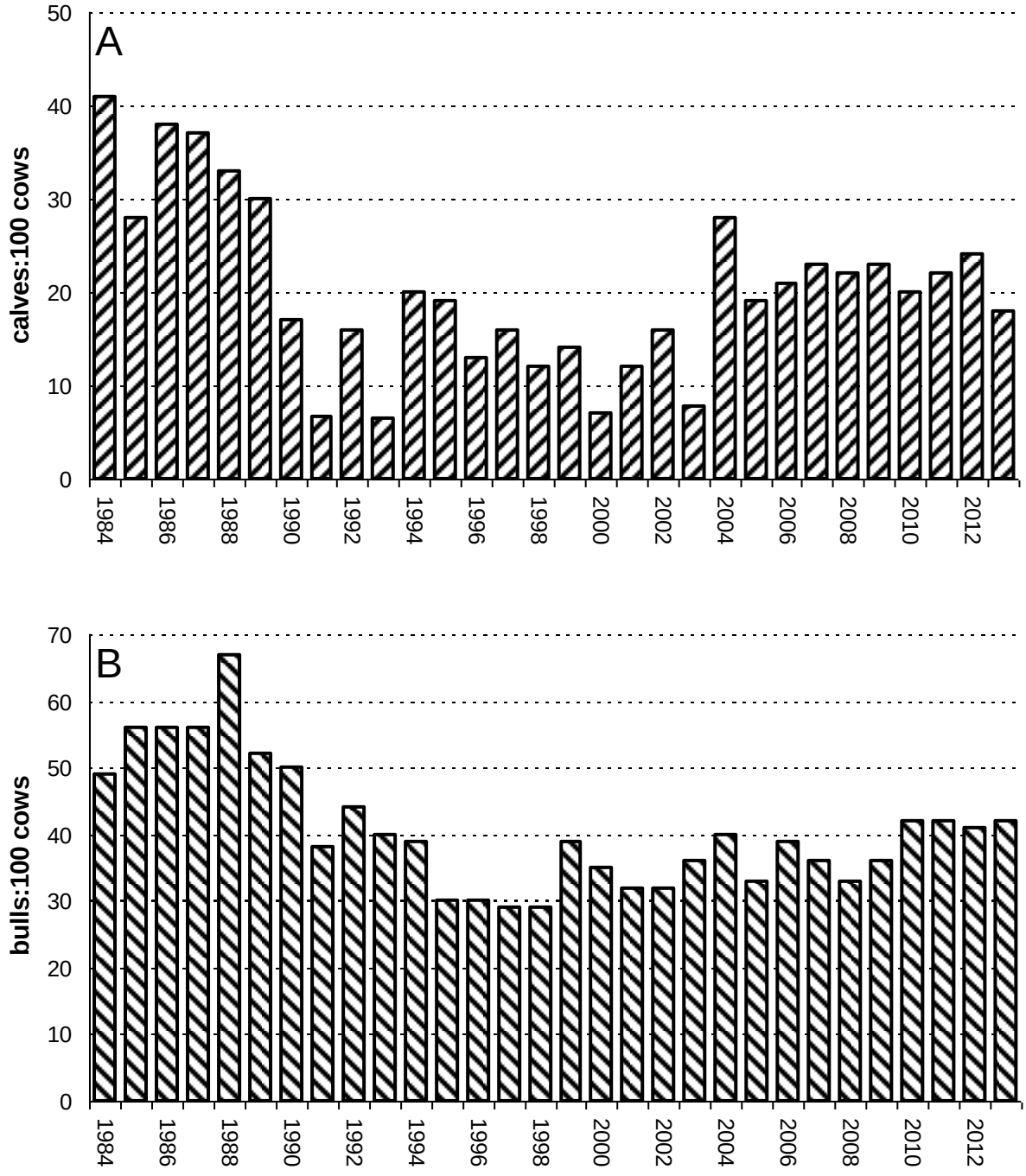


Fig. 3. Estimated calf survival to late September in the Denali Caribou Herd during 1987 – 2013, based on annual estimates of natality of radiocollared cows, adult female survival, and fall calf:cow ratios.

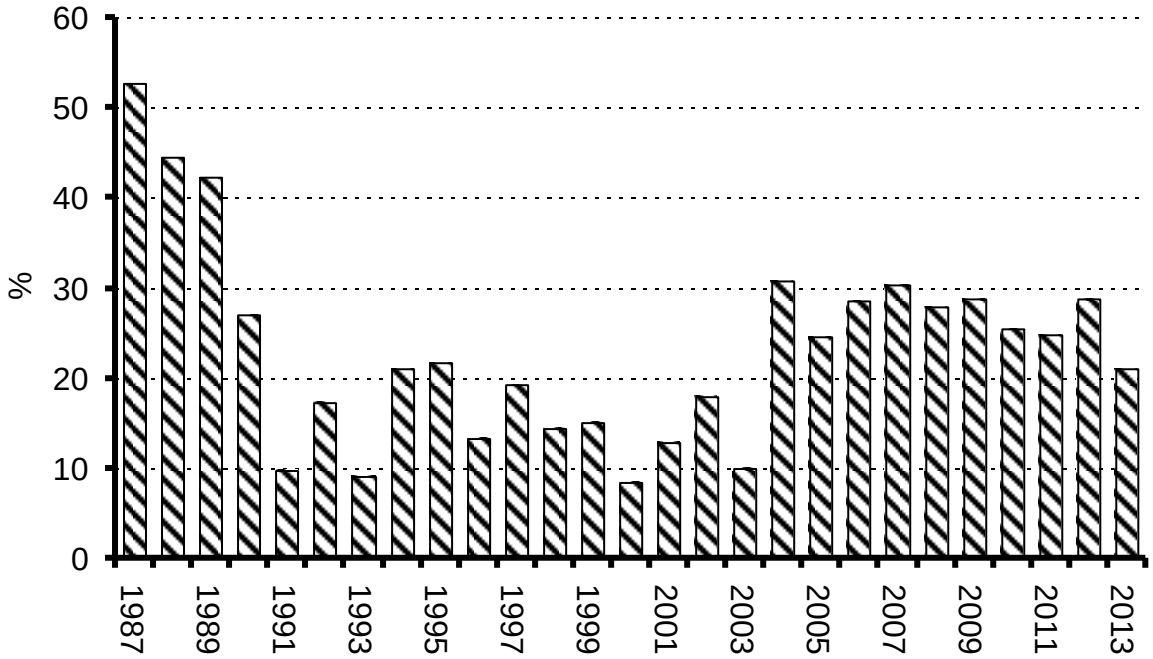


Fig. 4. Estimated age structure of the female segment of the Denali Caribou Herd on 1 May 2013 (*n* = 67 cows).

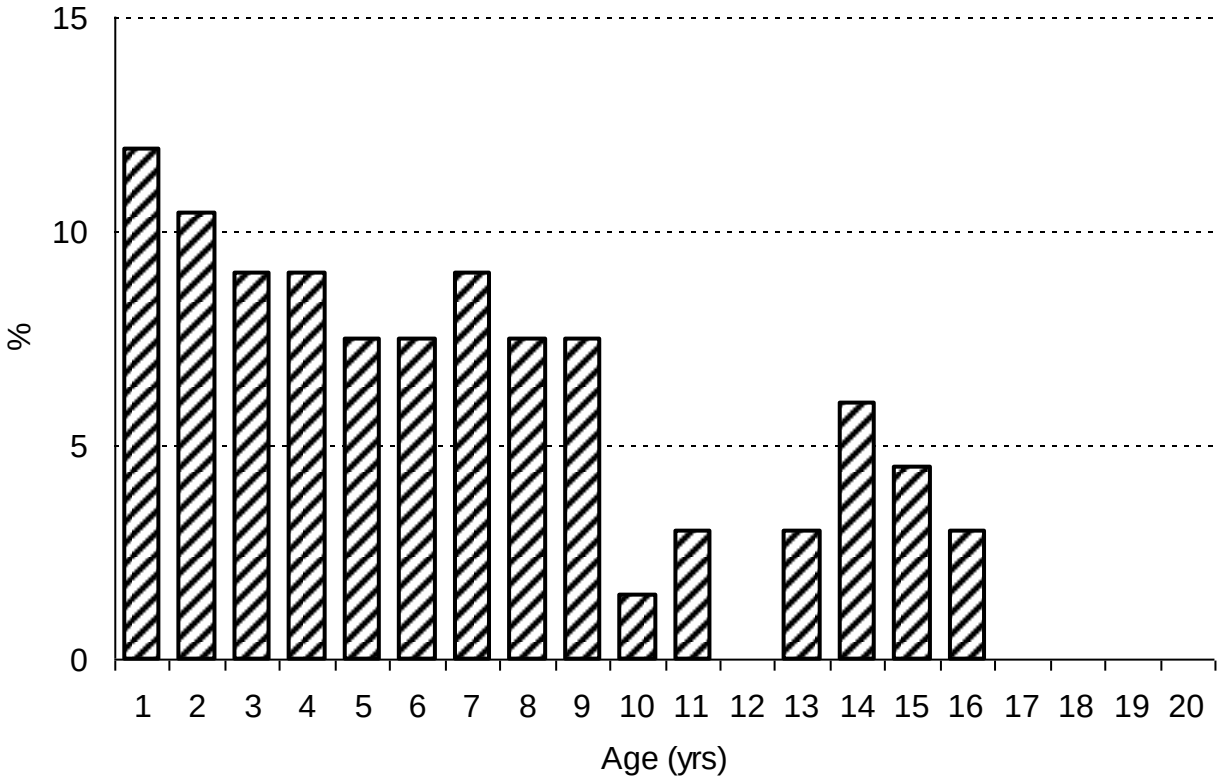


Fig. 5. Proportion of the adult female segment of the Denali Caribou Herd ≥ 13 years old on 1 May 1987-2013.

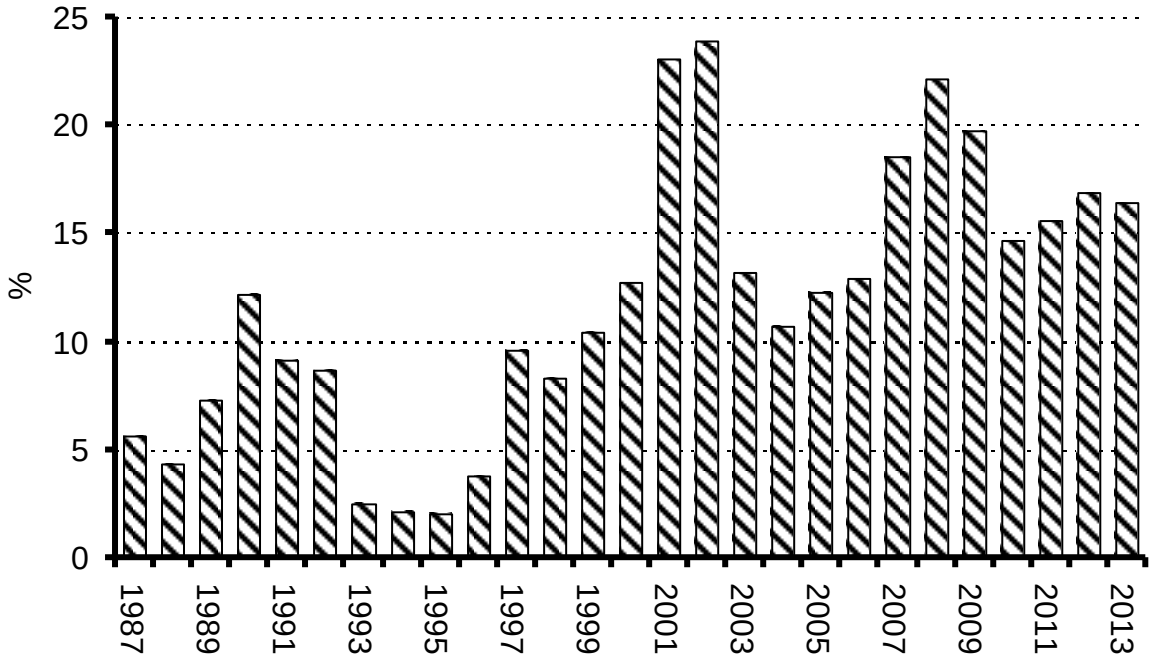


Fig. 6. Age-specific survival rates (± 95% confidence intervals) for female Denali caribou, based on 394 individual caribou monitored for 1,955 caribou years during October 1986-September 2013.

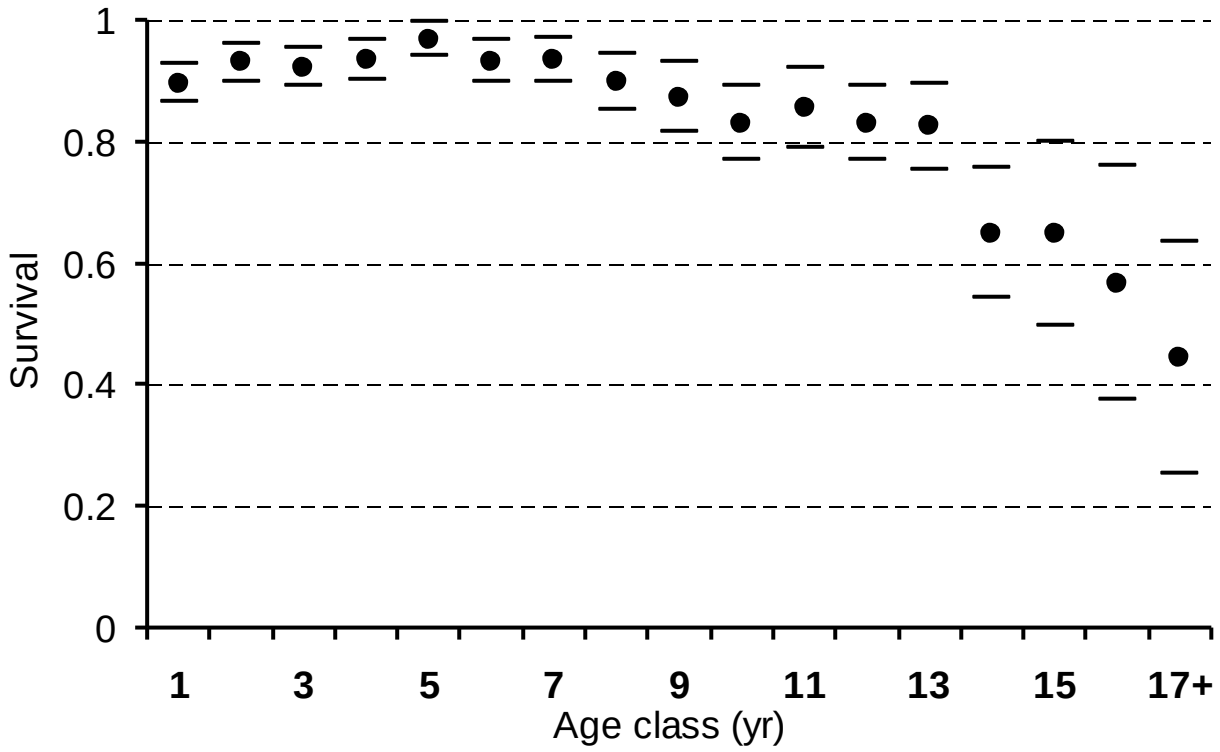


Fig. 7. Estimated survival rates (± 95% confidence limits) by age-class for male caribou in the Denali Herd, based on 189 individual caribou monitored for 373 caribou years during October 2007 –September 2013.

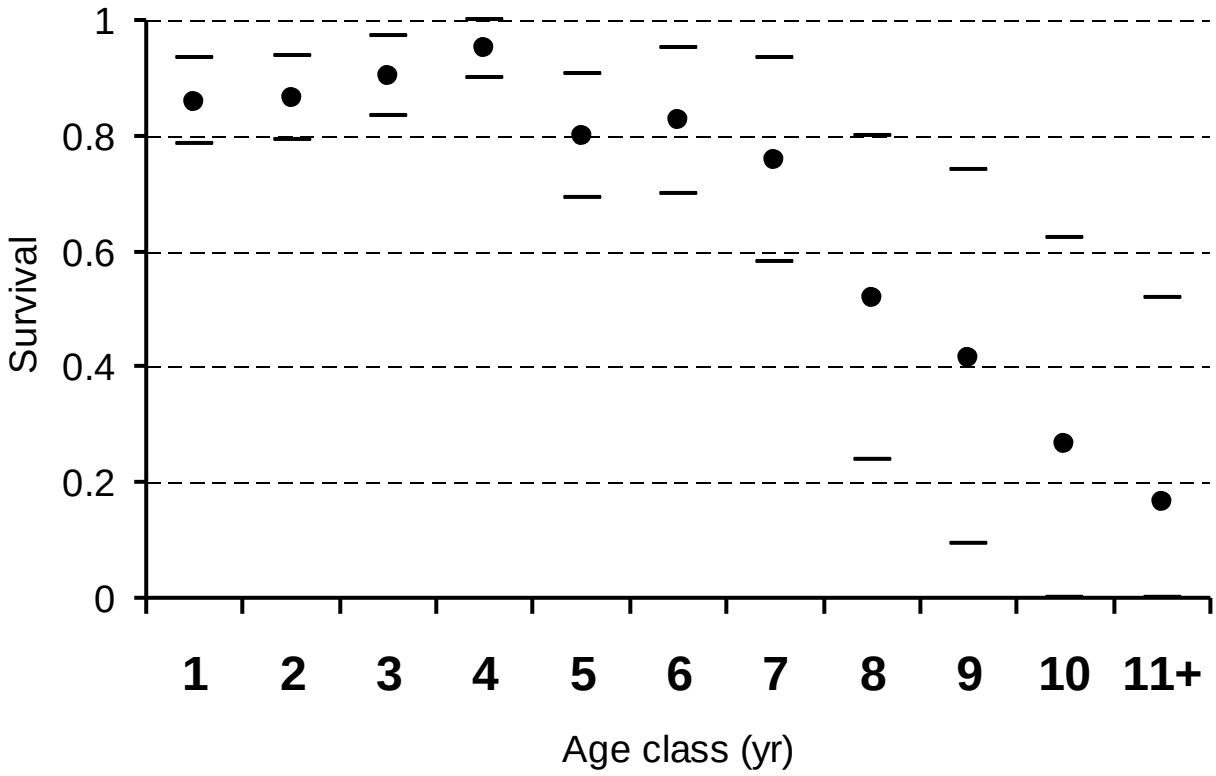


Fig. 8. Timing of annual mortality for male and female caribou ≥ 3 years old in the Denali Herd, based on radiotelemetry data collected during October 1986-September 2013 for females (*n* = 190 deaths), and October 2007-September 2013 for males (*n* = 49 deaths).

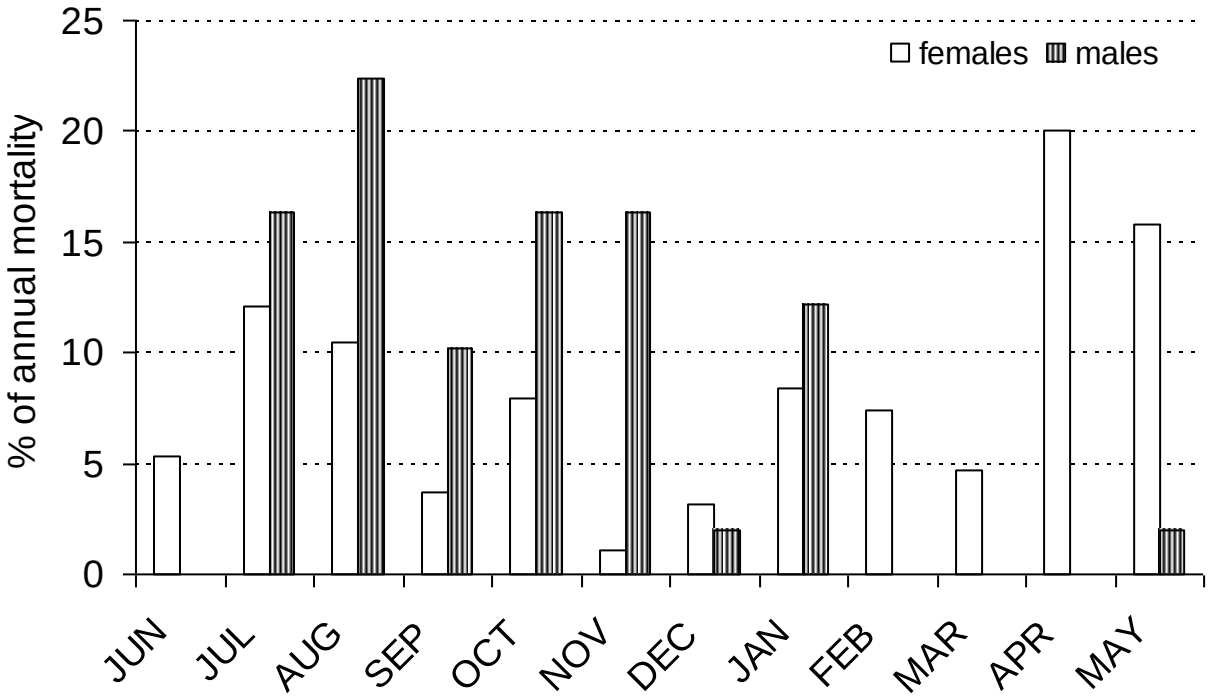


Fig. 9. Body masses of bull caribou ≥ 1 year old (*n* =158) weighed in September 2007-2013. Dashes indicate means for age-classes including ≥ 4 individuals.

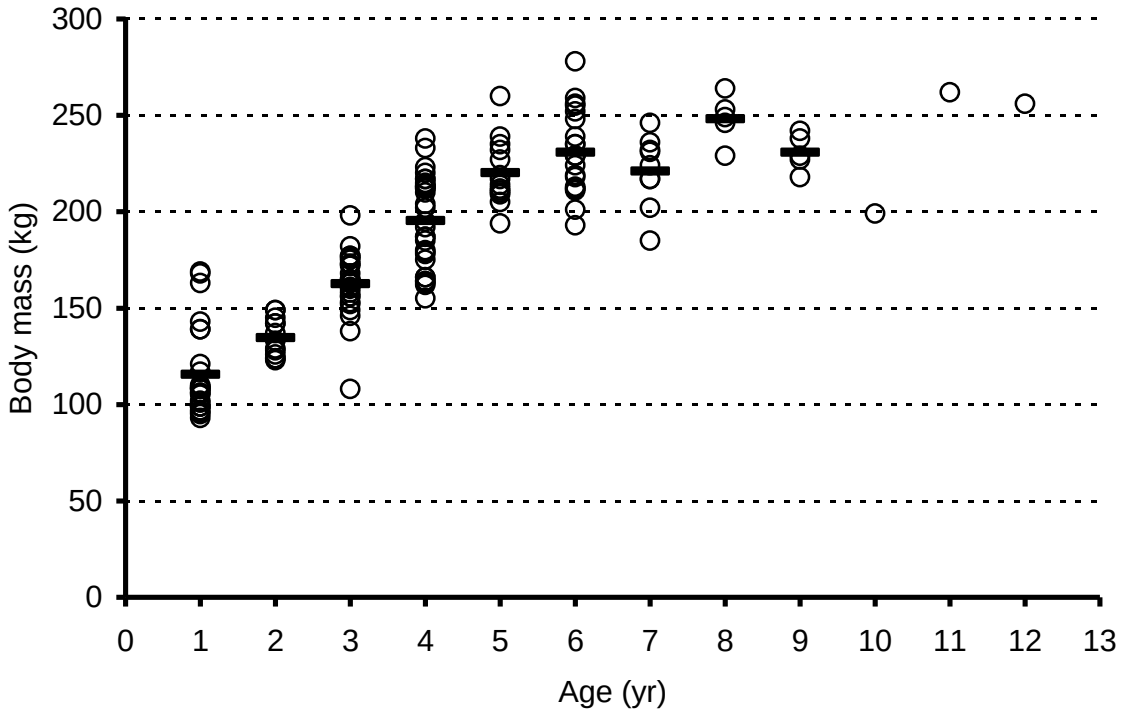
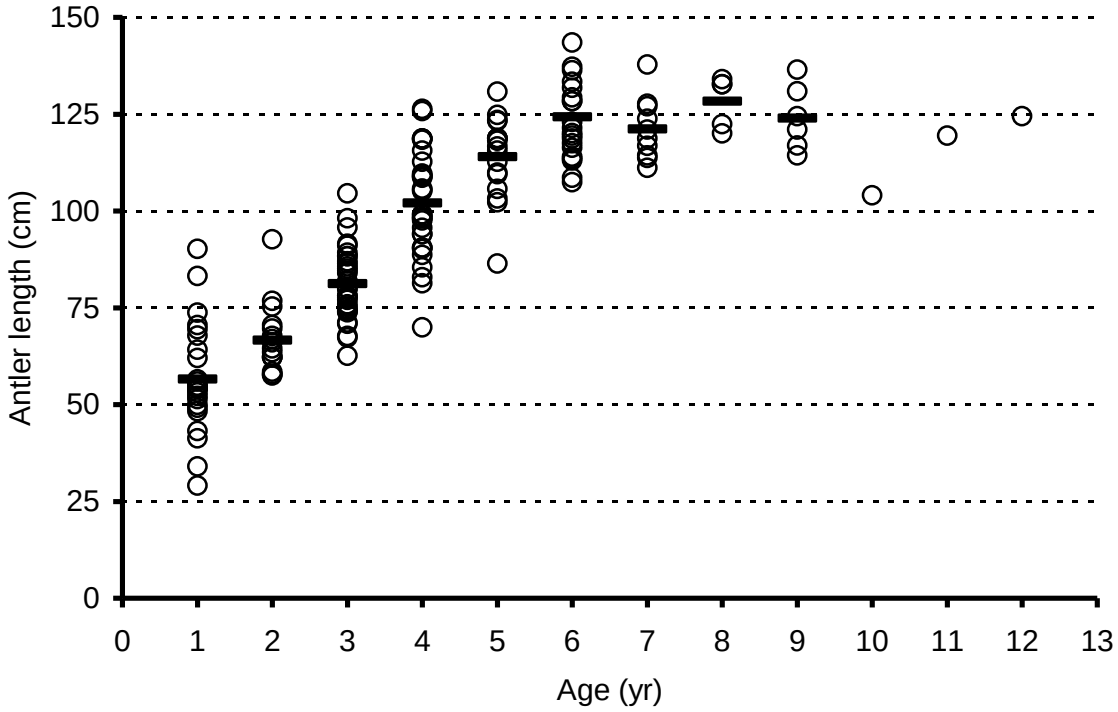


Fig. 10. Antler lengths of bull caribou ≥ 1 year old (*n* = 170) relative to age in the Denali Caribou Herd, September 2007-2013. Dashes indicate means for age-classes including ≥ 4 individuals.



Appendix 1. Products of the Denali Caribou research program during 1986-2013.

Report – Adams, L.G. 2013. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2011 – September 2012). USGS Alaska Science Center, Anchorage, AK. 24pp.

Report – Adams, L.G. 2012. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2010 – September 2011). USGS Alaska Science Center, Anchorage, AK. 29pp.

Publication -Gustine, D.D., P.S. Barboza, J.P. Lawler, L.G. Adams, K.L. Parker, S.M. Arthur, and B.S. Shults. 2012. Diversity of nitrogen isotopes and correlates of protein balance in caribou: implications for monitoring northern ungulates. Journal of Mammalogy 93:778-790.

Report – Adams, L.G. 2011. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2009 – September 2010). USGS Alaska Science Center, Anchorage, AK. 24pp.

Report – Adams, L.G., and G.H. Roffler. 2010. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2008 – September 2009). USGS Alaska Science Center, Anchorage, AK. 35pp.

Report – Adams, L.G., and G.H. Roffler. 2009. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2007 – September 2008). USGS Alaska Science Center, Anchorage, AK. 18pp.

Report – Adams, L.G., and G.H. Roffler. 2008. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2006 – September 2007). USGS Alaska Science Center, Anchorage, AK. 20pp.

Report – Adams, L.G., and G.H. Roffler. 2007. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2005 – September 2006). USGS Alaska Science Center, Anchorage, AK. 17pp.

Publication - Adams, L.G., T. Meier, P. Owen, and G.H. Roffler. 2006. Interrelationships of Denali's large mammal community. Alaska Park Science 5(1):36-40.

Report – Adams, L.G., and G.H. Roffler. 2006. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2004 – September 2005). USGS Alaska Science Center, Anchorage, AK. 15pp.

Publication - Adams, L.G., B.W. Dale, and G.H. Roffler. 2005. Extraordinary movements of the Denali Caribou Herd following the perfect storm. Rangifer Special Issue 16:19-25.

Publication - Adams. L.G. 2005. Effects of maternal characteristics and environmental variation on birth masses of Alaskan caribou. Journal of Mammalogy 86:506-513.

Report – Adams, L.G. 2005. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2003 – September 2004). USGS Alaska Science Center, Anchorage, AK. 16pp.

Report – Adams, L.G. 2004. Dynamics of the Denali Caribou Herd, Denali National Park, Alaska: progress report (October 2002 – September 2003). USGS Alaska Science Center, Anchorage, AK. 11pp.

Publication - Adams, L.G. 2003.Marrow fat deposition and skeletal growth in caribou calves. Journal of Wildlife Management 67:20-24.

Report - Adams, L.G. 2002. Population dynamics of wolves and their prey in Denali National Park, Alaska: progress report (May 2000 - April 2001). USGS Alaska Biological Science Center, Anchorage, AK. 26pp. + appendices.

Publication - Ben-David, M., E. Shochat, and L.G. Adams. 2001. The utility of stable isotope analysis in studying foraging ecology of herbivores: examples from moose and caribou. Alces 37:421-434.

Report - Adams, L.G. 2001. Population dynamics of wolves and their prey in Denali National Park, Alaska: progress report (May 1998 - April 2000). USGS Alaska Biological Science Center, Anchorage, AK. 26pp. + appendices.

Report - Adams, L.G. 1999. Population dynamics of wolves and their prey in Denali National Park, Alaska: progress report. USGS Alaska Biological Science Center, Anchorage, AK. 17pp. + appendices.

Publication - Adams, L.G., and B.W. Dale. 1998. Reproductive performance of female Alaskan caribou. Journal of Wildlife Management 62:1184-1195.

Book - Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch, and B.W.Dale. 1998. The wolves of Denali. University of Minnesota Press. 238pp.

Publication - Adams, L.G., and B.W. Dale. 1998. Timing and synchrony of parturition in Alaska caribou. Journal of Mammalogy 79:287-294.

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Publication - Adams, L.G., F.J. Singer, and B.W. Dale. 1995. Caribou calf mortality in Denali National Park, Alaska. Journal of Wildlife Management 59(3):584-594.

Publication - Adams, L.G., B.W. Dale, and L.D. Mech. 1995. Wolf predation on caribou calves in Denali National Park, Alaska. Pages 245-260 in L.N. Carbyn, S.H. Fritts, and D.R. Seip, eds. Ecology and conservation of wolves in a changing world - proceedings of the second North American symposium on wolves. Canadian Circumpolar Institute Occasional Paper 35. University of Alberta, Edmonton. 642pp.

Publication - Adams, L.G., and L.D. Mech. 1995. Population trends of wolves and caribou in Denali National Park, Alaska. Pages 347-348 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals and ecosystems. U.S. Department of Interior, National. Biological Service, Washington, DC. 530pp.

Popular article - Adams, L.G. 1992. Snowfall tips the balance of wolf-caribou relationships in Denali National Park. Pages 56-57 in Highlights of natural resource management. U.S. Department of Interior, National Park Service, Washington, DC. 67pp.

Publication - Davis, J.L., L.G. Adams, P. Valkenburg, and D.J. Reed. 1991. The relationship between caribou body weight and age and cohort specific reproduction. Pages 115-142 in Butler, C.E. and S.P. Mahoney (eds.). Proceedings of the fourth North American caribou workshop. Newfoundland and Labrador Wildlife Division, St. John's, Newfoundland. 529pp.

Report - Adams, L.G., B.W. Dale, and B. Shults. 1989. Population status and calf mortality of the Denali Caribou Herd, Denali National Park and Preserve, Alaska - 1984-1988. U.S. National Park Service Natural Resources Progress Report AR-89/13. Anchorage, AK. 131pp.

Publication - Adams, L.G., B.W. Dale, and F.J. Singer. 1988. Neonatal mortality in the Denali Caribou Herd. Proceedings of the third North American caribou workshop. Alaska Department of Fish and Game Wildlife Technical Bulletin 8:33-34.

Publication - Adams, L.G., P. Valkenburg, and J.L. Davis. 1988. Efficacy of carfentanil citrate and naloxone for field immobilization of Alaskan caribou. Proceedings of the third North American caribou workshop. Alaska Department of Fish and Game Wildlife Technical Bulletin 8:167-168.

Popular article - Adams, L.G. 1987. Fate of caribou calves studied in Denali. Page 16 in Highlights of natural resource management. U.S. Department of Interior, National Park Service, Washington, DC. 53pp.

Report - Adams, L.G. 1986. Population status and neonatal mortality of the Denali Caribou Herd-progress report. U.S. National Park Service Natural Resources Progress Report AR-86/05. Anchorage, AK. 13pp.