

PROJECT TITLE: DYNAMICS OF THE DENALI CARIBOU HERD, DENALI NATIONAL PARK, ALASKA: PROGRESS REPORT (OCTOBER 2011 - SEPTEMBER 2012)

INVESTIGATORS: Layne G. Adams, USGS-Alaska Science Center, 4210 University Drive, Anchorage, AK 99508

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Population dynamics of the Denali Caribou Herd has been investigated continuously at Denali National Park since 1984. Denali National Park, totaling 18,800 km², encompassing nearly the entire Denali Herd range, provides 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 by primarily by natural processes and are largely unaffected by human harvest. Thus, research on Denali's large carnivore/ungulate system serves as an important naturally-functioning benchmark for comparison to manipulated systems throughout northern North America. Further, caribou investigations are a component of Denali's large mammal monitoring program, supplying objective information on the status and long-term trends of park wildlife populations and understanding of the causes of population changes.

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, then declined by nearly a third to 2,300 caribou by fall 1992. During the decline, adult cow survival dropped substantially, to an average of 85%/year, and calf recruitment dropped to just 5%. 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 calf recruitment to fall continued to be very low (mean = 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, an estimated 24% of the females in the herd were ≥ 13 years old. 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 are comparable to rates measured during the extreme winters of 1990-93.

During the last 9 years (2004-12), calf survival to fall has improved, averaging 28% annually, allowing for limited growth of the herd at about 2.5% per year. The age structure is still weighted disproportionately to older females (17% 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. Information on male survival patterns is sorely lacking, even though males generally accommodate 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 72% of the observed mortality of adult males occurring during July – November.

The current goals of this research are 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 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 2011-September 2012 (FY12). 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 marked variation in productivity. 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 have been captured in 2008-122as

needed to maintain that sample. In addition, 12 10-month-old male calves were radiocollared each year in March 2008-12 to investigate growth patterns and survival of young bulls.

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 caribou we handled was relocated within 1-3 days of 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, 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) 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 to determine marked groups that were missed by the helicopter; those groups are 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

We monitored a total of 92 female caribou during all or a portion of the year, including 80 radiocollared females on 1 October 2011, and 12 10-month-olds radiocollared in April 2012. We removed collars from 7 individuals during April and September capture operations; 5 females died of natural causes during the year, and we experienced 1 apparent radiofailure during summer 2012. As of 1 October 2012, we

had 79 radiocollared females as a part of these studies.

We started with 85 male caribou instrumented with radiocollars at the beginning of the year, including 48 captured as adults and 37 initially captured as 10-month-old calves from the 2007-10 cohorts. We captured 13 10-month-old calves from the 2011 cohort in April 2012 and an additional 10 adult males in September 2012 to maintain sample sizes. During the year, 8 males died of natural causes, and we experienced 9 dropped collars, and 3 radiofailures. In addition, we had 1 capture-related death in September 2012 of a young male that survived the capture but died in a fall down a steep gully within a couple days following capture. We ended the year with a total 88 bulls radiocollared in the herd, including 43 captured as adults and 45 initially instrumented as 10-month-old calves (5, 6, 10, 11, and 13 from the 2007-11 cohorts, respectively).

Herd Size

I derived a preliminary herd size estimate of 2,300 caribou for September 2012 (Table 1, Fig. 1); that number will likely change some depending on results of the 2013 census as described above. This population estimate is indicative of continued slow growth of the caribou herd at about 2.5% per year and the highest number of caribou in the Denali Herd since 1992.

Adult Sex Ratio

The herd's adult sex ratio of 41 bulls:100 cows was similar to the last 2 years; these rates are also the highest noted since 1992 (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 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 2012, based on 65 radiocollared females in the age-structured sample (Table 2). Of the 13 non-parturient females in the sample, 12 were ≤ 2 years-old (7 yearlings, 6 2-year-olds) and the remaining female was 19 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 early-June 2012 postcalving composition survey, we noted 37 calves:100 cows (Table 3). By the late September composition count, that ratio had declined to 24:100 (Table 1, Fig. 2A). Based on these ratios and accounting for adult female mortality between mid-May and late September, I estimated 29% survival to fall for the 2012 cohort. Calf survival has averaged 28% over the last 9 years, compared to 15% during 1991-2003.

Female Survival and Age Structure

During October 2011 – September 2012, 5 females from the age-structured sampled died for an annual mortality rate of 8%, lower than the study average of 12% (range 2-23%). The female age structure in May 2012 (Fig. 4) exhibited the effects of improved recruitment over the last 8 cohorts, as well as the losses of females ≥ 13 years old, thus the proportion of older females has declined some since 2008 (Fig. 5).

The adult female mortality rate has varied from an average of 7% during 1986-89 when the herd was growing at 8%/year to an average of 19% 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 largely been due to age structure that was strongly skewed toward older females and the losses of most of these old females during this period.

Adult Bull Survival

During September 2007- September 2012, we have radiocollared and monitored 188 male caribou including 127 captured as adults (≥ 1 year old) and 61 captured as 10-month-old calves (12-13 each March 2008-12). As of 30 September 2012, 88 carried carrying functioning radios, 67 have died, 18 have dropped their collars, and 15 radiocollars have failed prematurely. In addition to 4 capture-related deaths, suspected causes of death include wolves (35), bears (11), unknown large predator (4), unknown (11), and accident (2).

During the 5 years we have evaluated survival of males (October 2007 – September 2012), annual survival appears to be comparable to that of adult females for bulls that are ≤ 4 years-old, then declines with age for older age-classes (Fig. 6). Mortalities occur predominantly during July-November (Fig. 7).

Bull Growth Patterns

We have weighed 142 of 161 adult bulls captured in September 2007-12 recording masses ranging from 93 kg to 278 kg. Body masses increased markedly with age from 1 to 6 years of age, gaining an average of 25 kg each year, and plateaued at an average of 229 kg for bulls ≥ 6 years of age (Fig. 8). Similarly, mean antler length varied from 29.1 cm to 136.5 cm for the 154 individuals we measured, and increased by 14.4 cm/year from 1-6 years of age. For bulls ≥ 6 years old, antler length did not vary with age, averaging 120.5 cm for these age classes.

The bull size classes we use for composition surveys (S, M, L) differed significantly in body mass ($F = 299.1$; $df = 2, 139$; $P < 0.001$) and antler length ($F = 343.6$; $df = 2, 151$; $P < 0.001$). These size classes include individuals of 1-3, 1-5, and ≥ 4 years of age, respectively (Table 4).

PLANNED ACTIVITIES (OCTOBER 2012 - SEPTEMBER 2013)

In the upcoming year, we plan to continue efforts to assess population dynamics of the DCH and studies of survival, growth, and seasonal distribution of bulls. 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. Maintain a sample of 45-50 radiocollared adult bulls and surviving collared individuals from the 2007-12 calf cohorts to assess age-specific growth and survival, and seasonal distribution.
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, 1984-2012.

Date	Fall Survey Results						Calf Sex Ratio (m:100f)			Bulls% ^b	Fall Herd Size	Estimated Fall Herd Composition		
	Cows ^a	Calves	Bulls	Ratios (:100 Cows)		Cows						Calves	Bulls	
				Calves	Bulls		S	M	L					
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	1,750	1,220	141	389	
9/29/2002	453	72	145	16	32	76	22	17	61	1,960	1,325	211	424	
9/30/2003	743	58	264	7.8	36	71	23	23	54	1,810	1,263	99	449	
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	

Table 1. Continued.

Date	Fall Survey Results									Fall Herd Size	Estimated Fall Herd Composition		
	Cows ^a	Calves	Bulls	Ratios (:100 Cows)		Calf Sex Ratio (m:100f)	Bulls% ^b						
				Calves	Bulls		S	M	L				
9/28/2007	628	142	227	23	36	84	31	37	33	2,060	1,298	293	469
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	2,300 ^c	1,398 ^c	333 ^c	569 ^c

^a Cows $\geq$ 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 2012 herd size estimate and composition are tentative.

Table 2. Estimated natality rates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska during 1987-2012. Rates are based on calving season observations of a sample of radiocollared females ≥ 1 year old designed to approximate the age structure of the population

Year	<i>n</i>	Pregnant	Not Pregnant	Natality Rate %	95% CI
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

Table 3. Results of post-calving composition surveys of the Denali Caribou Herd, Alaska, 1984-2012.

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

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 2007-12.

	Age (yr)	Mass (kg) mean (range)	Antler Length mean (range)
Small	1 – 3	116 (93-156)	56.0 (29.1-75.2)
Medium	1 – 5	164 (108-213)	83.7 (62.0-118.8)
Large	≥ 4	225 (163-278)	118.5 (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, 1986-2012 (2012 estimate is preliminary).

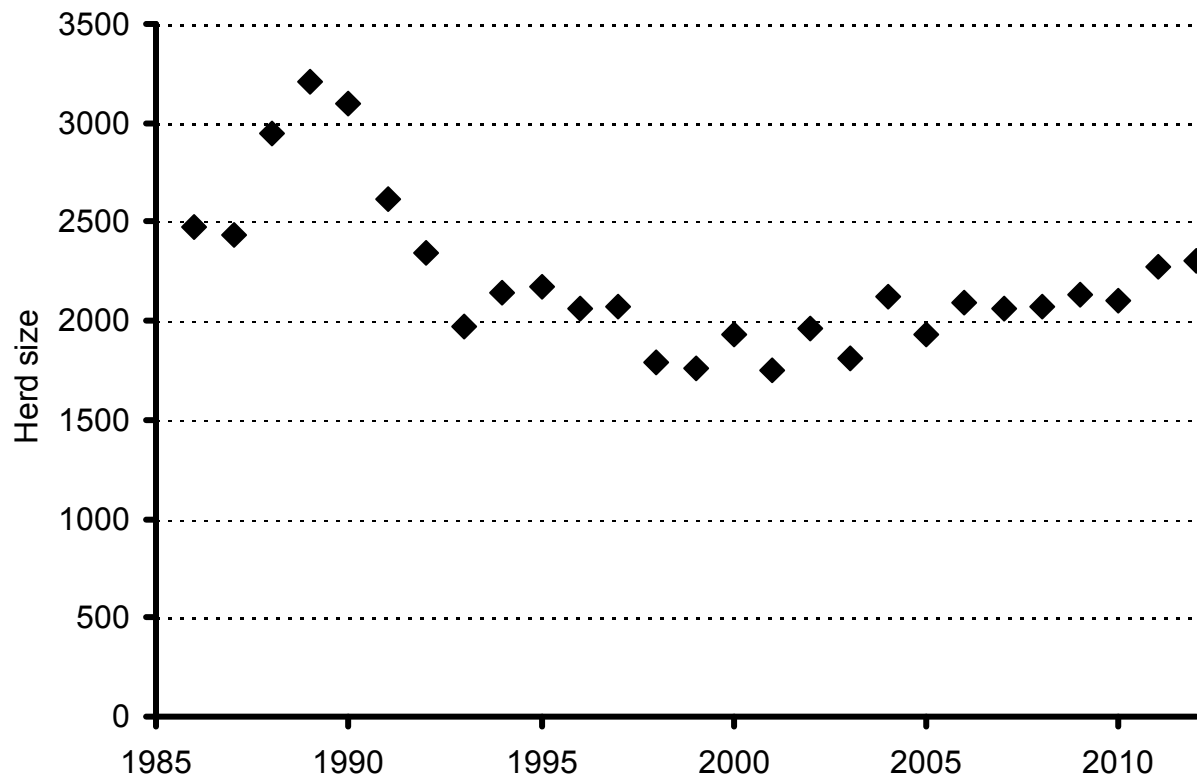


Fig. 2. Calf:cow ratios (A) and bull:cow ratios (B) for the Denali Caribou Herd, Denali National Park, Alaska, late September, 1984-2012.

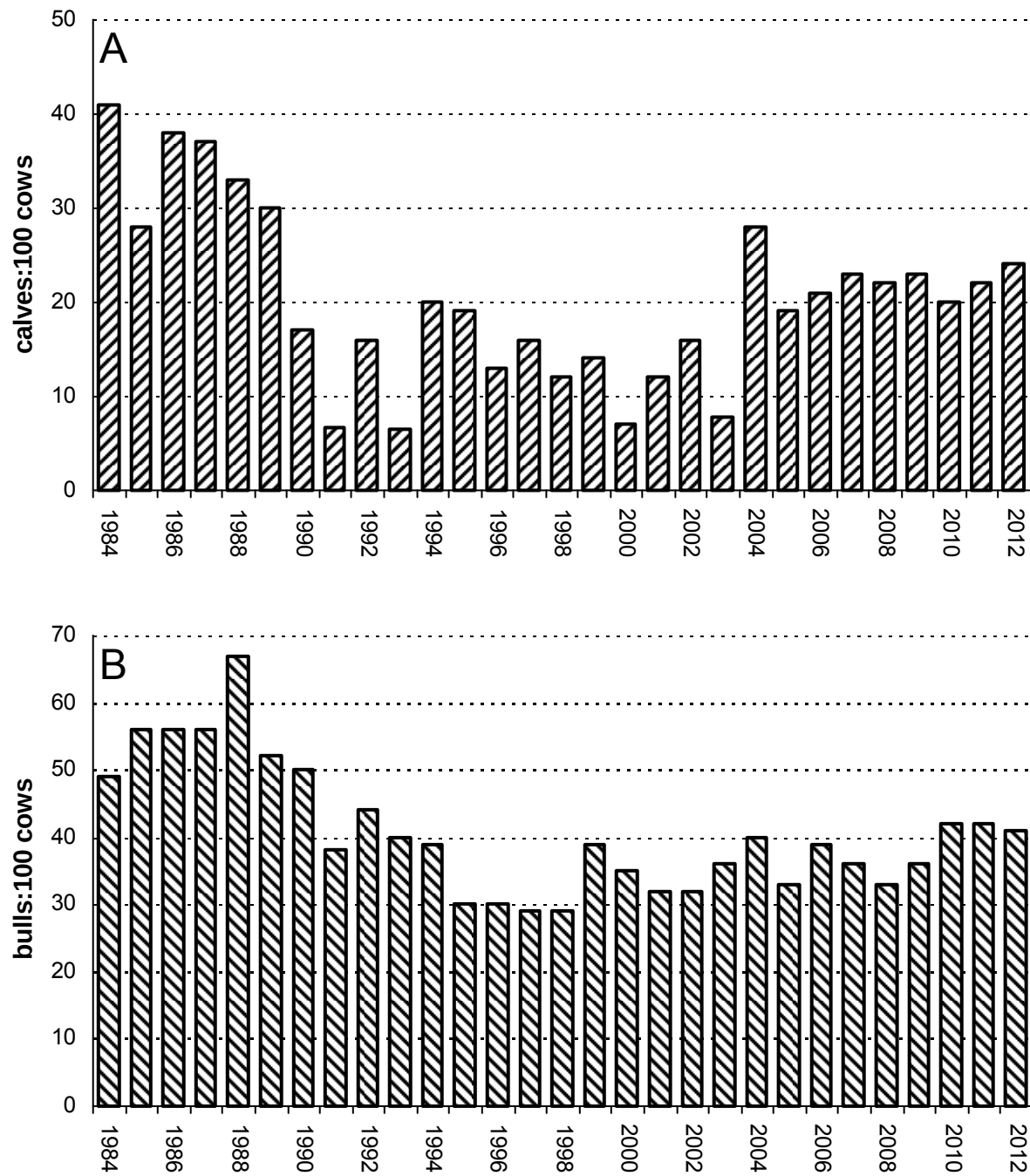


Fig. 3. Estimated calf survival to late September in the Denali Caribou Herd during 1987 – 2012, based on annual estimates of natality of radiocollared cows, adult female survival, and fall calf:cow ratios.

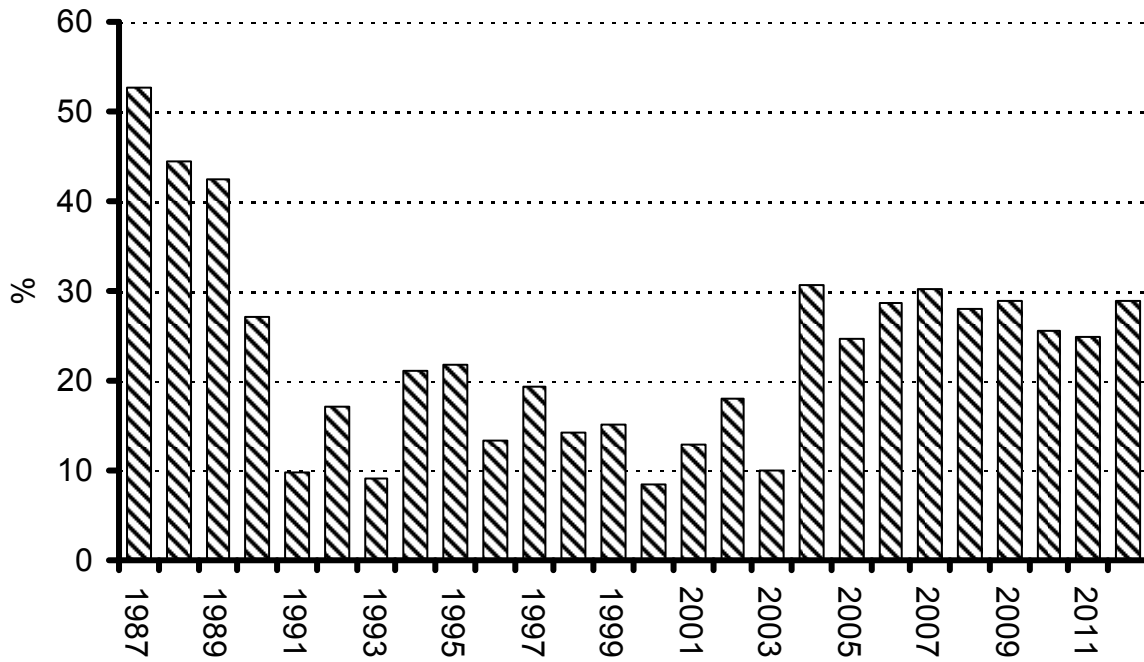


Fig. 4. Estimated age structure of the female segment of the Denali Caribou Herd on 1 May 2012 ($n = 65$ cows).

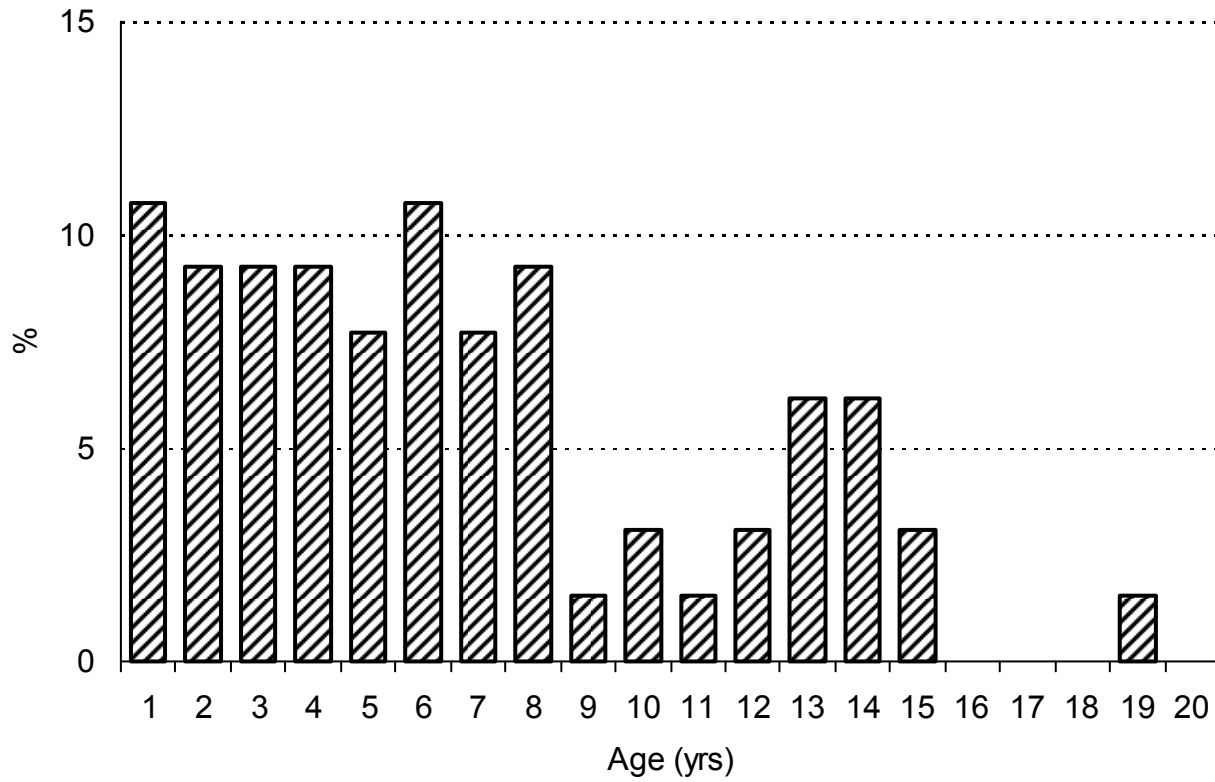


Fig. 5. Proportion of the adult female segment of the Denali Caribou Herd ≥ 13 years old on 1 May 1987-2012.

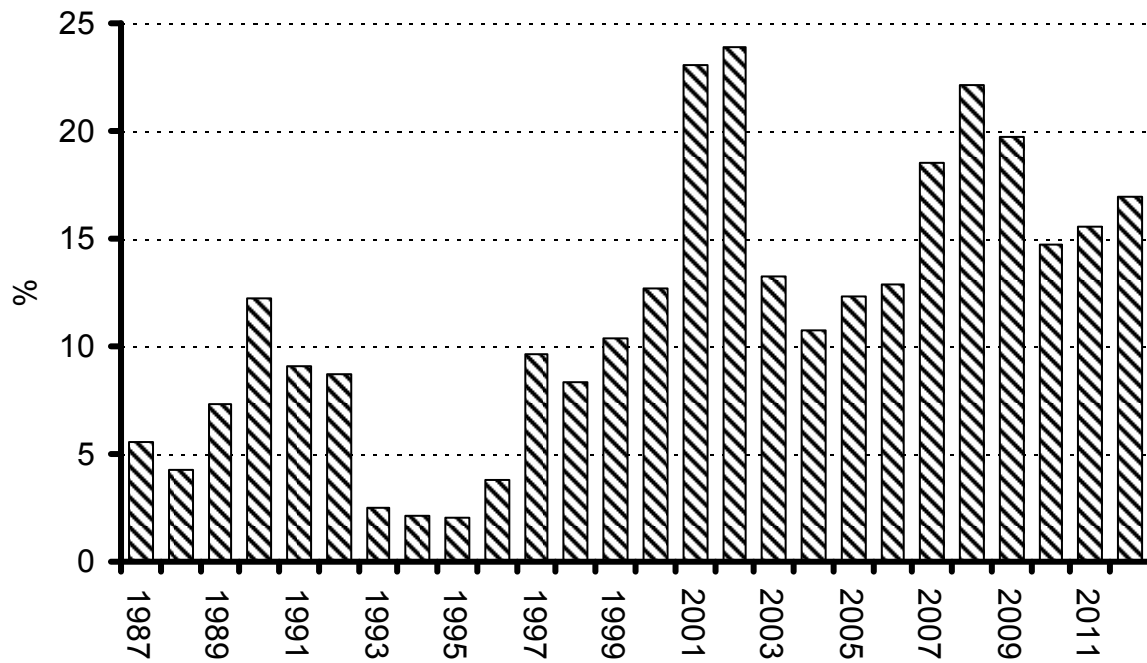


Fig. 6. Estimated survival rates (and 95% confidence limits) by age-class for male caribou in the Denali Herd, October 2007 –September 2012.

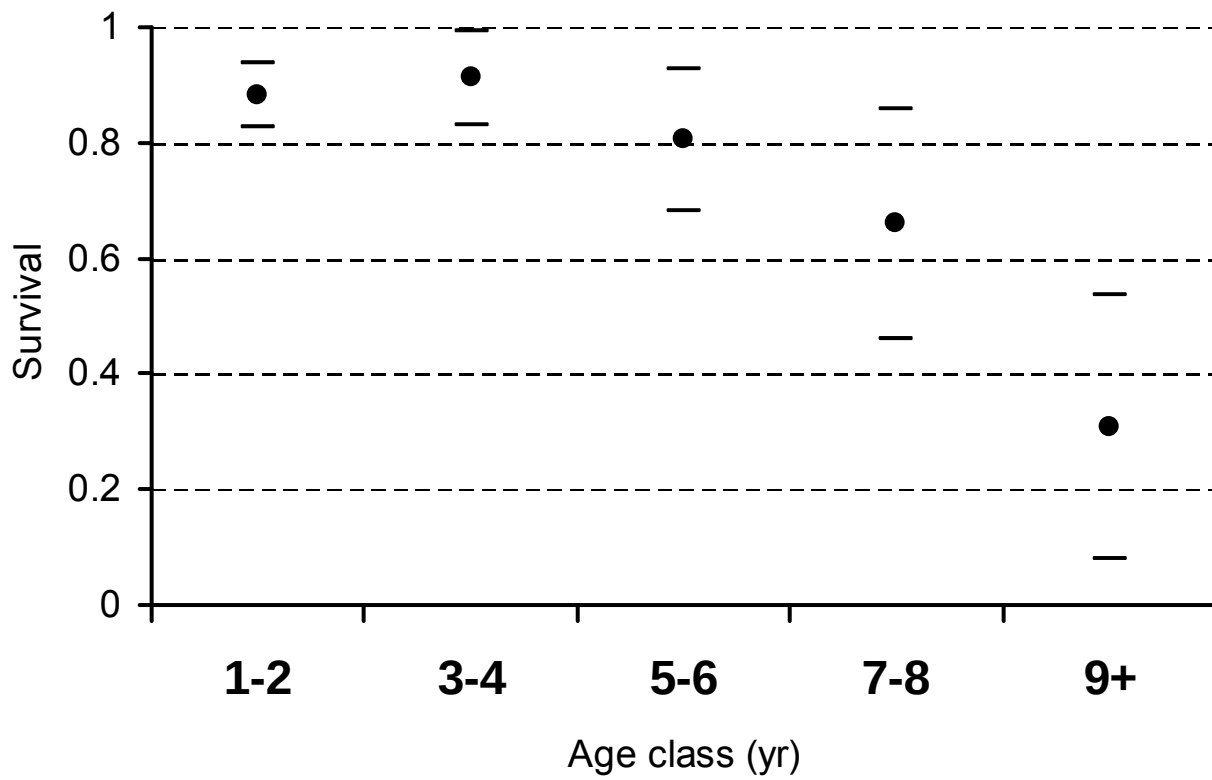


Fig. 7. Timing of annual mortality for adult caribou by sex in the Denali Caribou Herd, based on radiotelemetry data collected during October 1986-September 2009 for females, and October 2007-September 2012 for males.

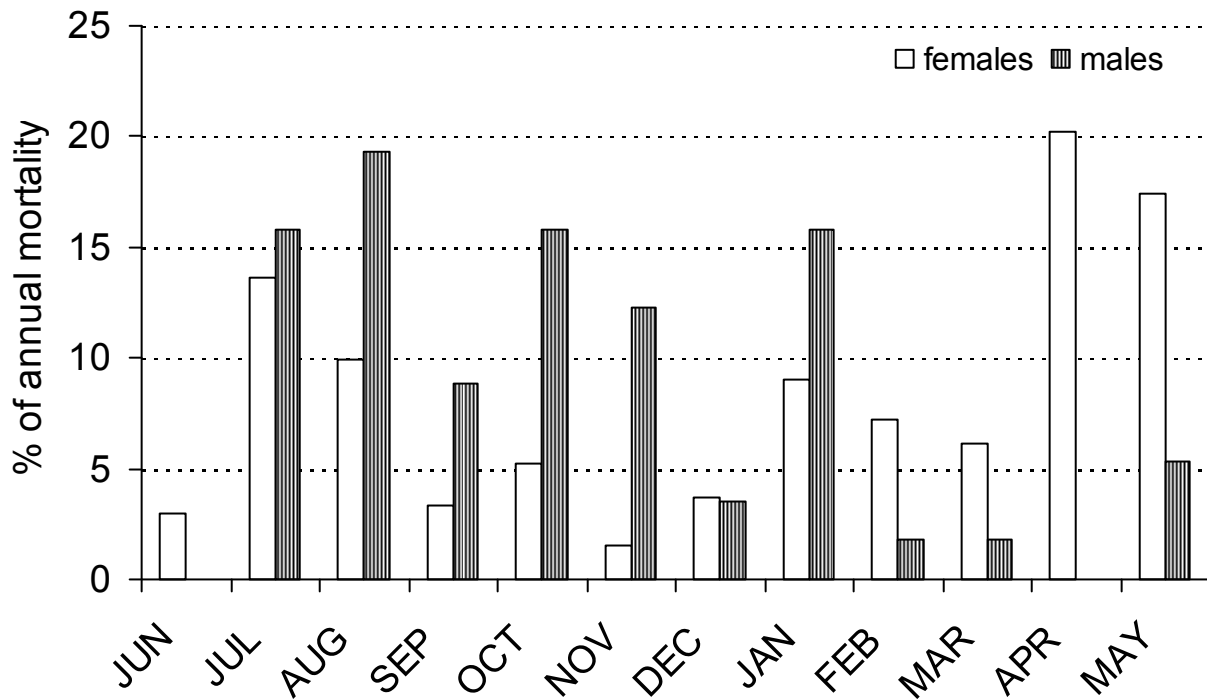


Fig. 8. Body masses of bull caribou ≥ 1 year old ($n = 142$) weighed in September 2007-12. Dashes indicate means for age-classes including ≥ 4 individuals.

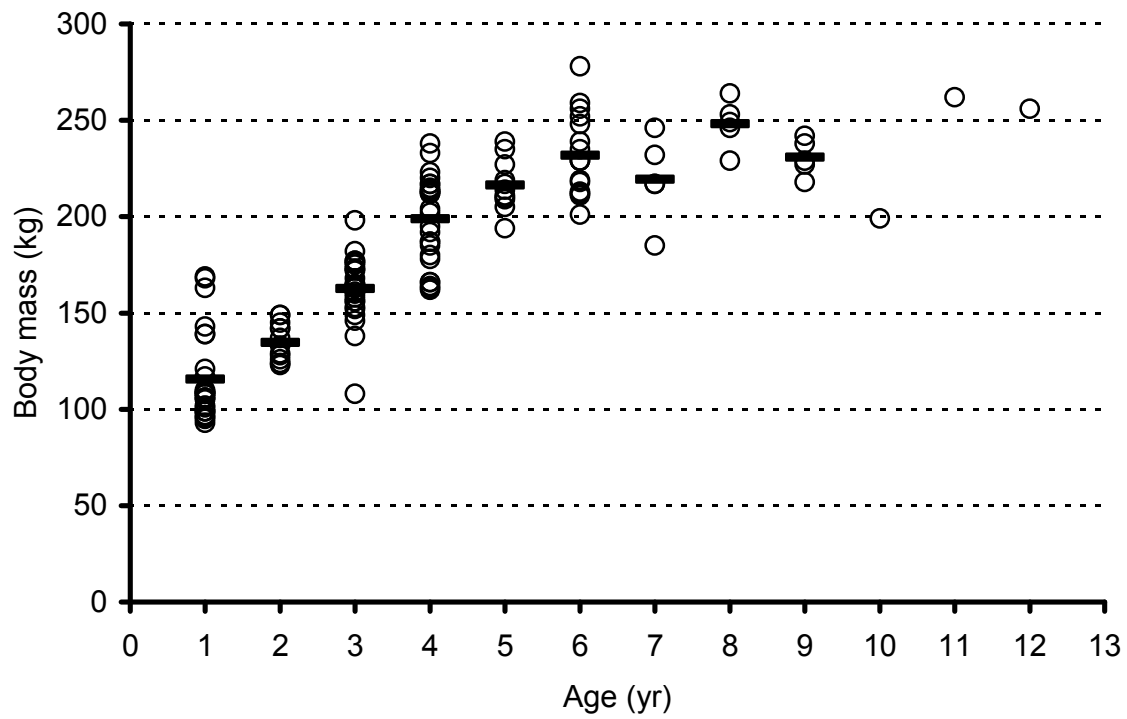
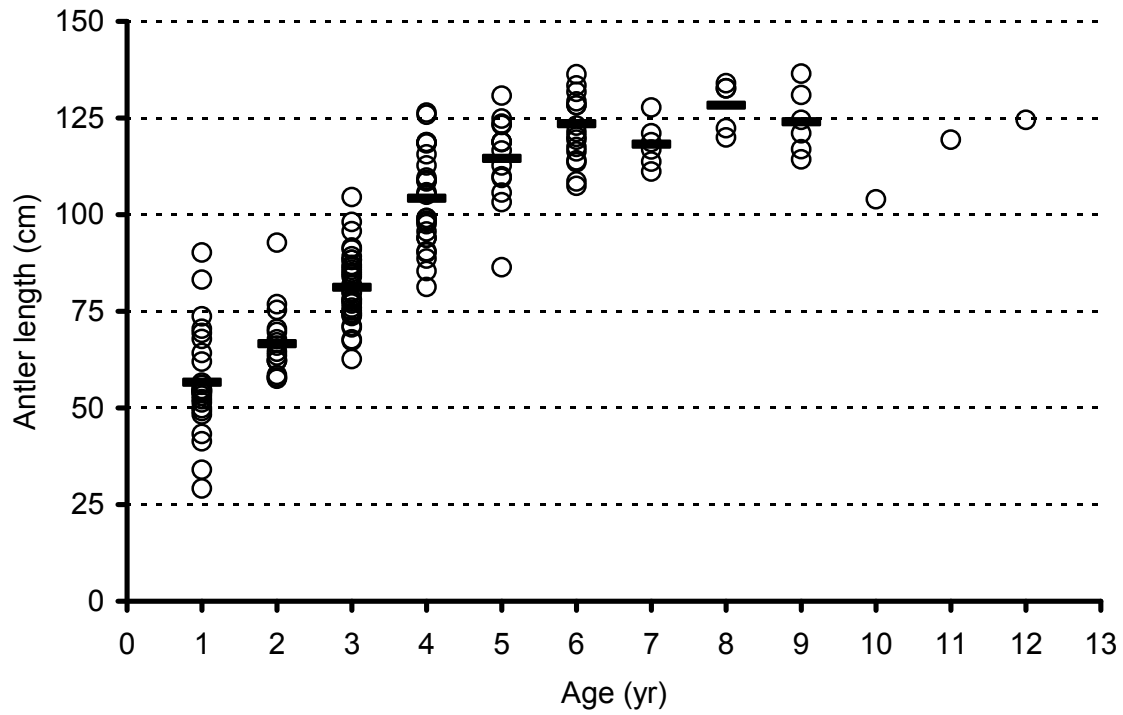


Fig. 9. Antler lengths of bull caribou ≥ 1 year old ($n = 154$) relative to age in the Denali Caribou Herd, September 2007-12. Dashes indicate means for age-classes including ≥ 4 individuals.



Appendix 1. Products of the Denali Caribou research program during 1986-2012.

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.

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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.

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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.

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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.

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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.

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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.