PROJECT TITLE: DYNAMICS OF THE DENALI CARIBOU HERD, DENALI NATIONAL PARK AND PRESERVE, ALASKA: PROGRESS REPORT (OCTOBER 2017–SEPTEMBER 2018)

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Population dynamics of the Denali Caribou Herd have been studied continuously since 1986. Denali National Park (18,800 km^2) encompasses nearly the entire range of the Denali Herd, thus 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 determine the dynamics of the Denali Herd. From 1976 to 1989, the herd increased at about 9% per year during a long period of relatively mild winters. In the late 1980s as this research program began, survival of caribou cows was high (96% per year), about 50% of the calves produced were recruited in the fall, and adult sex ratios were 52 bulls:100 cows or greater. With the onset of six consecutive, high-snowfall winters in 1988, caribou numbers leveled off at 3,200 by Fall 1989, and then declined by a third to 2,000 caribou over just 4 years**.** During the decline, adult cow survival dropped substantially, to an average of 85% per year, and fall calf recruitment dropped to about 10%. Further, bull:cow ratios declined to around 40:100 as a result of poor calf recruitment and reduced survival of adult males. During 1993–2003, with a return to moderate winter snowfall, adult female survival returned to high levels but fall calf recruitment remained low, averaging 15%. Bull:cow ratios continued to decline reaching 29:100 by 1997. Because of these population vital rates, herd size remained relatively stable at about 2,000 caribou. With the prolonged low calf recruitment, the female age structure became heavily weighted towards older females, peaking at 24% ≥ 13 years old in May 2002. As a result of these old females dying, adult female survival was low in the 2002–2003 and 2003–2004 winters (average = 83%) even though winter

snowfalls were substantially below average. These survival rates were comparable to rates measured during the extreme winters of 1990–1993. However, at about the same time, calf survival increased sufficiently to offset the high adult female losses, and bull numbers slowly increased based on the trend in adult sex ratios. Since 2004, calf survival to fall has averaged 27% annually. Through 2013, that allowed for limited herd growth of about 2% per year. In the last few years since September 2013, adult female survival has been high, averaging 95% per year, as a result of relatively low-snowfall winters during the period; improved female survival has brought about average annual herd increases of about 7% per year.

The current goals of caribou studies in Denali 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. This progress report summarizes research and monitoring of the Denali Caribou Herd conducted during October 2017–September 2018 (FY2016). 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; and
4. Relate caribou population status, trends, and vital rates to climatic variables and predator population characteristics.

METHODS

Capture and Radiocollaring

Female caribou are 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.

Caribou captures generally occur in March. Caribou are immobilized by helicopter darting with a mixture of carfentanil citrate and xylazine hydrochloride, with specific doses for adult females, adult males, and 10-month-olds. A PA-18 Supercub working with the helicopter locates caribou for darting, monitors darted caribou during induction, and checks on caribou captured on previous days. Once a caribou is immobilized, it is fitted with a mortality-sensing radiocollar and standard body measurements are taken. All caribou are weighed to the nearest 0.5 kg. A canine tooth is extracted for age determination from all adults on their first capture. Once processing is completed, caribou were given naltrexone hydrochloride and yohimbine hydrochloride to antagonize the effects of carfentanil and xylazine, respectively.

Radiotelemetry: survival and seasonal distribution

All radiocollared caribou are relocated by aerial radiotracking from fixed wing aircraft approximately every 2 months throughout the year to determine their distribution and survival. In addition, caribou are 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. Mortalities are observed from the radiotracking aircraft during monitoring flights and investigated by helicopter as soon as practical. Survival rates are 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 are 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 works with a Supercub that radiolocates caribou in advance of the helicopter to increase efficiency of the overall effort.

Composition surveys

I conduct 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, is intensively searched and all caribou encountered are approached at close range with a helicopter and classified into a small handheld tape recorder. In early June following the calving season, caribou are 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 is 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 are 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 is determined from an estimate of the number of adult cows in the population based on postcalving survey results. Prior to that survey, the distribution of radiocollared adult females is assessed and a survey area delineated that ideally included > 67% of the marked females surrounded by a buffer of a few kilometers defined by identifiable topographic features. The survey area usually consists of 2 to 4 large blocks of mountainous terrain along the main Alaska Range that take 1–2 days to fully survey. Each survey block is intensively searched by helicopter without the aid of radiotelemetry. Caribou groups encountered are counted and classified, and the occurrence of marked individuals within groups is determined via radiotelemetry. Simultaneously, a Supercub pilot locates all radiocollared females in or adjacent to the survey block. Periodically through the survey as portions of a survey block are completed, the 2 aircraft crews compare information to determine marked groups missed by the helicopter in areas previously surveyed; those groups are then relocated

by the helicopter and counted. In addition to adding these caribou to the totals counted, this information provides 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 is 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 use 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 use the mean of the 3 estimates as the estimated number of adult females for year t. Finally, I determine a fall population estimate by applying the adult female survival rate from radiotelemetry for June–September to estimate fall cow numbers, and fall herd composition to account for bulls and calves.

RESULTS

On 1 October 2017, 94 radiocollared females were being monitored in the Denali Herd. Of these collared females, 4 died of natural causes, 5 had their radios removed, and 1 radiocollar failed in July 2018. In March 2018, we radiocollared 10 10-month-old female calves; 1 died in April 2018. Thus, on 30 September 2018, 93 females were instrumented in the herd.

Herd Size

I calculated a preliminary herd size estimate of 3,230 caribou for September 2018 (Table 1, Fig. 1); that number will be adjusted based on results of the 2019 census as described above. Although the 2018 population estimate is preliminary, the caribou herd has grown at about 7% per year since Fall 2013, equating to a 40% increase of 930 caribou over the 5-year period. During these 5 years, winter snowfalls have been generally low and adult female survival over winter (Oct-May) has been very high, averaging 98%.

Adult Sex Ratio

I classified 1,589 caribou during 27-28 September 2018, resulting in an adult sex ratio of 42 bulls:100 cows (Table 1, Fig. 2B). Adult sex ratios declined from an average of 56:100 during 1984–1989 to a low of 29:100 during 1997–1998 because of increased mortality of males during severe winters in the late 1980s and early 1990s along with very low recruitment of calves. Bull:cow ratios increased slowly from 1998 to 2010, and have averaged 42:100 since then.

Calf Production and Survival

Productivity of cows ≥ 1 year old was estimated at 82% in mid-May 2018, based on 83 radiocollared females in the age-structured sample (Table 2). Calf production has varied from 59% in 1990 to 92% in 1994 and is largely influenced by the number of yearling recruits, the highly variable productivity of 2-year-olds, and the proportion of older females in the herd.

During the mid-June 2018 postcalving surveys, we noted 25 calves:100 cows (Table 3); by 1 October, that ratio had declined to 16:100 (Table 1, Fig. 2A), lower than the average during 2004–2017 (22:100). Based on these measures of calf production and survival, and accounting for adult female survival between mid-May and late September, survival to fall was estimated at 19% for 2018 calves (Fig. 3). Fall calf survival averaged 28% during 2004–2017, compared to 42% and 15% during 1987–1990 and 1991–2003, respectively.

Female Survival and Age Structure

During October 2017–September 2018, I estimated an annual mortality rate of 4% for adult females, markedly lower than the long-term study average of 11% (range of annual values = 2–23%). Females ≥ 13 years old made up 8% of the population in May 2018 (Fig. 4, 5), declining from a peak of 22% in 2008. With continued moderate recruitment, I expect the proportion consisting of these older females should stabilize at about current levels barring some major change in herd demography.

Based on data collected from radiocollared females during October 1986–September 2013, age-specific survival rates of females tend to be generally high for 2- to 7-year-olds, 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.

PLANNED ACTIVITIES (OCTOBER 2018–SEPTEMBER 2019)

In the upcoming year, we will continue efforts to assess population dynamics of the Denali Caribou Herd. Specifically, objectives for the year include:

1. Capture and radiocollar caribou females as needed to maintain an age-structured sample of ≥ 60 individuals for estimation of calf production, age structure, survival patterns and seasonal distribution, and to aid in population monitoring.
2. 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, 1984–2018.

	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
9/27/1984	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

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
9/28/2007	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	2,350	1,429	340	581
9/28/2013[c]	184	33	78	18	42	136	29	38	32	2,300	1,435	257	608
9/28–29/2014	922	210	407	23	44	75	32	24	44	2,500	1,498	341	661
10/1/2015	781	189	368	24	47	58	34	30	36	2,760	1,611	390	759
9/29/2016	622	139	236	22	38	81	22	36	42	2,750	1,722	385	653
9/27/2017	1,074	222	436	21	41	74	22	33	44	3,010	1,835	379	745
9/27-28/2018	1,005	158	426	16	42	74	32	24	44	3,230[d]	2,043[d]	321[d]	866[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] 2018 herd size estimate and composition are tentative.

Table 2. Estimated natality rates for the Denali Caribou Herd, Denali National Park and Preserve, Alaska during 1987–2018. 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	*n*	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
2013	66	53	13	80.3	68.3 – 88.7
2014	66	49	17	74.2	61.8 – 83.9
2015	72	55	17	76.4	64.7 – 85.3
2016	76	55	21	72.4	60.7 – 81.7
2017	81	63	18	77.8	66.9 – 86.0
2018	83	68	15	81.9	71.6 – 89.2

Table 3. Results of post-calving composition surveys of the Denali Caribou Herd, Alaska, 1984–2018.

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	1,124	487	43:100
5/27–29/1988	1,002	435	43:100
5/30/1989	1,263	500	40:100
6/1/1990	1,402	512	37:100
6/4–5/1991	1,213	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	1,036	359	35:100
6/9–10/2010	1,038	316	30:100
6/8–9/2011	1,141	377	33:100
6/15/2012	702	260	37:100
6/14–15/2013	981	325	33:100
6/14–15/2014	1,060	297	28:100
6/13–14/2015	1,236	481	39:100
6/9–10/2016	1,224	318	25:100
6/9,13/2017	1,528	430	28:100
6/9-10/2018	1,026	254	25:100

Fig. 1. Population estimates for the Denali Caribou Herd, Denali National Park, Alaska, late September, 1986–2018 (2018 estimate is preliminary).

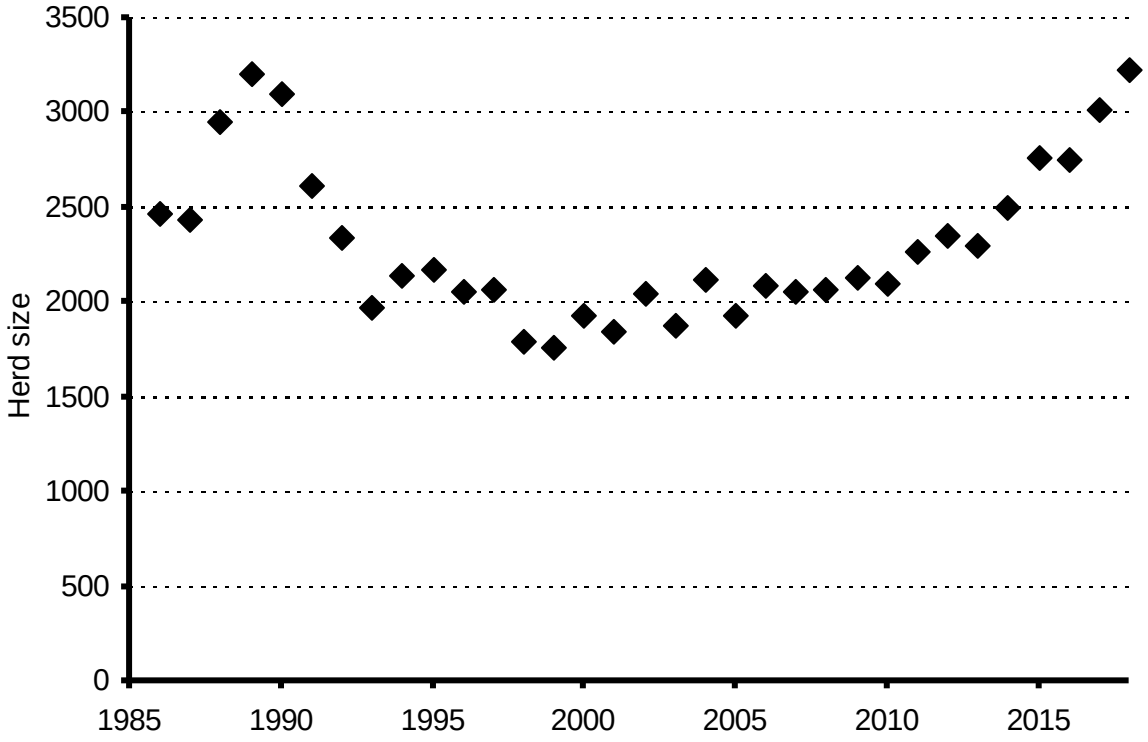


Fig. 2. Calf:cow ratios (A) and bull:cow ratios (B) for the Denali Caribou Herd, Denali National Park, Alaska, late September, 1984–2018.

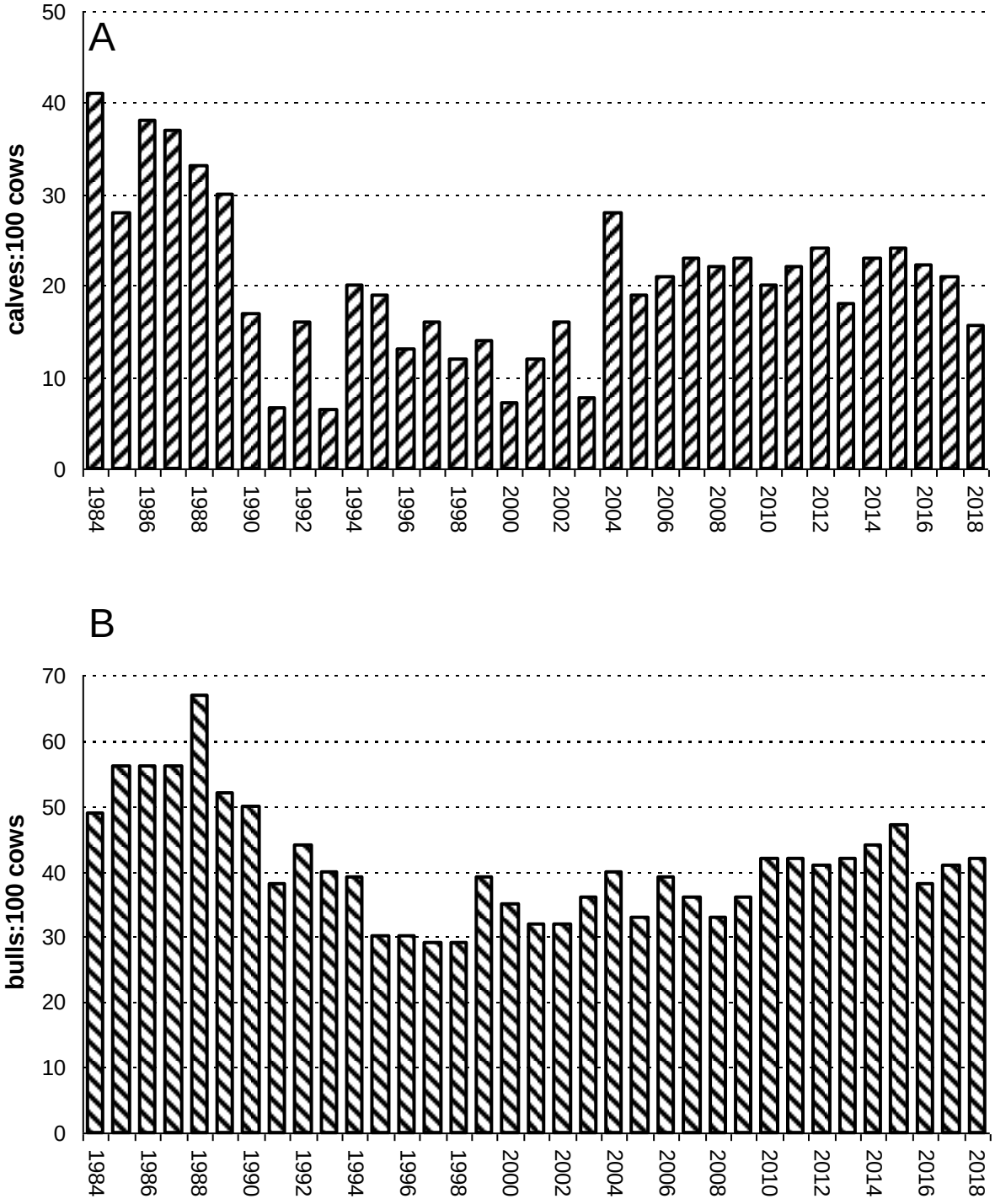


Fig. 3. Estimated calf survival to late September in the Denali Caribou Herd during 1987–2018, based on annual estimates of natality of radiocollared cows, adult female survival, and fall calf:cow ratios.

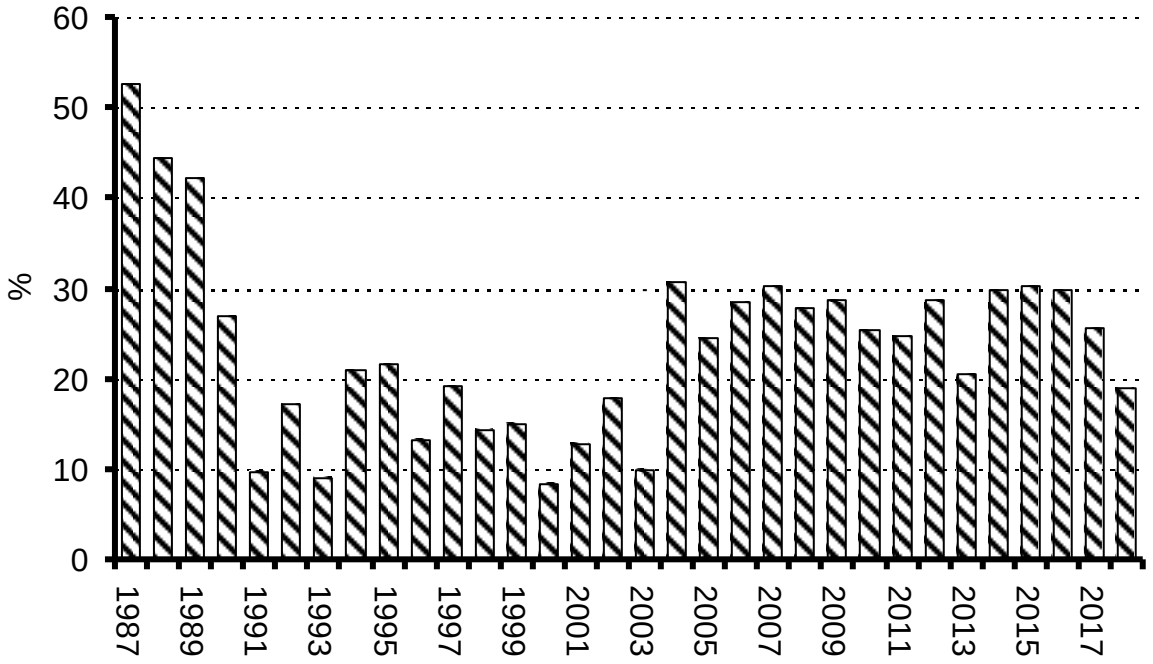


Fig. 4. Estimated age structure of the female segment of the Denali Caribou Herd on 1 May 2018 (*n* = 84 cows).

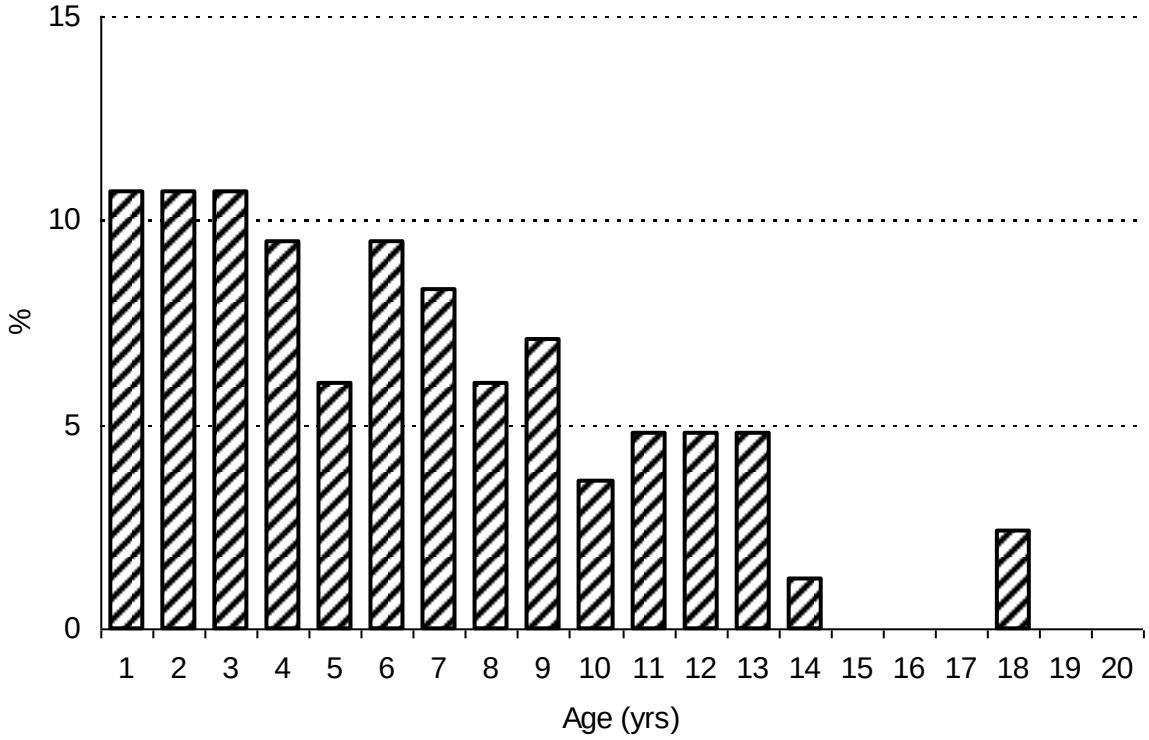


Fig. 5. Proportion of the adult female segment of the Denali Caribou Herd ≥ 13 years old on 1 May 1987–2018.

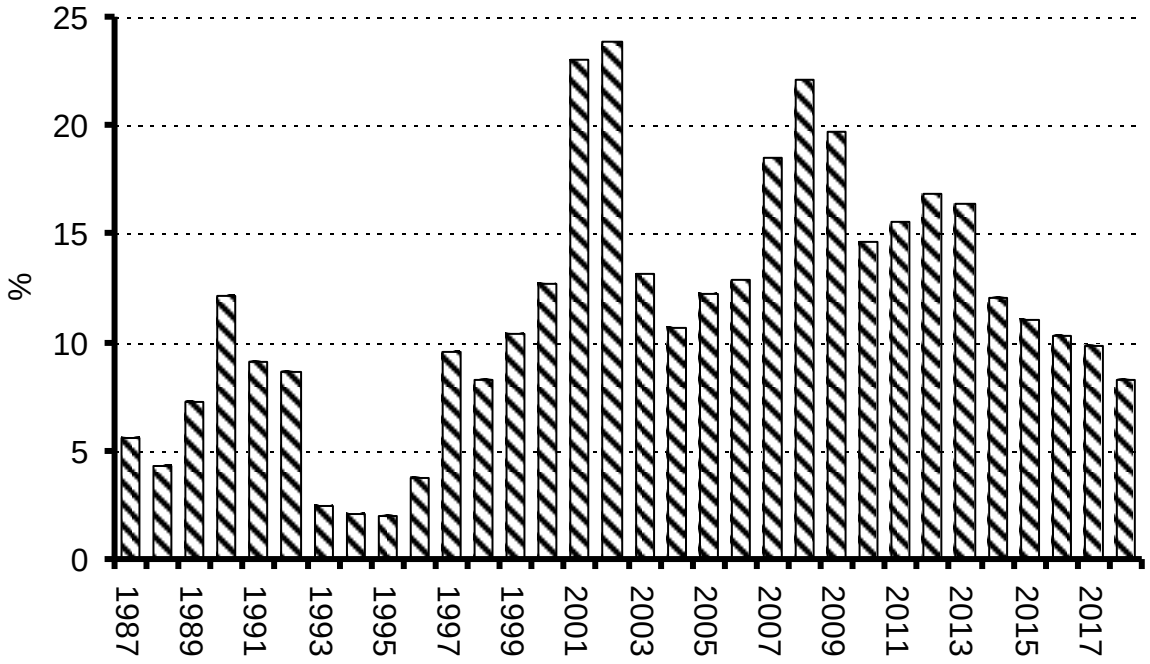
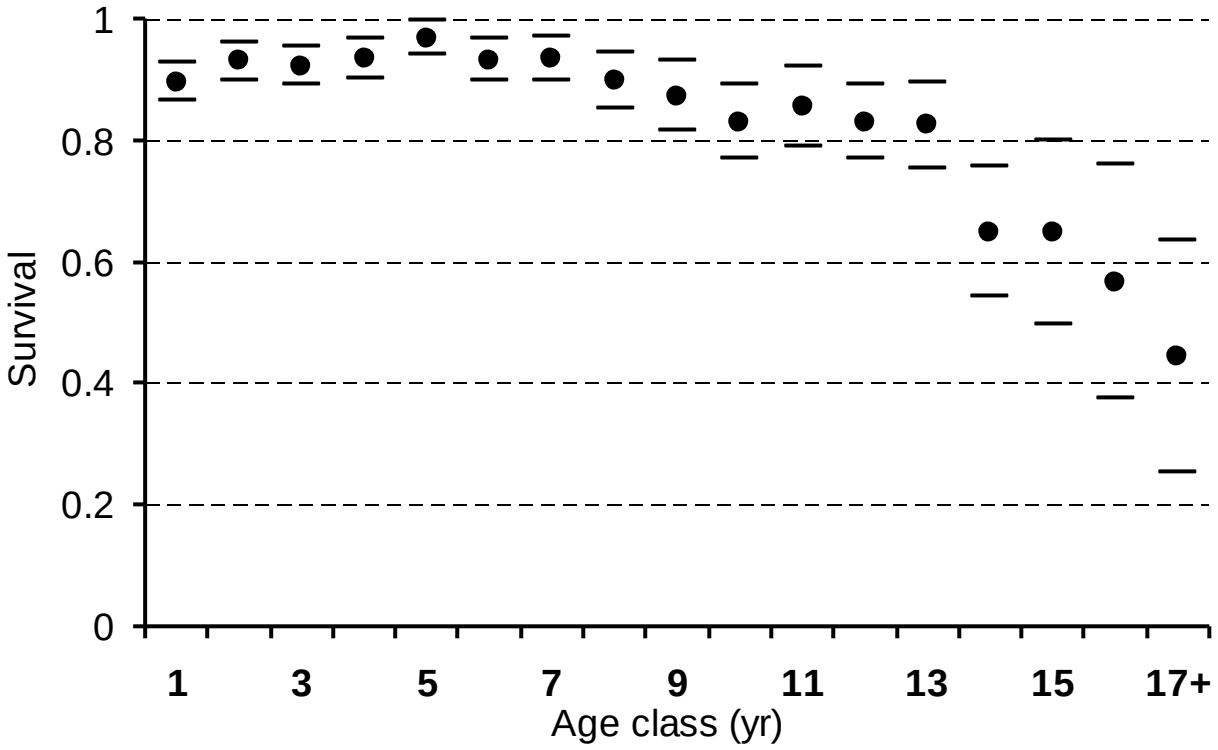


Fig. 6. Age-specific survival rates (± 95% confidence intervals) for female Denali caribou, based on 394 individual caribou monitored for 1,955 caribou years during October 1986–September 2013.



Appendix 1. Products of the Denali Caribou research program during 1986–2018.

Publications, Popular Articles

-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.

-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.

-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.

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

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

-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.

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

-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.

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

-Adams, L.G. 1996. Calf production and survival in the Denali Caribou Herd, Alaska. Ph.D. Thesis. University of Minnesota, St. Paul. 152pp.

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