Alaska Department of Fish and Game
Division of Wildlife Conservation
November 2002

Investigation of Regulating and Limiting Factors in the Delta Caribou Herd

Patrick Valkenburg, Mark A. Keech, Richard A. Sellers
Robert W. Tobey and Bruce W. Dale

Final Research Technical Report
1 July 1996–30 June 2002
Project 3.42

ADF&G

Please credit the author(s) and the Alaska Department of Fish and Game when referencing this report: Valkenburg, P., Keech, M. A., Sellers, R. A., Tobey, R. W., and Dale, B. W. 2002. Investigation of Regulating and Limiting Factors in the Delta Caribou Herd. Alaska Department of Fish and Game. Final Research Technical Report, July 1996-June 2002. Project 3.42. Juneau, Alaska. 98 pp.

FINAL RESEARCH
TECHNICAL REPORT

Alaska Department of Fish and Game
Division of Wildlife Conservation
PO Box 25526
Juneau, AK 99802-5526

STATE: Alaska **STUDY**: 3.42

COOPERATORS: Layne G Adams (US Geological Survey, Biological Resources Division); David R Klein (University of Alaska Fairbanks); Andrew R Aderman, Michael T Hinkes, and Gail H Collins (US Fish and Wildlife Service, Dillingham); Ronald C Squibb (US Fish and Wildlife Service, King Salmon); and Michael Roy (US Fish and Wildlife Service, Cold Bay)

GRANTS: W-24-5, W-27-1 to 4, and W-27-5: Federal Aid in Wildlife Restoration

TITLE: Investigation of Regulating and Limiting Factors in the Delta Caribou Herd

AUTHORS: Patrick Valkenburg, Mark A Keech, Richard A Sellers, Robert W Tobey, and Bruce W Dale

PERIOD: 1 July 1996–30 June 2002

SUMMARY

POPULATION DYNAMICS OF INTERIOR CARIBOU HERDS

The main purpose of this 22-year research program on caribou population dynamics was to determine the primary factors that cause population fluctuations in the Delta Caribou Herd (DCH) and other similar caribou herds in Alaska's Interior. Important secondary purposes were to develop and refine techniques for monitoring population processes and population condition and to determine how caribou population management could be improved.

Since 1979 the DCH has gone through 5 growth phases. Herd size rapidly grew after wolf control from 1979–1982 ($r = 0.18$), with high recruitment and low mortality from hunting and natural causes. The herd then grew slowly ($r = 0.05$) from 1982–1985, with moderate-to-high recruitment, low-to-moderate natural mortality, and high hunting mortality. The herd also grew slowly ($r = 0.07$) from 1986–1988, with moderate recruitment, moderate-to-high natural mortality, and low hunting mortality. Then the herd rapidly declined ($r = -0.20$) from 1989–1993, with low recruitment, high natural mortality, and low hunting mortality. The fifth phase from 1994 to 2000 has been one of relative stability or slow decline with low recruitment, moderate adult mortality, and insignificant hunting mortality.

Density-dependent feedback mechanisms may occasionally influence the upper bounds of Interior caribou herd sizes, but, in the absence of hunting, sizes of Interior Alaskan caribou herds

can be expected to fluctuate with unpredictable amplitudes and periods or remain relative stable. Few, if any, of the proposed theoretical models of population growth and regulation have been supported by empirical data from the Interior caribou herds, and these theoretical models appear to have little relevance in caribou management. In the caribou herds of Interior Alaska, predation and weather are the primary factors that influence population size and the numbers of caribou that can be harvested. In many herds, in the absence of heavy hunting of females, the size of a particular herd at a given time is likely to be a function of the number of caribou remaining in the herd at the end of the previous decline and the number of favorable years of weather in the interim. However, in other herds, predation is such an overwhelming influence that herd growth is very slow, even during highly favorable weather, and in a few herds, the populations may remain on the verge of extinction for years.

We suggest that if the term “carrying capacity” is used in relation to caribou, it should be defined as discussed by Leopold (1948). That is, the maximum number of animals that can be indefinitely maintained in a given area (i.e., herd) in a reasonably healthy condition. We suggest that this approach will be the most useful concept for management and will approximate an optimum population size that will allow managers to maximize harvest over long periods of time. With historical data on population size and with data collected annually or periodically on population parameters and body condition, managers will be able to make reasonable estimates of “carrying capacity” in the few caribou herds where we have the ability to control the upper limits of herd size through harvest.

OTHER FINDINGS AND CONCLUSIONS FROM THE STUDY

1 Natality in caribou herds is variable and is determined by caribou density on summer range, summer range quality, and summer weather. Variable natality has only a minor effect on population growth rate in Interior Alaskan herds, but it is likely to be a much more important limiting factor in the larger herds, especially in coastal parts of the state.

2 Caribou herds can be considered populations or metapopulations, and dispersal had no significant influence on caribou herd sizes in Interior Alaska during 1970–2002. In addition, there appears to be no credible evidence that the interchange of groups of caribou between herds has ever occurred in Alaska. However, in two cases, one involving the Delta and Yanert herds in the late 1980s, and another involving the Mulchatna and Kilbuck herds more recently, a large caribou herd has overwhelmed and assimilated a small herd by repeated mixing on all seasonal ranges.

3 Nutrition can explain the entire range of body size of caribou in Interior Alaska. However, caribou in Southwest Alaska appear to be inherently smaller than Interior caribou, and caribou from the Western Arctic Herd are much smaller than any of the other caribou in Alaska.

4 Live body weight of female calves is likely to be the most useful index to condition in Alaskan caribou. Other potentially useful indices are difficult to employ because of logistical and/or sampling problems.

5 Diversionary feeding of wolves near caribou calving areas could be a successful method of reducing predation in some circumstances, but it has significant limitations, primarily because wolves will continue to hunt even when they are not hungry.

6 The wolf control program during 1993–1994 contributed to reversing the decline of the Delta caribou herd, but it did not result in a dramatic increase in recruitment of caribou calves or a dramatic population increase. The program was of limited success because it was terminated prematurely and it was not conducted on the main caribou calving area.

Key words: body condition, body weight, calf mortality, carrying capacity, diet, diversionary feeding, genetics, Mulchatna Herd, natality, Nelchina Herd, Northern Alaska Peninsula Herd, Nushagak Herd, population regulation, predator control, Rainy Pass Herd, *Rangifer tarandus caribou*, *Rangifer tarandus granti*, trapping, Unimak Herd, weather, White Mountains Herd, wolf control, woodland caribou.

CONTENTS

FIGURES, TABLES, AND APPENDICES

BACKGROUND

A continuing long-term population dynamics study of the Delta caribou (*Rangifer tarandus*) herd (DCH) began in 1979. Results of the first 17 years of research were presented in 8 progress reports, 3 final reports (each covering 5 years) (Davis and Valkenburg 1985; Davis et al. 1991; Valkenburg 1997), and numerous scientific papers (c.f. Boertje et al. 1996; Valkenburg et al. 1996). Predator–prey relationships and harvest of moose (*Alces alces*), caribou, sheep (*Ovis dalli*), grizzly bears (*Ursus arctos*), and wolves (*Canis lupus*) within the range of the DCH were reviewed by Gasaway et al. (1983) and Boertje et al. (1996).

Since 1979 the DCH has gone through 5 growth phases. Herd size rapidly grew after wolf control from 1979 to 1982 (r = 0.18), with high recruitment and low mortality from hunting and natural causes. The herd then grew slowly (r = 0.05) from 1982–1985, with moderate-to-high recruitment, low-to-moderate natural mortality, and high hunting mortality. The herd also grew slowly (r = 0.07) from 1986–1988, with moderate recruitment, moderate-to-high natural mortality, and low hunting mortality. Then the herd rapidly declined (r = -0.20) from 1989–1993, with low recruitment, high natural mortality, and low hunting mortality. The fifth phase from 1994 to 2000 has been one of relative stability or slow decline with low recruitment, moderate adult mortality, and insignificant hunting mortality (data in this report).

In June 1993 the Alaska Board of Game approved a 3-year ground-based wolf predation control program for a portion of Unit 20A. One of the objectives of the program, which began in October 1993, was "to reverse the decline of the DCH and increase the midsummer population to 6000–8000 caribou, with a sustainable annual harvest of 300–500 caribou." (Eagan 1993) To better evaluate the effectiveness of intensive management (i.e., control of wolf numbers) of the DCH, we extended the caribou research project with state funds to include 3 annual calf mortality studies from 1995 to 1997.

Population decline in the DCH was reversed in 1994, coincident with the wolf control program, and the herd increased somewhat to over 4000. However, after wolf control ended in December 1995, the herd once again began slowly declining. Since 1997, work in the DCH has been concentrated on monitoring body condition to determine if lowered population size will eventually result in improved condition and long-term weight gain, and also to determine if the population objective (6000–8000) is realistic.

During the mid 1990s, with the cooperation of other agencies, the study of limiting and regulating factors in caribou was extended to other herds where pressing research and management questions have resulted in greater availability of funding. This new approach was possible because of the active interest taken by cooperating area biologists and cooperating federal agencies in establishing a coordinated caribou research and management program. Besides the DCH, the Nelchina, Northern Alaska Peninsula (NAP), Southern Alaska Peninsula (SAP), Mulchatna, Kenai Mountains, Killey River, White Mountains, Ray Mountains, and Nushagak herds have yielded valuable information in the study of limiting and regulating factors on population and determination of optimum herd sizes. In 1999 Bruce Dale filled a new caribou research biologist position in the Palmer office. Future reports containing more detailed data on the Nelchina Herd will be forthcoming under his separate research project. For a complete review of caribou research done in Alaska in the late 1990s and early 2000s, readers should also refer to the biennial survey–inventory management reports written by Alaska Department of Fish and Game (ADF&G) area biologists, research progress reports (Boertje and Gardner 1999, 2000, 2001), special reports (e.g., Sellers et al. 1998*a*,*b*, 2000), reports from the Biological Resources Division (BRD) of the US Geological Survey, and papers published in *Rangifer* from the North American caribou workshops and arctic ungulate conferences.

STUDY OBJECTIVE

- Evaluate the influence of weather, density, food limitation, hunting, and predation on the population dynamics of the DCH and other Alaskan caribou herds.

JOB OBJECTIVES

- Census the DCH annually.
- Determine annual natality rate and timing of calving in the DCH.
- Determine recruitment in the DCH from annual fall and spring composition counts.
- Monitor harvest annually.
- Determine weight and size of calves in October and April to determine influence of summer versus winter weather on body condition, and test a model that predicts recruitment (i.e., fall calf:cow ratio) from April calf weights in the Delta and Nelchina herds.
- Radiocollar female calves in fall to maintain known-aged cohorts in the DCH.
- Determine if weather is a factor that limits growth of the DCH.
- Assess and analyze food habits of the DCH and other caribou herds.
- Monitor movements, dispersal, and mortality in the DCH.
- Recollar adult females to maintain cohorts of collared, known-aged females.
- Monitor density, natality, mortality, body weight, condition, and weather in Alaskan caribou herds on an opportunistic basis as time and funding allow.
- Improve and develop techniques for monitoring body condition in caribou.
- Begin investigating genetic relationships of Alaskan caribou to determine if genetic differences might contribute to differences in body size.

METHODS

ANNUAL CENSUSES OF THE DCH

In cooperation with area management staff, we were successful in censusing the DCH annually. Methods used have been similar each year, and all censuses through 1999 were described in previous annual progress reports. In 2000 we used 5 aircraft (2 Bellanca Scouts and 3 Super Cubs) to visually search all of the summer range of the DCH on 24 June. All aircraft were equipped with tracking gear and biologists listened for radiocollared caribou while searching visually. Groups of caribou larger than about 200 were photographed with color print film (Kodak© Gold 200).

The 2001 census was also conducted with 5 2-place aircraft. However, bad weather delayed the census until 10 July. As in 2000, all aircraft were equipped with radiotracking gear and groups of caribou were photographed with color print film. After the initial visual search, 1 aircraft conducted a high-altitude (12,000 ft) search for missing radios within Unit 20A and northern Unit 13. A few days later, we searched for the few remaining missing radio collars in the foothills and mountains of the Alaska Range, the Tanana and Copper River valleys, and Unit 13 north of the Denali Highway from high altitude with a Cessna 185. This search covered the winter ranges of the Macomb, Nelchina, Fortymile, and Mentasta herds. Biologists and pilots also searched for potentially missing Delta radios in the summer ranges of the Denali and Fortymile herds. Because radio collars occasionally fail prematurely, it was not always possible to determine the fate of all caribou with missing radio collars.

DETERMINING NATALITY RATE IN THE DCH AND OTHER HERDS

We observed collared female caribou in the DCH annually from 1980 to 2001 during the calving period (i.e., during 12–31 May). We also observed natality in other herds opportunistically. Each collared female was observed periodically for signs of pregnancy or parturition. The presence of a calf at heel was considered proof of parturition, and hard antlers or a distended udder were considered proof of parturition or pregnancy (Whitten 1995b). Yearling females were usually observed only once during the period. Most observations were from Super Cubs or Bellanca Scouts, but from 1995 on, we also used a Robinson R-22 helicopter. We considered the helicopter cheaper, safer, and more efficient for observing radiocollared caribou in large groups or in areas where they were concentrated. This was especially true when weather was turbulent.

DETERMINING RECRUITMENT IN THE DCH AND OTHER HERDS

The primary method used for determining recruitment in caribou herds was the fall composition count preferably conducted slightly before or during the rut (about 25 Sep–5 Oct in Interior herds and 5 Oct–15 Oct in southwestern Alaska). In most cases, the fall composition counts were a cooperative effort by research and management staff, and occasionally with Bureau of Land Management (BLM) or US Fish and Wildlife Service (FWS) staff as well. In most cases, these counts were paid for with management funds, but if no composition count was planned in the management program, we sometimes paid for it with research funds. Other agencies (BLM and FWS) occasionally also provided funding. All data thus collected are published in the semiannual caribou management reports. Only data from the Delta Herd are also published in this research report.

Fall composition counts were conducted by tracking all radiocollared caribou a day or 2 prior to the count with a fixed-wing aircraft. We then flew to caribou concentration areas and classified a sample of caribou with the aid of a helicopter (Robinson R-44 or R-22). Caribou were classified as cows, calves, small bulls, medium bulls, or large bulls.

Because calf:cow ratios in fall may overestimate recruitment (i.e., numbers of calves that survive to adulthood), we also estimated subsequent survival of calves until their survival rates approximated those of adults. From 1980 to 1990 we did this primarily with the change-in-ratio method by conducting composition counts during April. However, once we began collaring calves in October, we abandoned the April counts because the April data were variable and subject to bias because of clumped caribou distributions, particularly where spring movements to calving areas had begun. Thus, after 1991, in herds where calves were collared routinely at 4 months of age (e.g., Fortymile, DCH, Nelchina), it was possible to estimate survival of calves during their first winter and second summer. In modeling the population trajectory of other herds, we compensated for potentially optimistic estimates of recruitment by decreasing survival estimates of adult females.

RADIOCOLLARING FEMALE CALVES IN FALL IN THE DCH

We began radiocollaring female calves in the DCH in early October 1991, after determining that varying summer weather patterns might have more influence on calf weight than winter weather. Since 1991 we radiocollared 11–20 four-month-old female calves annually and subsequently changed their collars after about 5 years. The intent was to maintain known-aged cohorts in the population from 4 months of age until death.

During this study, we caught all female calves by shooting them with dart guns from helicopters. However, during the mid 1990s we realized that use of powdered charged Cap-Chur® rifles (Palmer Chemical and Equipment Company, Douglasville, Georgia, USA) was resulting in significant injury and death of calves, so we changed to using a Cap-Chur CO_2 pistol (Valkenburg et al. 1999). This change in capture technique reduced capture mortality from about 5% to less than 1%. Most calves received 0.33 ml Wildnil® (4.46 mg/ml carfentanil citrate—equivalent to 3 mg/ml carfentanil, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA) combined with 0.66 ml Cervizine® (100 mg/ml xylazine hydrochloride, Wildlife Pharmaceuticals) for immobilization, and 2 ml Trexonil® (naltrexone hydrochloride 50 mg/ml, Wildlife Pharmaceuticals) with 200 mg Tolazine® (100 mg/ml tolazoline hydrochloride for reversal; Wildlife Pharmaceuticals). Before 1999 we used yohimbine hydrochloride (Antagonil®, Wildlife Pharmaceuticals) as a reversal agent for xylazine. In years (or herds) when calves appeared to be in poorer condition, we reduced the dose of Cervizine to 0.33 ml to minimize problems with lowered respiration rates and apnea.

All female calves were weighed and measured and blood samples were taken (about 25 ml from each caribou). Great care was exercised to ensure that scales were calibrated annually and that measurements were taken in a consistent manner. Weights were either measured with a load cell or 160 lb spring scale, and mandible and metatarsus measurements were taken with tree-measuring calipers (Haglof, Inc., Stockholm, Sweden) to the nearest millimeter. Mandible and metatarsus measurements taken with tape measures were found to be highly variable and not repeatable. Girth, hind foot, and total length measurements were taken with a flexible tape. We also used a categorical condition scoring system (Gerhart et al. 1996).

MONITORING HARVEST

Harvest in the DCH and other caribou herds is monitored through the management program and reported in the semi-annual management reports. As part of the long-term study of mortality in the DCH, we also summarized harvest. Davis et al. (1991) summarized hunting regulations and harvest in the DCH from 1968 to 1989. In this report, we extended the summary through 2001. Hunting was open under a general hunt and registration hunt (reported on harvest ticket and registration permit report cards) during 1989–1991. The season was closed during 1992–1995, and then open under a limited drawing permit hunt (with 100 permits issued) from 1996 to 2001.

DETERMINING THE WEIGHT AND SIZE OF CALVES IN APRIL AND TESTING A MODEL THAT PREDICTS RECRUITMENT BASED ON WEIGHTS OF CALVES

Determining weight and size of female calves in April has been ongoing since 1980. During the late 1980s we noticed a good correlation between calf weight and subsequent calf:cow ratio in fall (Valkenburg 1997:45). We therefore continued to monitor this relationship in the DCH and in the Nelchina Herd where sufficient data now has accrued. We used simple linear regression in Microsoft®Excel for Windows® (Microsoft Inc., Seattle, Washington, USA).

DETERMINING IF WEATHER IS A FACTOR IN THE GROWTH OF THE DCH

We used linear and multiple regression models to examine relationships between indices of herd productivity and condition, and July temperature and rainfall, and winter snow data obtained from Delta, Fairbanks, and Healy weather stations. Mean July temperature (°F) was obtained from each of the 3 climate stations and combined to produce a July temperature index representative of conditions experienced on the summer range of the DCH. The same procedure was used to create an index to total July rainfall (inches) for the summer range of the DCH. For the time period 1981–2001, the indices of temperature and rainfall were regressed against observed DCH natality rates using both 1- and 2-year time lags. For the time period 1991 to 2001, the indices of temperature and rainfall were regressed against 4-month-old calf weights using both the concurrent year and a 1-year time lag. We also constructed an index to snow depth from measured snow depth on 1 December, 1 February, 1 March, and 1 April at Fairbanks and McKinley Park. The resulting index represents combined total depth of snow in inches from the 4 months and 2 climate stations divided by 2. To summarize correlations between the 3 weather variables and the 10 population and condition variables, we constructed a matrix of Spearman correlation coefficients.

In August 1993 we cooperated with the Natural Resources Conservation Service (formerly Soil Conservation Service) to establish 4 aerial snow markers in Unit 20A. These sites were Gold King (64 11 77, 147 55 02), Edgar Creek (63 35 65, 148 01 41), Upper Wood River (63 45 65, 147 57 20), and Ptarmigan Airstrip (63 48 18, 146 28 25). These data will eventually replace the snow index derived from Fairbanks and McKinley Park data, but we did not include any of these data in analyses used in this report.

In addition to analyses of weather data described above, and the work on establishing the 4 new snow stations, we also cooperated with D Klein of the Cooperative Wildlife Research Unit at the University of Alaska and 2 graduate students (E Lenart and F Morschel) in weather manipulation experiments on arctic vegetation important to caribou and on the effects of insects on caribou behavior and activity budgets. During summers 1993 and 1994, we also conducted shading experiments on willow (*Salix pulchra*) leaves on the upper Wood River (Lambert's Airstrip). In these experiments, we investigated the potential effects of cloudy summers on the nutritional quality of *Salix pulchra*. We hypothesized that willow (*Salix pulchra*) leaves would be more digestible (primarily from lower tannin content) and would maintain a lower ratio of carbon to nitrogen under shade than under bright sunshine (i.e., cloudy summers vs. sunny summers). We also hypothesized that willow leaves would maintain their nutritional value longer in cloudy summers. We developed this hypothesis based on work in Norway with moose, and based on our observations that caribou ranges in east central Alaska and the Nelchina Basin turned brown prematurely during the very dry summers of the early 1990s (c.f. Bryant et al. 1983; Bo and Hjeljord 1991). In these shading experiments, we established 3 replicate shade plots (55% shading, 3×3 m in size) and 3 unshaded controls on a gentle south-facing willow shrub hillside (primarily *Salix pulchra*) at about 1000 m elevation. Leaves of *Salix pulchra* were then sampled 4 times during each of the 2 summers. During each sampling, we harvested all of the available willow leaves from a quadrant under shade tarps or in control plots. We had willow leaves analyzed for 1) percent protein, 2) percent in vitro dry matter digestibility, and 3) tannin levels (ug of tannin/ml). Because different labs were used in 1993 and 1994 for protein and tannin analysis, these results may not be directly comparable between years.

Similar, but more extensive weather manipulation experiments were also conducted as part of a master's thesis project by Elizabeth Lenart in 1994 and 1995 (Lenart 1997; Lenart et al. 2002). Another graduate student, Frank Morschel, conducted work on the effects of insect harassment on DCH caribou during 1994 and 1995 to help determine how insects might influence caribou nutrition (Morschel 1996; Morschel and Klein 1997).

MONITORING FOOD HABITS IN THE DCH AND OTHER HERDS

Occasionally during 1995–2001 we collected fecal pellets from winter ranges of several caribou herds. We were primarily interested in determining the relative proportion of lichens in the winter diet between herds, and over time within herds. We collected a single pellet from each of 25 pellet groups within a feeding area. Samples were stored by drying in open plastic bags with uniodized table salt added as a desiccant. Until 1998, samples were sent to the Composition Analysis Laboratory (Fort Collins, Colorado, USA). Subsequent samples were sent to the Habitat Lab (Department of Natural Resource Sciences) at Washington State University (Pullman, Washington, USA). At the Fort Collins lab, mean percent diet composition was calculated from 5 slides per sample with 20 fields viewed per slide (100 fields). At the Pullman lab, 4 slides with 25 views per slide were used, and plant fragments were identified to the Forage Class and Major Forage Plants level (level B, cost: $100/sample).

CARIBOU MORTALITY AND MOVEMENTS IN THE DCH

We routinely monitored movements, dispersal, and mortality by radiotracking collared caribou that were older than 4 months. Thorough searches of the range of the DCH were conducted with fixed-wing aircraft (Cessna 185, Bellanca Scout, or Piper Super Cub) during late May, late June/early July, late September/early October, early December, early February, early March, and early April. During these searches, collared caribou were located to the nearest kilometer, and any dead caribou were located exactly and subsequently retrieved by helicopter (Robinson R-22).

Mortality of Caribou from Birth to 4 Months

Primarily because of the wolf control program in 1993 and 1994, we monitored mortality of calves during their first summer of life by collaring samples of newborn calves during 3 years (1995–1997). Calves were caught by hand from a helicopter (R-22), weighed, and fitted with a cryptic, expandable collar with a mortality sensor (1-hr delay) (Telonics, Inc., Mesa, Arizona, USA). Calves were collared beginning 12 May (approximately the first day that newborn calves were seen) and collars were then deployed based on the progression of calving observed in radiocollared adults. The last collars were deployed about 31 May, by which date about 90% of the calves were born. Collared calves were monitored daily with a Bellanca Scout or Super Cub. Death sites of calves were investigated by flying to the site in the Robinson (R-22) helicopter the first day that deaths were detected. Carcasses or parts of carcasses of calves that died were retrieved, skinned, and necropsied the same day. Cause of death was determined from evidence at the kill site, or wounds on the carcass.

Experimental Diversionary Feeding to Reduce Calf Mortality

In May 1996 and 1997, we also experimented with a diversionary feeding technique to determine if wolves from the Wells Creek Pack (the primary pack inhabiting the main calving area) could be kept from hunting on the calving area. In 1996, 8 wolves remained in the Wells Creek pack at the end of the hunting/trapping season. In early April we radiocollared 1 adult female and 2 subadults and placed a visual (pink flag) collar on 1 female pup (11 months old). On 16 May we caught and collared 1 of the remaining uncollared wolves (a small yearling female) about 1 mile east of the den. On 22 May we caught a large dominant male (apparently the alpha male) and put a global positioning system (GPS) collar (Telonics, Inc.) on him. The collar was programmed to record a GPS location every half hour for up to 3 weeks, and it was removed from the wolf on 9 June. The GPS collar was then sent to the manufacturer to have the data retrieved. The remaining uncollared wolf in the pack was collared on 1 June with a conventional collar. From 15 May to 5 June we provided carcasses (primarily of bull caribou) to the wolves about every other day except on 23 May when bad weather prevented us from getting to the calving area. Caribou were either shot in place near the den or slung in with the R-22 helicopter to an open patch of tundra about ¼ mile east of the den. Carcasses were not touched to minimize chances of rejection by the wolves (Magoun 1976). Observers watched the wolf den and carcasses from a high vantage point about a ½ mile from the den. These observers recorded reactions of wolves to carcasses and also recorded their movements and activity pattern as much as possible, both visually and with telemetry gear.

In May 1997 the Wells Creek pack numbered 11. Eight of them were radiocollared, and 1 was collared with a visual collar (pink flag). Because the alpha male was becoming adept at evading the helicopter, he was not recollared with the GPS collar until 25 May. The GPS collar again recorded a location every half hour. On 15 May we deployed a field crew of 2 observers at the same observation point used in 1996. From this observation point, the observers could watch the den, the area we placed carcasses for diversionary feeding, and travel routes to the calving area. Rotating crews of 1–3 observers watched the den and surrounding area and recorded all movements and activities of wolves during daylight hours from 15 May to 5 June. Also from 15 May to 5 June, we brought caribou, beaver, and moose carcasses and kibbled dog food to an area about one-quarter mile east of the den. The beaver carcasses were bought from trappers in the Fairbanks area for $25 each, and the moose were found dead adjacent to the study area (a cow moose with twins that died of a breached birth, and a road-killed yearling from the Cantwell area). The GPS collar was removed from the wolf in early October.

In 1998 we did not conduct diversionary feeding. However, we did deploy the GPS collar on the alpha male of the Wells Creek pack on 14 May. We intended to compare his movements in 1998, when there was no diversionary feeding, to his movements in 1996 and 1997. Unfortunately, sometime during the summer, the GPS unit separated from the collar and the data were lost. We were unable to find the GPS unit and its VHF transmitter despite a thorough low search over most of the range of the Wells Creek pack. The loss of the GPS collar in 1998 left 1995 as the only year of no treatment that we could use for comparison with treated years of 1996 and 1997. During 1995, 2 of the 11 wolves in the Wells Creek pack were collared, and we tracked them every day while we were doing the calf mortality study during 12 May–5 June.

CHANGING COLLARS ON ADULT FEMALES IN THE DCH

We changed the collars of adult female caribou when their collars had been operating for 5 years or more. These caribou were also weighed and measured, and their blood was sampled to collect serum for future disease screening. If we were unable to recollar these females in October, they were captured the following spring. To avoid biasing our estimates of natality rate, we avoided handling adult females during the rut (which peaks in the DCH about 1 Oct) by changing collars after 15 October.

MONITORING DENSITY, NATALITY, MORTALITY, BODY WEIGHT, CONDITION, AND WEATHER IN ALASKAN CARIBOU HERDS OTHER THAN THE DCH

We used data on population size and distribution of radiocollared and uncollared caribou to monitor trends in summer density of caribou in Alaska in 1990 and again in 1997. Population size of Alaska’s more accessible and high profile caribou herds has been monitored since the early 1950s (Valkenburg 1998; 2002). Routine monitoring of most herds began during the mid-to-late 1970s. Size of the Nelchina Herd was estimated at least every 2 years since its last population low in the early 1970s, and every year since 1989 (Tobey 1993, 1999, Table 17). Estimates of population size were based on counts of aerial photographs in 1972, 1997, and 2000. These counts were extrapolated to a fall estimate based on July and October composition counts (Aerial Photo-Direct Count Extrapolation—APDCE technique) (Hemming and Glenn 1968). All other population estimates for the Nelchina Herd were based on visual counts of postcalving groups with extrapolation to a fall estimate based on July and October composition counts. Population estimates for most other herds conducted before 1979 were also APDCE estimates based on aerial photos (herds larger than 5000) or total visual counts of postcalving aggregations. After 1979 all estimates of caribou herds (except for those of the Nelchina) were either total direct counts of postcalving groups or total direct counts of rutting groups (herds <1000). Estimates of density were rough and based both on distribution of radiocollared caribou and observations of caribou movements by the area biologists. We did not calculate overall herd density because of the even greater difficultly in determining it in a meaningful way, and because density of caribou on summer range is more likely to affect natality rate and body size/condition. However, because expansion of winter range into new areas could compensate in some ways for poor quality or high population density on summer range, we also noted significant changes in winter range.

We monitored natality and calf weights and measurements in the Nelchina, NAP, SAP, Mulchatna, White Mountains, Ray Mountains, and Chisana herds by observing radiocollared adult females during the calving period (Bergerud 1964; Whitten 1995b), and by weighing and measuring calves in collaring programs. Some of these herds (e.g., Nelchina and Chisana) were monitored annually while other herds (e.g., White Mountains and Ray Mountains) were monitored sporadically as time and resources allowed. Mortality of radiocollared calves and adults was also monitored sporadically in Interior and Southwest Alaska caribou herds. For condition monitoring, the primary focus has been on weights and measurements of 4-month-old, and 10-month-old female calves captured during collaring. Calves were immobilized using techniques described above. In some cases calves were shot from a helicopter and necropsied, especially where we were interested in investing pathogens in herds, or where we were interested in correlating weights and measurements with fat deposition. Collared caribou were subsequently monitored to estimate natality, census the herd, conduct composition counts, determine causes and timing of mortality, and determine density based on herd distribution and size. We monitored weather patterns during the year, and in some cases deliberately sampled calf weights and measurements when weather appeared extreme (e.g., dry summers in southwestern Alaska during the mid 1990s).

IMPROVING AND DEVELOPING TECHNIQUES FOR MONITORING BODY CONDITION IN CARIBOU

Since 1991 we have investigated various methods for monitoring body condition/nutrition in caribou that could be used in a statewide program. After reviewing the literature, collecting nearly 100 calves in the early 1990s, and weighing and measuring several hundred live calves, we settled on a program of weighing and measuring samples of 10–30 newborn, 4-month-old and 10-month-old calves. We also calculated the weight:metatarsus ratio in 4- and 10-month-old calves. Although there were some advantages to collecting (i.e., killing) calves because direct measurements of fat deposits, femur marrow fat content, and carcass weight could be obtained, we concluded that measuring the weight and size of live calves provided an adequate measure of condition. In addition, it seemed unlikely that calves could be collected, or carcasses obtained from hunters in enough herds to provide the comprehensive annual data sets needed for a regional or statewide condition assessment program. Carcass weight, although theoretically a better measure of condition than live weight (c.f. Langvatn 1977; Allye–Chan 1991; Gerhart 1995), and potentially available from hunter-killed animals, was also not found to be a better measure in practice because of variations in the way that carcasses are handled by different people, and because hunters seldom shoot calves.

In the Delta Herd we had been gathering information on weight and size of 10-month-old female calves since 1979 (c.f. Davis et al. 1991). We expanded the program in 1991 to include sampling of 4-month-old females, and in 1995 we began sampling weights of newborn calves. In the Nelchina Herd, we began sampling of 10-month-old females in 1992 and subsequently expanded the program to obtain annual samples of 4-month-old females in 1995 and newborn calves in 1996. In the Fortymile Herd, Boertje and Gardner (1999) also began collecting data on 4-month-old calves in 1990 and on newborn calves in 1994. In other herds (particularly Macomb, White Mountains, Ray Mountains, and Chisana), beginning in 1991, we collected data on an opportunistic basis when caribou were collared or we collected caribou when we were particularly interested in assessing condition and monitoring the prevalence of diseases and parasites, as in the NAP and the Mulchatna Herd. In all cases (except when handling newborn calves) we collared or collected only female calves. During this study (including Fortymile data) we were able to obtain mean weights of 25 cohorts of newborn calves from 5 herds, and mean weights and measurements from 126 cohorts of 4-month-old and 10-month-old calves from 19 herds. Additional data were collected on weights of newborn, 4-month-old, and 10-month-old female calves by other biologists beginning in 1987 from the Denali and Mentasta herds (Adams, unpublished data), and from the Central Arctic Herd in 2001 (Arthur 2002).

INVESTIGATING GENETIC RELATIONSHIPS IN ALASKAN CARIBOU HERDS

ADF&G biologists in Alaska have been routinely collecting blood serum for disease screening since the 1960s (c.f. Zarnke 1996, 2000). Beginning in the early 1980s we began using some of this serum for genetic analyses (Roed and Whitten 1986). At about the same time we were encouraged by R Zarnke to begin saving blood clots because the development of DNA fingerprinting techniques appeared promising. Initial work with blood serum using electrophoretic techniques was focused on evolution of caribou subspecies and genetic interchange between geographic regions (e.g., Alaska, mainland Canada, the high arctic, etc.), and was based on variation in allele frequencies at one polymorphic locus (transferrin). Beginning in 1998 we cooperated with biologists in the Yukon Territory and federal agencies in Alaska to determine the relatedness of caribou herds in which we had been collecting data on body condition.

The primary reason for our interest in genetics was to begin to determine how much the differences in body weight, size, and conformation between herds could be due to genetics rather than nutrition, and also to determine whether caribou herds can be considered populations for management purposes (i.e., whether significant interchange occurs between herds). For most herds, we sent 20 samples of whole blood or blood clots to the University of Alberta Genetics Laboratory (Edmonton, Alberta, Canada). Most blood samples were from female calves. DNA from red blood cells was amplified using standard Polymerase Chain Reaction techniques, and then allele frequencies at 8 heterozygous loci of neutral selectivity (microsatellites) were compared between herds. Genetic distance between herds was computed based on allele frequencies at each of the 8 loci. In addition, the lab conducted an assignment test in which each sample was assigned to a particular herd, based on the likelihood of finding that particular genotype in the herd. In the first analysis, Zittlau et al. (2000) compared Chisana caribou with 2 other adjacent Yukon herds (Wolf Lake and Aishihik). Subsequently, in 1999, we conducted similar work on the Nelchina, Mentasta, Fortymile, White Mountains, Macomb, and Porcupine herds, and during winter 2000–2001, we included 5 Southwest Alaska caribou herds (Mulchatna, Northern and Southern Alaska Peninsula, Nushagak, and Unimak). All of the recent genetics work was funded cooperatively, with the National Park Service, Geological Survey, FWS, BLM, and ADF&G contributing.

RESULTS

POPULATION SIZE, TREND, AND COMPOSITION IN THE DCH

The DCH has been relatively stable since 1993 (Table 1). After wolf control was initiated, it appears the herd initially responded; the 1994 and 1995 census estimates were higher than in 1993. Subsequently, the herd declined slowly, apparently because the high mortality of calves that continued from birth through 16 months of age could not balance even the relatively low mortality experienced by adults.

Adult sex ratio in the DCH has varied considerably over the last 25 years. The most recent low in bull numbers occurred during the mid 1990s. Since then, the bull:cow and large bull:cow ratios have increased steadily (Table 1).

NATALITY RATE IN THE DCH

Natality of females (3 years old and older) in the DCH has been variable since the early 1990s (Table 2). It was particularly low in 1991, 1993, 1994, and 2001. Most variability in natality occurred in 3-year-olds.

Two-year-old females occasionally produced calves, especially during the early 1980s when the herd was increasing rapidly (Table 2). During 1980–1985, 21% (10/47) of the radiocollared 2-year females produced calves. During 1987–1995, a period when the herd was either at a relatively high level or declining, no 2-year-old females (0/56) produced calves, and during 1996–2001, a few 2-year-olds again produced calves (4%, 4/60).

In females older than 3 years, natality was generally high ($\bar{x}$ = 88%) over the 20 years for which data are available (Table 2). In only one year (1993) was natality in older females low. The 1993 calving period was preceded by the very short summer growing season of 1992, intense early snowfall that began on 11 September 1992, and unusual caribou movements during the rut (Valkenburg 1997). During late May 1993, only 40% of radiocollared caribou ≥6 years old were parturient.

NATALITY RATE IN HERDS OTHER THAN THE DCH

Natality in the Nelchina Herd was also variable but consistently lower than in the DCH during 1995–2001 ($x^2 = 24.6$, $P<0.001$, df = 2) (Table 3). In the DCH, 84% (232/276) of all females (≥3 years) were parturient during 1995–2001. In the Nelchina Herd during 1995–2001 only 65% (108/166) of these females were parturient. Unlike the DCH, Nelchina 4- and 5-year-old females continued to have relatively low natality rates, and only females aged 6 or older had consistently high natality (Table 3).

In the NAP Herd, data from composition counts in early June 2000 indicated about 76% of 1146 females older than yearlings were parturient, and in the SAP Herd 74% of 341 females older than yearlings were parturient. Although natality rates appear similar in the NAP and SAP, younger females may be more productive in the SAP. Female calves collared in the NAP during the late 1990s experienced high mortality, and the population structure became biased toward older cows, which tend to have higher natality rates.

RECRUITMENT IN THE DCH

Fall Composition Counts

Recruitment in the DCH, as measured by calves:100 cows in fall, varied considerably (2:100 to 49:100) over the 34 years that consistent fall composition data are available (Table 1). Fall calf:cow ratios were lowest immediately before wolf control in the mid 1970s during a period of extreme winters and high wolf numbers and again during a similar period 20 years later (Table 1). Calf:cow ratios were highest immediately after wolf control in mid 1970s and remained relatively high until wolf numbers increased and weather patterns changed in 1989 (see also Gasaway et al. 1983; Boertje et al. 1996; McNay 2000). Fall calf:cow ratios again increased coincident with wolf control that began in October 1993 and a return to milder winters, but ratios did not increase to the extent they did during the 1970s. From 1994 on, there was a slow downward trend in fall calf numbers.

Change in Calf:Cow Ratios from Fall to Spring

We found that it was difficult to estimate overwinter survival of calves by comparing fall ratios with those the following spring (Table 4). However, during the 1980s, the change-in-ratio data did indicate that calves survived as well as adults after October, so they often could be considered as recruits at 4 months of age (Davis et al. 1991). After 1991, when we began collaring calves at 4 months of age, we abandoned the April counts.

Survival of Radiocollared Calves from 4 to 16 Months

In contrast to the 1980s, calf survival from 4 to 16 months of age was low during the 1990s (Table 5). During 1991–2001, only 59% of radiocollared 4-month-old calves survived to 16 months, and during 1992–1993 only 30–50% of these calves survived. Wolves were the primary known cause of death (30/56), followed by lynx (3/56) and then grizzly bears (1/56) (Table 5). However, deaths caused by grizzly bears and wolves may have been underestimated because many deaths occurred during the snow-free season when determining cause of death was difficult. Twenty-one of the 56 calves (aged 4–16 mo) that died succumbed from unknown predators or unknown causes in summer, and most were probably killed by wolves and grizzly bears. Lynx were uncommon on the caribou summer range until the lynx population high during 1999–2002. There was no evidence of disease in this or any other age group of DCH caribou.

HARVEST

Harvest was a significant factor in the population dynamics of the Delta Herd during 1969–1973, and again during 1981–1991 (Tables 6 and 7) (Davis et al. 1991). In other years, the season was either closed or restricted to permit drawing hunts primarily for bulls (Table 6).

DETERMINING THE WEIGHT AND SIZE OF CALVES IN APRIL AND TESTING A MODEL THAT PREDICTS RECRUITMENT BASED ON WEIGHTS OF CALVES IN APRIL

Over the 19 years that data were available, mean April weights of female calves in the DCH varied from 51 kg to over 62 kg (Table 8, Fig 1). Heaviest mean April calf weights occurred during 1979–1983 as the herd was recovering from its population low in the early 1970s. Mean calf weights declined dramatically from 1989 to 1991 coincident with deep snow winters and dry summers (Valkenburg et al. 1996). There may have been some recovery after 1991, but calf weights remained relatively low between 1992 and 2001, and they have never recovered to the high levels seen during the late 1970s and early 1980s.

During the late 1980s we noticed a strong correlation between April calf weight and autumn calf:cow ratio (Valkenburg et al. 1996). This correlation has continued to be relatively high over the 19 years for which data are available ($r^2 = 0.60$, $P<0.001$, $n = 19$) (Fig 2). Since 1989 April calf weights have been low to moderate while fall calf:cow ratios have continued to be relatively low. In the Nelchina Herd, however, there was no correlation between April calf weights and autumn calf:cow ratio ($r^2 = -0.01$, $P>0.5$, $n = 10$).

DETERMINING IF WEATHER IS A FACTOR IN THE GROWTH OF THE DCH

Snow Depth and July Temperature and Rainfall

We constructed a 13×13 correlation matrix with the results of the Spearman's Ranked Correlation analyses performed on snow depth, July temperature, July rainfall, and 10 caribou population and condition variables (Table 9). Several interesting, statistically significant ($P>0.1$), and very likely biologically meaningful relationships were apparent although the only significant association between weather and the condition or population variables was the negative correlation between winter snow depth and fall calf:cow ratio (Table 9). In addition, it is apparent that there was a significant relationship between snow depth and July temperature and rainfall, a relationship also noted in previous reports (Valkenburg 1997).

Shading Experiments in the DCH Range

Percent protein was slightly higher in leaves of Salix pulchra in shaded plots sampled on 12 July and 29 July in 1993, and in shaded plots sampled on 23 June 1994, but differences were not statistically significant ($P>0.1$) (Table 10). There were no differences in percent protein in other sampling periods. Protein levels in *Salix pulchra* peaked around greenup in early June and then declined but remained relatively high through the end of July (Table 10). In vitro dry matter digestibility did not consistently differ between shaded and unshaded plots in either 1993 or 1994 (Table 10). Tannin levels were consistently lower in shaded plots in both years (Table 10). However, in the plots where leaves were removed for sampling (i.e., grazed), tannin levels were higher in the shaded plots than in the control plots on 29 July. Protein levels may not have been comparable between years because of differences in analytical techniques between labs.

FOOD HABITS

Spring

The flowers and flower buds of cottongrass (*Eriophorum vaginatum*) are the first green vegetation available to caribou from the DCH. In average years, these buds first become available on the north side of the Alaska Range during the first few days of May. However, there is considerable variation in the timing of bud growth and availability. In the earliest springs caribou were feeding extensively on cottongrass flowers by 20 April, and during capture operations in years with early snowmelt, many caribou had yellow muzzles from cottongrass pollen. In late years cottongrass flowers did not become available to caribou until around 10 May. In some years flowers and flower buds appeared early, only to become frozen and snow covered when the weather turned winter-like in late April and early May. On the south side of the Alaska Range (the new caribou calving area) cottongrass flower buds came out about 10 days to 2 weeks later than on the north side because of the higher elevations and consistently deeper snow.

Summer

In normal years, the flush of green willow (*Salix* spp.) and dwarf birch (*Betula* spp.) leaves occurred around 25 May on south slopes on the north side of the Alaska Range. The timing of leaf flush was highly variable, however, depending on elevation, aspect, snow cover, and temperatures in May. On the south side of the Alaska Range (i.e., Wells Creek), leaf flush did not occur on south slopes in normal years until around 1 June, and in late years until about 10 June. We did not annually record the timing of leaf flush in the Alaska Range, but we did note the dates of the first flush of green leaves on the south slopes of Chena Ridge as an index to the lateness of spring. During 1979–2001, leaf flush on Chena Ridge varied by almost a month, from 30 April to 25 May. Once willow leaves erupt in the Alaska Range, caribou switch from feeding primarily on *Eriophorum* flowers and flower buds to feeding almost exclusively on new willow leaves, particularly those of *Salix pulchra*. Once tundra forbs are available, caribou also begin to feed on them extensively, and they continue on this diet of willow leaves and forbs until vegetation senesces and mushrooms and blueberries become available in late July or early August. Caribou then feed on whatever green foods, berries, and mushrooms remain. In September they begin feeding on their winter diet of terrestrial and arboreal lichens, sedges, and shrubs (*Cladonia* spp., *Cetraria* spp., *Bryoria* spp., *Vaccinium* spp., *Ledum* spp., and *Salix* spp.). We did not examine summer feces and this description of summer food habits is based on observation.

Winter

From 1985 to 1999, we collected 34 samples of fecal pellets from winter ranges of the DCH, and 27 samples from other herds for comparison (Tables 11 and 12). Mean proportions of lichens in the winter diet were high in all Interior herds. Lichens averaged 70% of discerned plant fragments in fecal pellets from the DCH during 1985–1999, 72% in the fecal pellets from the White Mountains Herd in 1992, and 69% in fecal pellets from the Nelchina during 1992 through 1996. Fecal pellets from the Kenai Mountains and Killey River herds on the Kenai Peninsula were also high in lichens (Table 12). In contrast, the few fecal pellets we collected from the Western Arctic, NAP, and Mulchatna herds were lower in lichens than Interior herds and higher in shrubs and sedges.

Mean proportion of lichens in the winter diet of DCH caribou declined during the course of this study from 84% prior to 1990 to 55% after 1990. In addition, the proportion of mosses in the winter diet of DCH caribou increased from 7% prior to 1990 to 25% after 1990, and the proportion of shrubs increased from 5% prior to 1990 to 11% after 1990. Fecal samples were not collected in a systematic manner across winter ranges and years in the DCH and statistical comparisons may therefore not be meaningful. However, we believe that fecal pellets collected in the DCH are indicative of the winter diets of DCH caribou over time.

MONITORING MOVEMENTS IN THE DCH

History of Winter Range Use

General information on wintering areas used by the DCH is available from the early 1960s to the present. Skoog (1968) and Hemming (1971) both described the foothills of the Alaska Range, the Tanana Flats, and the Yanert River drainage as primary winter range. During the 1960s the DCH numbered about 5000–6000 caribou. When ADF&G biologists began more detailed surveys in the early 1970s, after the herd had declined to about 2500, the primary winter range was on the Gold King Benches between the Wood River and the Tatlanika River. This pattern of winter range use continued until the early 1980s. During the early 1970s, particularly 1972–1973 (the winter before the Parks Highway bridge was completed), at least several hundred caribou wintered in the Nenana River valley in the vicinity of Healy, but it was never documented whether they were caribou from the Delta Herd or the Denali Herd. Hemming (1971) and Skoog (1968) believed that Nelchina caribou also occasionally used the lower Yanert River valley in winter during the 1960s.

Information from the first radiocollared caribou became available during late winter 1979 and records of locations of radiocollared caribou were used to document major winter ranges used by the DCH since then (Table 13). As herd size increased in the late 1970s, wintering areas of the DCH began to include foothill areas west of the Tatlanika River. By 1983 most rutting and wintering was occurring west of the Tatlanika River, but east–west movements in the foothills between the Nenana River valley and 100-Mile Creek were common in late August and September. During 1988–1991, as population size peaked, caribou started also wintering on the western Tanana Flats north about halfway between the Rex Trail and the Tanana River. Some groups were seen north of Wood River Buttes and in the vicinity of Clear Creek Butte during these years. By 1991–1992, herd size had declined and use of the Tanana Flats decreased. A severe snowstorm that began 11 September 1992 and continued until 28 September caused extensive and unusual caribou movements and resulted in DCH and Denali mixing in the vicinity of Clear and moving north to the Fairbanks, Eielson, and Chatanika areas. Some also continued as far as the White Mountains where they mixed with White Mountains caribou. Some DCH and Denali caribou wintered as far northeast as Granite Tors on the upper Chena River, and as far east as the middle Salcha River. After 1992–1993 the DCH has used more traditional winter ranges in the Alaska Range foothills between the Nenana River and the Delta River. However, during 1997–2000 some caribou from the DCH used winter ranges around Donnelly Dome, Jarvis Creek, and the western slopes of the Granite Mountains. In addition, in 2000–2001, besides traditional winter ranges north of the Alaska Range, they also used the Wells Creek and upper Nenana River drainages and the Monahan Flats, where they were mixed with some caribou from the Nelchina Herd.

History of Calving Area Use

Major calving areas used by DCH caribou have changed considerably since we began documenting them thoroughly with the advent of radio collars in 1979 (Table 14). Valkenburg et al. (1988) reviewed calving distribution from 1979 through 1987. During that period most calving occurred in the vicinity of the Trident and McGinnis glaciers, east and west of upper Delta Creek, with some in the Buchanan Creek drainage. In years of late snowmelt (particularly 1992), caribou calved farther north at lower elevations on flats along Delta Creek that also serve as a bombing range impact area. However, in 1987 when snowmelt was early, some collared caribou calved in the upper Wood River where Yanert Herd caribou had been calving. In 1988 the southwestward shift continued, and most DCH caribou calved in Dick Creek and the upper Wood River. This change turned out to be the beginning of a major shift in calving areas, and over the next few years, DCH caribou progressively used the upper Wood River, Dick Creek, the upper Yanert River, and eventually, Wells Creek in 1990. During 1990–1997 most calving occurred in a very concentrated area centered around the forks of Wells Creek. During 1998–2001 snowmelt was late, and calving was shifted south and east from Wells Creek along the upper Nenana River and Monahan Flats, although 15–20% of parturient cows began using the Little Delta and Delta Creek drainages again in 2000 and 2001.

History of Summer Range Use

In contrast to winter range and calving area use, use of summer ranges by the DCH has been stable. Little data on summer range use exists prior to 1979. After 1979 information from radiocollared caribou accrued, and the herd was counted each year in late June or early July. The primary areas used in summer by DCH caribou from 1979 to 2001 were Mystic Creek, upper Gold King Creek, upper Tatlanika River, Iowa Ridge, upper Buchanan Creek, upper Wood River, and Dick Creek. Lesser numbers of DCH caribou also used the Totatlanika and upper Delta Creek drainages. Typically, DCH caribou formed large aggregations in mid June and continued to be more or less aggregated until the first few days of August, when they spread out as individuals, pairs, or small groups.

Unusual Movements

Unusual movements of large numbers of DCH occurred during calving in 1987 through 1990, and during September 1992. During 1987 through 1990, parturient cows from the DCH progressively shifted their calving area to the southwest. This movement was particularly noteworthy in 1990 because the caribou moved into a new calving area in Wells Creek, south of the Alaska Range. Because it is unlikely that the Wells Creek area had ever been visited by any DCH caribou alive in 1990, it appeared that they were pioneering a new calving area and traveling by routes that these caribou had never used previously. The shift in calving area use that began in 1987 did not result in a permanent egress of caribou to the Nelchina Herd. The use of summer ranges remained unchanged, and almost all radiocollared caribou that calved in Wells Creek returned to the traditional summer ranges each year.

The unusual movements of DCH caribou that occurred in September 1992 were briefly discussed above under “History of winter range use” and previously by Valkenburg (1993:7). An unusually heavy snowstorm came from the northwest and began on 11 September. Almost all radiocollared DCH caribou were located on 22 September in the foothills of the Alaska

Range in the Totatlanika drainage. When the collared caribou were located next on 28 September, about half were approaching or had arrived on the south bank of the Tanana River between the mouth of the Wood River and Fairbanks. This movement was particularly noteworthy because the Denali Herd and the DCH mixed together in the vicinity of Clear as they were moving north. These caribou began crossing the Tanana River on 29 September, and they subsequently moved north through the Fairbanks area and surrounding residential areas. They were seen by many people in the Cripple Creek Subdivision, in Ester, and along the Murphy Dome Road. One female became entangled in a volleyball net at about 2 mile Murphy Dome Road, and we collared and released her. She wintered about 10 miles northwest of Murphy Dome. Mixed groups of DCH and Denali caribou, including many radiocollared individuals also wintered within a mile of the east end of the runway at Eielson Air Force Base, where they were subjected to frequent jet traffic. Other large groups with many radio collars wintered in spruce forest in the vicinity of the trans-Alaska pipeline near the Chatanika River, near Granite Tors, and in the White Mountains near Cache Mountain. Smaller groups (without radios) were seen wintering in Minto Flats, between Chena Ridge and the Parks Highway east of Ester, and in Goldstream Valley. All surviving radiocollared caribou that participated in this northerly movement in September 1992 traveled back to their respective calving ranges by mid May, 1993. Older residents of the Fairbanks area remembered a similar movement of caribou in the early 1940s (W Waugaman, personal communication).

During late October or November 1994, 1 radiocollared DCH caribou crossed the Delta River and wintered on upper Jarvis Creek. This was the first documented movement of a collared caribou across the Delta River since the study began in 1979. Increasing numbers of collared DCH caribou wintered in the vicinity of Donnelly Dome, Jarvis Creek, and the western Granite Mountain between 1994–1995 and 2000–2001. This movement may have peaked in fall 2000, when 8 radiocollared caribou moved into the area in late September and early October. These collared caribou were still present in the Jarvis Creek area in mid November, and in March 2001. We radiocollared about 6 females calves in the Jarvis Creek drainage in October 2000 and 2 more in April 2001. All collared caribou, except 2, moved west across the Delta River in April and May 2001. The 2 that remained in the vicinity of Jarvis Creek in summer 2001 were ones that had been collared there. However, because caribou from the Macomb Herd were also in the area during October 2000 and April 2001, we were not sure if these 2 yearlings were born in the Delta Herd or the Macomb Herd. In fall 2001, no collared DCH caribou moved across the Delta River, and only 1 of the DCH/Macomb collared yearlings that spent the summer there (through late September) could be found. In early September 2000 and 2001, motorists saw groups of caribou (mainly bulls) in the vicinity of Donnelly Dome, but by the time the Macomb hunting season opened on 10 September, these caribou were no longer being seen from the road. It is possible that a few bulls from the DCH may have been killed in this area during Macomb caribou hunts in 1998–2001.

During late September 2000, about 25% (13) of the collared DCH caribou moved from the Yanert River drainage to Wells Creek and Monahan Flats, where they became mixed with several thousand Nelchina caribou. About half of these moved back to the Yanert River or further north during winter, but 7 collared caribou remained to winter in the Brushkana, Nenana, or upper Susitna drainages.

During the period of this study (1979–2001), in addition to the unusual movements of relatively large groups of DCH caribou described above, small groups of caribou or individual radiocollared caribou also made some unusual movements. In fall 1983 during the rut in early October, a few DCH caribou (not including any with radios) crossed the Nenana River and Parks Highway in the vicinity of Lignite and Ferry, where some groups were seen by motorists. These caribou apparently moved back to the east and we received no more reports of caribou in the area during the winter.

In September 1992 (at the time of the severe snowstorm), 1 radiocollared 2-year-old female moved from the lower Yanert drainage to the Chulitna Mountains. She was not pregnant the following spring and remained in the Chulitna Mountains all summer. In 1994 when she was parturient, she traveled to the Wells Creek and subsequently remained with other DCH caribou. In addition, biologists working with the Denali Herd collared about 15 female calf caribou in the vicinity of the Liberty Bell Mine thinking they were primarily Denali caribou. However, 3 of them remained with the Delta Herd during the summer, and we recollared them with our own radio collars in October. They spent the winter in the Delta Creek drainage, but late in the winter 1 disappeared. It was later found dead on the Toklat River in Denali Park. After winter 1992–1993, when Delta and Denali caribou became mixed, it is possible that some caribou, especially calves and yearlings, and perhaps bulls, were exchanged. However, if any exchange occurred, it was not numerically detectable in subsequent censuses of the either the Denali or Delta herds.

During the mid-to-late 1990s, as DCH caribou increased their use of the Wells Creek and upper Nenana drainages, occasional radiocollared DCH caribou lived for short periods in the Chulitna Mountains southeast of Cantwell. These caribou were invariably yearlings that were away from their mothers for the first time during their second summer or winter of life. All of these caribou that survived eventually rejoined the DCH before having their first calf.

During late May 2000, a collared 4-year-old DCH female that gave birth to a calf near the west fork of the upper Susitna traveled as far eastward as McClaren River during the summer and fall and mixed with Nelchina caribou. She remained away from the DCH during the following winter, calving season, and summer (2001) as well. However, sometime during fall 2001 she returned to the DCH and wintered in the lower Yanert drainage during 2001–2002.

A female caribou, collared as a 4-month-old calf in the DCH near Slide Creek in 1996, calved for the first time in Wells Creek in 1999. She spent winter 1999–2000 in the lower Yanert, but then traveled southeast to Last Tangle Lake in May 2000, where she calved. During winter 2000–2001 she remained in the upper Susitna drainage and subsequently calved near the Valdez Creek Mine in 2001. She again spent winter 2001–2002 in the upper Susitna drainage.

Another female caribou (Orange 66), collared as a 4-month-old in the Little Delta drainage in October 1997, wintered in the vicinity of Healy during 1999–2000. Although she was not found in the range of the DCH during the calving period during 2000, she was present in DCH aggregations in late June. During winter 2000–2001 she was located west of Healy at Shushana Lakes. She did not calve with the DCH in 2001 and we did not determine if she was pregnant. She apparently remained west of the Nenana River all summer because she did not join the DCH aggregations in late June. We found her again in late September 2001 near the park boundary on the Teklanika River where she wintered, and on 22 May 2002, she calved near the junction of the Denali Park Road and the Teklanika River. Also in 2002 a single radiocollared DCH female (Orange 31) that was collared and had previously calved in the DCH calved on the calving area of the Nelchina Herd in the Oshetna River drainage.

DISPERSAL OF RADIOCOLLARED DCH CARIBOU

During the course of this study (1979–2001), we did not document any significant calving by radiocollared DCH caribou in calving areas of any other recognized herds (except for the 2 cases mentioned in the paragraph above). However, the DCH did expand its calving area into an area used for calving by a small resident group of caribou in the upper Susitna. This resident group was never extensively surveyed, but between 1980 and 1995, biologists periodically counted up to 2000 caribou with calves in late May or early June between the east fork of the Susitna River and the McClaren River north of the Denali Highway. These caribou had been heavily hunted in the Cantwell area in the early-to-mid 1990s, but at least a thousand apparently still calved in this area during the late 1990s. A separate, expanded study of population dynamics and winter and summer range ecology of the Nelchina Herd is in progress, and caribou were radiocollared in the upper Susitna drainage during 1999–2001. During the 2000 and 2001 calving seasons, a few radiocollared DCH caribou also began using this area for calving. It remains to be seen whether this trend will continue and whether continued interaction during calving, summer, fall, and winter between Delta and Upper Susitna caribou results in amalgamation of these herds.

During the DCH study so far, no collared caribou from the adjacent White Mountains, Denali, Fortymile, or Macomb herds used any seasonal ranges of the DCH within the area bounded by the Nenana River on the west, the Delta River on the east, or the Tanana River on the north. However, during 1994–1995 we counted 2282 caribou in the Chulitna Mountains southeast of Cantwell. Only 2 collared caribou were in this group. One was a yearling from the DCH, and the other was a Nelchina caribou. In January 1995 the collared Nelchina caribou moved north into the lower Yanert drainage and remained there until late March. This caribou was next found on the calving area of the Nelchina Herd in late May. A small movement of Nelchina caribou including 2 with radio collars again moved into the lower Yanert drainage in October 2001, where they mixed with DCH caribou.

During the course of our study, we frequently lost track of 1–3 radiocollared caribou each year. Some of these were never found. However, we annually provided a list of missing radio collars to other biologists working with the adjacent Denali, Fortymile, and Nelchina herds, and no DCH collars were ever found with these herds, except for the cases mentioned above. It is likely that most missing DCH radios either failed or were disabled by predators or humans. In some cases, “missing” radio collars later turned out to be errors on data sheets where frequencies or collar numbers were incorrectly transcribed or mistakenly left on the active frequency list after the caribou had died and the collar was retrieved. In a few cases we eventually visually found the missing caribou in the DCH and determined that the transmitter had failed.

MONITORING MORTALITY IN THE DCH

Mortality of Caribou from Birth to 4 Months

During 1981–1987 we estimated the mean summer mortality rate for calves to be 56% based on observed changes in calf ratio from birth to the end of September (Davis et al. 1991:103). During the same period, mortality of calves from late September to April averaged 6%.

In calf mortality studies in the DCH during 1995–1997, annual mortality of radiocollared newborn calves from birth to 30 September did not differ between years ($\chi^2 = 0.07$, $P = 0.97$, df = 2 for all radiocollared calves) and averaged 63% (n = 164) (Table 15). Causes of mortality of all radiocollared calves did not differ between years ($\chi^2 = 3.84$, $P = 0.43$, df = 4). Over the 3 years the studies were conducted, wolves killed 25% (41/166) of all radiocollared calves, grizzly bears killed 20% (33/166), and golden eagles (*Aquila chrysaetos*) killed 14% (24/166). Differences between the proportions of calves killed by wolves, bears, and eagles were not statistically significant (P>0.15), except for the difference between wolves and eagles ($\chi^2 = 5.53$, $P = 0.02$, df = 1). During the 3 years of calf mortality studies, coyotes (*Canis latrans*) killed a total of 3 calves. We did not record any accidental, disease, or weather-related deaths.

Mortality of Radiocollared Female Calves 4–16 Months of Age

During the late 1970s and throughout the 1980s data on changes in ratios of calves in the DCH from October to April indicated that mortality of calves during their first winter was low and not significantly different from mortality of adults (Davis et al. 1991). This pattern of mortality changed sharply in about 1990. During 1991–2001, mortality rates of female calves radiocollared in early October each year ranged from 18% to 70% and averaged 41% (36/138) (Table 5). Wolves killed most of these calves during winter, but many also died during summer when cause of death could not often be determined. Lynx (*Lynx canadensis*) killed 3 collared calves in winter 1992–1993 when many DCH caribou moved north onto the Tanana Flats and into boreal forest north of the Tanana River. This was also a period when snowshoe hares were declining.

Mortality of Radiocollared Females 16–30 Months of Age

Data collected over the 22-year period of this study showed that mortality of young radiocollared female caribou 16-30 months of age was low (16/185—9%) (Table 5). Sample sizes were too small to discriminate between years, but mortality may have been slightly higher in this age group after 1990 (6.4% vs. 10.3%, $\chi^2 = 0.86$, $P = 0.34$, df = 1). About half of the caribou that died in this age group were killed by wolves, and the rest died largely of unknown causes (likely wolf and bear predation) during the summer. One radiocollared caribou was killed illegally (i.e., poached).

Mortality of Caribou Older than 30 Months

During 1980–2000, mortality of female radiocollared caribou older than 30 months averaged 12% (Table 5). Mortality of this age group may have been slightly higher than the 16- to 30-month-olds (11.7% vs. 8.6%, $\chi^2 = 1.39$, $P = 0.24$, df = 1). Mortality was probably also slightly higher in this age group from 1989 to 1994 (16%) when the herd was declining rapidly.

EXPERIMENTAL DIVERSIONARY FEEDING TO REDUCE CALF MORTALITY IN THE DCH

Effects of Diversionary Feeding on Numbers of Calves Killed by Wolves on the Wells Creek Calving Area

Diversionary feeding may have been successful in reducing the number of caribou calves killed by wolves, but sample sizes of collared calves were too small to be conclusive and there was doubt about the cause of death of several calves. In 1995, when there was no diversionary feeding during the calving season, wolves killed 5 collared caribou calves on the Wells Creek calving area. In addition, 3 calves that seemed to have been killed by eagles may actually have been killed by wolves and scavenged by eagles because wolves were known to have been in the vicinity near the time of death of the calves. In 1996, when there was diversionary feeding (Table 15), wolves killed 3 collared calves and none were thought likely to have been killed by wolves and then scavenged by eagles. However, several calves died of unknown causes. The caribou left the range of the Wells Creek Pack on 9 June, about 4 days after we stopped diversionary feeding. In 1997, when there also was diversionary feeding (Table 16), wolves killed 3 collared caribou calves on the Wells Creek calving area between 15 May and 20 May. During this period, all collared Wells Creek wolves remained at the den, but the 3 uncollared Wells Creek wolves could have been traveling to the calving area. It is also possible that other wolves were also present there without us knowing it. Around 30 May to 1 June, wolves killed 4 collared calves on the Wells Creek calving area. Movements away from the Wells Creek den started on 29 May. Although many caribou remained in the vicinity of Wells Creek until about 20 May no more collared calves were killed in the area. However, in 1997, calving was more spread out than in the 2 previous years, and 1 collared calf was killed in Monahan Flats to the east and at least 4 more were killed in Louis Creek and Edgar Creek in the Yanert drainage during late May and throughout June.

To try to determine the total number of DCH calves that may have been "saved" from wolf predation by the diversionary feeding during 1996, we attempted to estimate numbers of caribou calves killed by wolves on the Wells Creek calving area in 1995 (no diversionary feeding) and 1996. In 1996 there were about as many calves available to wolves in the Wells Creek calving area as in 1995 and the number of cows was similar in both years. Although natality may have been slightly higher in 1996 than in 1995, neonatal mortality may also have been slightly higher (Table 15). Distribution of parturient cows was also similar in both years. Although fewer cows were in the Yanert and upper Wood River in 1996 than in 1995 (i.e., not in the range of the Wells Creek pack), more were south and east of the Wells Creek area. Assuming there were about 2250 calves available on the calving area in both years, there were about 50 calves:radiocollared calf in 1995 and about 45 calves:radiocollared calf in 1996. Therefore, we estimated that Wells Creek wolves killed about 135 calves in 1996 versus 250–400 in 1995. If 115 more (difference between 135 and 250) had all survived to fall, the fall calf:cow ratio should have increased by about 4 calves:100 cows. However, unlike 1995, when calf mortality ceased after early August, calves continued to die in August and September 1996. By the end of September total mortality of collared calves from wolf predation was probably lower after diversionary feeding in 1996 than in 1995 (18% vs. 30%) but differences were only marginally statistically significant ($\chi^2 = 1.92$, $P = 0.17$, df = 1). Total mortality of collared calves in both years was similar (62% in 1996 vs. 67% in 1995, $\chi^2 = 0.30$, $P = 0.58$, df = 1).

In 1997, the second and final year of diversionary feeding, caribou calved in a more dispersed distribution than in either 1995 or 1996. In addition, in Unit 20A wolf numbers had largely recovered from the control program in 1994 and 1995. As a result, any positive results from diversionary feeding of the Wells Creek pack may have been negated by greater wolf predation in other parts of the calving and summer range. By the end of September, wolves had killed 19 of 73 collared calves (26%); mortality from wolf predation was virtually unchanged compared with 1995 ($\chi^2 = 0.24$, $P = 0.62$, df = 1). Total mortality of collared calves by the end of September in 1997 was again 62%, the same as 1996, and not significantly lower than in 1995 (62% vs. 67%, $\chi^2 = 0.39$, $P = 0.53$, df = 1).

Effects of Diversionary Feeding on Pack Hunting Behavior

In 1995, the year before diversionary feeding began, 2 wolves from the Wells Creek Pack were collared, and many of the 11 members of this pack regularly hunted on the calving area that was about 4 miles from their den site. In 1996, the first year of diversionary feeding, there were 8 wolves in the Wells Creek Pack and they occupied the same den as in 1995. The 10 caribou and 2 moose carcasses that were placed near the den successfully kept most pack members in the vicinity of the den from 18 May to 9 June when caribou left the area, but diversionary feeding was not completely successful because the wolves did kill 3 collared caribou calves on the Wells Creek calving area; 1 on 17 May, 1 on 25 May, and 1 on 27 May.

In 1996, 7 members of the pack were already centering their activities around the den when intensive tracking began on 12 May, but 1 collared wolf was seldom with the pack and was usually alone in an area about 20 miles southeast of the den, well away from the Wells Creek calving area. Although the first caribou was shot near the den on 15 May, the wolves did not find it for over 3 days. They probably continued to hunt on the calving area and did not become accustomed to feeding on carcasses near the den until the night of 17 May after the second carcass was placed nearer the den in a more open area. Carcasses were delivered to or shot within a mile of the den on 19 and 21 May, but weather was bad on 23 May and no carcass was delivered. Some of the wolves were already hunting away from the den on 24 May when the wolves were next located. A cow moose was shot about a mile from the den on 24 May, but the wolves did not discover the carcass until 28 May. On 28 May we realized the moose carcass was too far away from the den for the wolves to find easily, so we placed a bull caribou carcass near the den in the same area as carcasses 2 through 4. Some of the collared wolves were located on the calving area near nursery bands of caribou during 24–27 May, and 2 collared caribou calves were killed (1 on the night of 24–25 May and 1 on the night of 26–27 May). No other collared calves were killed by the Wells Creek wolves, and they did not visit the calving area again until after the caribou left the area about 9 June.

In 1997 the diversionary feeding was initially more successful at keeping the Wells Creek wolves away from the calving area. This was likely because we delivered most of the food to the same area only about ¼ mile east of the den. The wolves thus found it immediately. All the collared wolves stayed within 4 miles of the den between 15 May and 27 May, and they were primarily within a mile of the den most of the time. However, on 28 May they began to make forays away from the den, and on night of 30–31 May they ate most of a caribou that had just been delivered and then traveled to the main calving area at the forks of Wells Creek. Wolves killed 4 collared caribou calves in this area between 30 May and 1 June. The wolves continued to feed on the carcasses provided near the den until about 7 June. After 7 June the male with the GPS collar began to range more widely and he visited the calving area frequently through 25 June when we tranquilized him and retrieved the collar.

RECOLLARING ADULT FEMALES AND MAINTAINING COHORTS OF COLLARED, KNOWN-AGED FEMALES

We were successful in recollaring most females that had been collared as 4-month-old calves or 10-month-old calves. Most commonly, we recollared females in late October when they were 5 years old, and if they survived, we changed collars again at about 10 years of age. Since 1998 we have been able to obtain slightly longer-lived collars, and we now only change collars once during an animal's life. During the course of this study, we never observed any more damage to the animals than hair breakage, and never experienced problems with tight collars. However, during the unusual September snowstorm in 1992, a collared adult female with a softball-sized ice ball on her collar was killed in Goldstream Valley by a coyote.

During the early 1990s, when 4-month-old calves decreased in size and began to have high mortality rates over winter, we switched to a lighter collar. However, mortality rates of these calves continued to be high, and mortality was probably not related to collar size. The animals from cohorts with lighter collars needed to have their collars changed at 3 years.

MONITORING DENSITY, MORTALITY, BODY WEIGHT, CONDITION, AND WEATHER IN ALASKAN CARIBOU HERDS (OTHER THAN THE DCH) ON AN OPPORTUNISTIC BASIS

Data on population size of Alaskan caribou herds since 1970 are presented in Table 17. Summer density estimates are also presented for 1990 and 1997 in Table 18. Estimates of caribou density must be interpreted with care because of incomplete knowledge of distribution. We summarized data on mortality of calves, body weight and condition, and important weather events for 5 of the more high-profile herds below. We monitored calf mortality in these herds on an opportunistic basis with calf mortality studies on the NAP in June 1999 and the SAP in June 2000. Some qualitative mortality data were also available from radiocollared 4-month and 10-month-old calves and adults in the NAP and the SAP.

Nelchina Herd

Population Size and Density. Density of caribou on the Nelchina Herd's summer range (i.e., the area used in June and July) increased steadily from 0.77/km^2 in 1974 to 3.8/km^2 when herd size peaked at about 50,000 in 1995. During this period the area used as summer range remained largely unchanged and was confined primarily to the eastern Talkeetna Mountains in June and July (about 13,000 km^2), with varying use of the lower-elevation hills of the eastern Talkeetna Mountains, the Lake Louise Flats, and southern Alphabet Hills in August. In 1998 most Nelchina caribou left the Talkeetna Mountain summer range early (i.e., in mid-to-late Jul) when the range became noticeably brown during a July drought. The caribou drifted northeast to the Lake Louise Flats where they stayed throughout August. This pattern of movement was repeated in 1999 and 2000, and it thus became more difficult to calculate summer range density.

The total range of the Nelchina Herd expanded greatly beginning in 1987–1988 when the herd began to use winter range in northern Unit 11 at the head of the Copper River (the last time this area was used as winter range was in the 1960s). In 1988–1989 about one-third of the herd repeated this movement and also continued farther northeast into southern Unit 12. By 1990–1991, most (probably about 90%) Nelchina caribou wintered in Units 12 and 20E. During some years in the early 1990s, about 10–25% of the herd also used areas of the western Yukon Territory as winter range. Since late 1990–1991 the Nelchina and Fortymile herds have occasionally mixed on winter ranges in the drainages of the Dennison Fork and the Ladue River. About 20–25% of the Nelchina Herd continued to use traditional winter ranges in Unit 13 and Unit 12 south of the Nutzotin Mountains until 1996–1999 when only about 15% continued to do so. During winter 2001–2002 most of the herd (about 85%) did not move to northern Unit 12 and Unit 20E but remained to winter between Mentasta Pass and Tangle Lakes.

Mortality. Estimated annual mortality rates of radiocollared Nelchina caribou have ranged from 5% to 15%, but the confidence intervals around these estimates are undoubtedly large (Tobey 1999:86). Although causes of mortality of radiocollared 4-month-old and 10-month-old calves and adults were not generally recorded, wolf predation was suspected in most cases. Wolf numbers increased during the late 1980s, and wolf numbers since fall 1998 have been the highest recorded in over 25 years in Unit 13 (Tobey 1999:86). In addition, fall calf:cow ratios have declined coincident with the increase in wolf numbers since the mid 1990s. During the snowshoe hare population decline in 2000–2001, a lynx was seen stalking a group of Nelchina caribou in October. Based on this observation and several instances where lynx were know to have killed collared calves in the Delta and Fortymile herds, we therefore suspected that during 1999–2001 lynx predation could have been an additional cause of mortality of calves between 2 and 23 months of age in the Nelchina Herd.

Body Weight and Condition. During 1996–2001, mean body weights of cohorts of newborn calves in the Nelchina Herd were as high or higher than those of newborn calves in other Interior herds, except Denali (Table 19). Except in 2000, mean weights of cohorts of newborn male calves ranged from 8.25 kg to 9.17 kg. Only in 2000 was the mean weight significantly below the low end of this range (7.66 vs. 8.25, $P = 0.04$, $t = 2.07$, df = 48). Results were similar for newborn female calves, which ranged from 7.72 kg to 8.57 kg during 4 of the 6 years of measurements (Table 19). However, mean weights of newborn female calves were relatively low in both 1996 and 2000 (7.19 vs. 7.72, $P = 0.05$, $t = 2.06$, df = 40, and 7.02 vs. 7.72, $P = 0.006$, $t = 2.85$, df = 54).

Although newborn calves in the Nelchina Herd were similar in weight to newborn calves in other Interior herds, by the end of summer, calves were consistently smaller and lighter than calves from other herds (Appendix A). For example, during 1991–2000, cohorts of 4-month-old calves in the DCH averaged 57.1 kg whereas during 1995–2000, cohorts of 4-month-old calves from the Nelchina Herd averaged 52.0 kg (Appendix A) (Valkenburg et al. 2002a). During winter, however, Nelchina calves generally gained weight while DCH calves consistently lost weight. The result was that, in most years, 10-month-old DCH calves were only slightly larger than Nelchina calves (Appendix A) (Valkenburg et al. 2002a).

Weather. We monitored summer and winter weather patterns in the range of the Nelchina Herd during 1991–2001. There were no climate stations within the herd's summer range, and we therefore relied on observations of the timing of snowmelt, greenup, and vegetation senescence. During 1991–2001, 3 significant weather events were observed. In 1998, very dry conditions during July resulted in early vegetation senescence, most vegetation in the Talkeetna Mountains was noticeably brown in early August. In addition, snowmelt in 1999, 2000, and 2001 was very late and most of the normal, higher elevation calving area remained snow covered until after 1 June. Greenup on south slopes in the calving area was about 2 weeks later than average, and did not start until about 5 June. During winters 1991–2001, the Nelchina Herd was largely in northern Unit 12 and southern Unit 20E where snow was relatively shallow. The herd thus largely escaped the influence of some very deep snow winters in Unit 13. During 2001–2002 when the herd did winter in Unit 13, snow depth was relatively shallow.

Northern and Southern Alaska Peninsula and Unimak Island Caribou Herds

Population Size and Density. These 3 caribou herds have a history of periodic population fluctuations. Valkenburg et al. (2002b) reviewed population dynamics of the Alaska Peninsula and Unimak Island caribou herds since the 1880s. Of the 3 herds, the NAP has been the most studied because of its proximity to the town of King Salmon. From 1960 to 1980, ADF&G biologists occasionally estimated population size of the NAP. Annual estimates were successfully obtained every year from 1981 through 2001, except for 1986 (Table 16). The herd remained largely stable at 16,000–20,000 from 1981 through 1993 due largely to a deliberate attempt by ADF&G to hold herd size stable through harvests that often approached or exceeded 10% of herd size. Density of caribou on the summer range was therefore relatively high and stable from about 1980 to 1993 and then declining from 1993 to 2000 (Table 17). Winter ranges between Becharoff Lake and the Naknek River were consistently used until 1986, when caribou began using relatively pristine range to the north between the Naknek River and Lake Iliamna. However, about the same time, caribou from the Mulchatna Herd also began using these ranges.

The SAP grew from about 1000 caribou in 1960 to 10,200 in 1983 (Skoog 1968) (Table 17). The insular nature of the southern Alaska Peninsula makes expansion of summer and winter ranges difficult, so that density increases relatively linearly with population size. Caribou density on summer range peaked at about 2.9 caribou/km^2 in the early 1980s and declined to about 1.1/km^2 by 1990 and 0.7/km^2 by 1997 (Table 18). Winter range use did not change appreciably.

Mortality. Results of studies on mortality of newborn calves in the NAP and SAP in 1998 and 1999, respectively, appear in Table 20 and in Sellers et al. (2002). Information on mortality of older caribou is published in management reports (c.f. Sellers 1999).

Body Weight and Condition. Body weights of cohorts of newborn, 4-month-old, and 10-month-old caribou calves in the NAP and SAP were relatively light compared with herds in Interior Alaska (Table 19 and Appendix A). Weights of newborn calves in the NAP were similar in 1998 and 1999. This period was 5 years after the herd began a significant decline, and was apparently beginning to stabilize. In contrast, in the SAP, newborn calves were extremely light in 1989 at the end of a protracted decline that began in the early 1980s.

In the NAP during the mid 1990s, most cohorts of 4-month-old and 10-month-old calves were small and light compared with caribou in other Alaskan herds except the Western Arctic Herd (Appendix A). The 1995 and 1996 cohorts were exceptionally small and light. In April 2001, 10-month-old calves were 10 kg heavier than the lightest cohort weighed in the mid 1990s, and it appeared that size and condition of calves in the NAP was improving significantly.

Weather. We observed summer and winter weather conditions in the NAP and noted any exceptional conditions that may have influence caribou nutrition, weight, and condition. Two weather events were notable during 1995–2001. Weather was exceptionally hot and dry during summer 1997, and spring was exceptionally late in 1999. At the end of summer 1997, weights of caribou calves in the NAP were low, but not exceptionally so.

Nushagak Peninsula Herd

Population Size and Density. Results of cooperative work on population size, movements, population density, mortality, and condition of caribou in the Nushagak Peninsula Herd were summarized by Hinkes and Van Daele (1996), Collins et al. (2002), and Valkenburg et al. (2000, 2002a).

Body Weight and Condition. Prior to 2002, body weights of cohorts of 4-month-old and 10-month-old Nushagak Peninsula Herd caribou were relatively heavy, and condition of the animals was exceptionally good compared with other herds in southwestern Alaska (Appendix A). The herd arose from a transplant of caribou from the NAP to pristine range on the Nushagak Peninsula in 1988. Calves collected in late winter 1995, had 0.5–1.0 cm of measurable backfat, and during the late 1990s, most collared females produced calves at 24 months of age. However, by 2000 it appeared that condition and size of calves was declining, and caribou were spending more time off the Nushagak Peninsula. By April 2002 mean body weight of Nushagak calves declined below 50 kg.

Weather. We did not rigorously monitor weather on the Nushagak Peninsula, nor did we frequently record calf weight and condition. We therefore were not able to determine how weather may have influenced weight and condition of calves. Climate on the Nushagak Peninsula is relatively moist compared with other caribou ranges in Southwest Alaska because the peninsula is relatively small and is surrounded on 3 sides by Bristol Bay. The area is subject to periodic deep snows and occasional icing conditions but wind usually blows snow away from the higher ridges where lichens have been relatively abundant.

Mulchatna Herd

Population Size and Density. The Mulchatna Herd increased at an average rate of 17% per year from 1978 to 1996. By 1996 it was the second largest caribou herd in Alaska (210,000) and had the highest summer density of any herd (6 caribou/km^2) (Tables 17 and 18).

Mortality. There is little data on mortality of Mulchatna Herd caribou. However, because population growth ceased during the mid 1990s while calf:cow ratios were still relatively high, natural mortality must have increased substantially during the 1990s. In 1998 an outbreak of hoofrot (*Necrobacillosis*) occurred, and we suspect that mortality from this disease was significant. In addition, in October 2000, 6 of 10 female calves collected had lesions on the anterior lobes of their lungs. Because lungworms were not present but respiratory viral diseases were, we suspected this pneumonia was ultimately of viral origin (Zarnke 2000). The contribution of pneumonia to overall calf mortality was unknown.

Body Weight and Condition. By the time we began monitoring weight and condition of cohorts of calves in the Mulchatna Herd, it is likely the herd was already declining in condition because of high population density. However, calves weighed in April 1995 were still about 5 kg heavier than those in the adjacent NAP. By April 2000 calf weight had declined by about 7 kg (Appendix A). Calves collected in October 2000 were in relatively poor condition, and 6 of 10 collected had purulent lesions on the anterior lobes of their lungs.

Weather. We did not monitor weather conditions within the range of the Mulchatna Herd. However, the previously mentioned dry summer 1997 and late spring 1999 also occurred within the range of the Mulchatna Herd. In addition, summer 1998 was exceptionally wet, and a severe outbreak of hoofrot occurred.

Small Interior Herds (White Mountains, Ray Mountains, Macomb, and Chisana)

We were able to periodically monitor weights of 4-month-old and 10-month-old calves in these 4 small Interior caribou herds. We did not monitor mortality or weather conditions, but suspect that weather followed general regional patterns. In the White Mountains Herd, calf weights were consistently relatively high for Interior herds (Appendix A), and approximately 50% of the radiocollared females produced calves at 2 years of age. No significant trends in calf weights, population size, and summer density were apparent (Appendix A, Tables 17 and 18). Population size increased during the 1980s, but censuses were too infrequent to adequately determine if the population fluctuated or remained stable during the 1990s. In 2000, there were about 700 caribou in the herd and summer density remained relatively low (Table 18). Body weight and condition of female calves in October remained good in 2001.

We first conducted caribou surveys in the Ray Mountains in 1982 in cooperation with the Bureau of Land Management (Robinson 1984). At that time, we estimated about 500 caribou occupied the Ray Mountains south and west of the trans-Alaska pipeline, north of the Yukon River, and east of the Tanana–Allakaket winter trail. Biologists, pilots, and hunters commented on the large body size of these caribou and the presence of very large, trophy bulls. The 20 female calves that were radiocollared in October 1995 were relatively large for Interior calves (Appendix A), and most subsequently gave birth to calves when they reached 2 years of age. We began regular fall composition counts in 1994. By 1999 herd size had increased to about 1800 caribou. By 1999 it was apparent there were fewer large, trophy bulls in the herd, and when calves were next weighed in March 2002, the mean weight of female calves had declined by about 8 kg (Table 19).

The Macomb caribou herd has been counted almost annually in October since 1988 (Table 17). We also began handling female calves in the early 1990s. During the early 1990s, weights of female calves were low for Interior herds as the herd declined from about 800 to less than 500 (Appendix A). During the late 1990s, however, calf weights increased and herd size increased to over 600.

Like the Macomb Herd, the Chisana Herd was a relatively high priority for management and was regularly counted beginning in the late 1970s (Table 17). Population size increased to over 3000 by the early 1990s but calf weights were low when first measured in 1990 (Appendix A). The herd began a protracted decline in 1989 and continued declining through 2001. (Hunting was closed in spring 1992). Calf weights increased in the late 1990s, and were probably the largest in the state by 2000 (Appendix A). Because of chronically poor recruitment, age structure of the herd became lopsided during the 1990s, and mortality of adults increased to high levels in the late 1990s. Despite their large body size and apparently good condition in recent years, calf production by 2-year-old females has not been observed (Gardner, personal communication).

IMPROVING AND DEVELOPING TECHNIQUES FOR MONITORING BODY CONDITION IN CARIBOU

Both carcass weight and femur marrow fat were closely correlated with live weight (Valkenburg 1997). We also have continued to monitor condition scores (Gerhart et al. 1996) in caribou calves but have seldom found these data useful. These data are categorical, relatively invariate, and subjective. In herds where there are several years of weight data, comparisons of these data across years appear to be a much more objective and meaningful measure of condition than condition scores.

Weight:metatarsus ratio appears to be a very useful index to condition because it is quantitative, and both measurements can be accurately taken in the field on live animals. The index is probably mostly useful within herds (or perhaps regions) because inherent body sizes of caribou appear to vary regionally. Also, because the long bones of calves continue to grow over the winter, spring ratios cannot be compared with fall ratios.

INVESTIGATING GENETIC RELATIONSHIPS OF ALASKAN CARIBOU TO DETERMINE IF GENETIC DIFFERENCES MIGHT CONTRIBUTE TO DIFFERENCES IN BODY SIZE

Genetic distance comparisons and assignment tests indicate 5 of 6 Interior Alaskan caribou herds tested (i.e., Nelchina, Mentasta, Macomb, Fortymile, and Porcupine) are relatively closely related (Tables 21 and 22). The Chisana Herd, however, is very different from other Interior herds, and seems to be most closely related to Yukon "woodland" or "mountain" caribou (*Rangifer tarandus caribou*) herds that also appear to be very different from each other (Zittlau et al. 2000). Genetic distances between 4 of 5 herds tested in southwestern Alaska were relatively high and followed a clinal gradient from southwest to northeast. As expected, Nushagak Peninsula and NAP caribou were very similar genetically, and in the assignment test, more Nushagak caribou were assigned to the NAP than any other herd (including the Nushagak). The Nushagak Herd arose from a transplant from the NAP in 1988 (Hinkes and Van Daele 1996). Differences in allele frequencies between the Nushagak and the NAP can be attributed to the founder effect (a small number of males in the transplant) and genetic drift.

DISCUSSION

POPULATION SIZE, TREND, AND COMPOSITION IN THE DCH

Population Size

Since the early 1960s, when population size of the DCH was first monitored, the herd has fluctuated between about 2500 and 10,700 caribou. During this period, there is no evidence that herd size has been significantly affected by immigration or emigration. Neither is there compelling evidence that density-dependent regulating factors have been responsible for maintaining the herd within the observed population size range. In the late 1980s as herd size peaked, there was no evidence that condition of caribou was declining or that natality rates of adults were declining. Population growth was reversed suddenly, as weather changed and wolf numbers increased (Valkenburg et al. 1996). A similar situation occurred in the neighboring Denali Herd (Mech et al. 1998). If weather had not changed, it is likely the herd would have continued to increase.

Population Trend

As mentioned in the Background section of this report and in previous reports, the DCH experienced 4 distinct growth phases between the mid 1970s and about 1994 (Davis et al. 1991; Valkenburg 1997). The rapid decline of the early 1990s ended coincident with the beginning of wolf control in October 1993. The DCH increased through the 1995 census, but began to decline as wolf numbers recovered. From 1995 to 2001, the DCH declined by an average annual rate of about 7% ($\lambda = 0.93$). The rate of decline may actually have accelerated since 1999, but it is also possible that the 2000 and 2001 censuses were undercounts.

Composition

The proportion of bulls represented in composition counts of DCH caribou varied considerably from 1969 to 2001 (Table 1). Some of this variation was undoubtedly real, but the sometimes wild fluctuations in bull:cow ratio from year to year cast doubt on the ability of biologists to measure bull:cow ratio accurately. Prior to 1981, bull:cow ratio data were probably less reliable than they have been since then, because counts were done later in October after the rut, some biologists had little experience with composition counts, and because herd distribution could not be as easily determined (i.e., there were no radio collars). When composition counts are done after the rut, bull:cow ratios can either by biased high or low because the sexes tend to segregate. Large bulls are very often missed altogether because they often become solitary for a time as a result of exhaustion. Even in recent years, year-to-year variation in bull:cow ratios have been as much as 17 bulls:100 cows (e.g. 1997 to 1998), indicating that our ability to measure bull:cow ratio is rather limited, even when counts are done as rigorously as possible.

Real changes in herd bull:cow ratios are primarily influenced by 3 factors: hunting, recruitment of calves, and natural mortality of adults. During 1971–1974, the bull:cow ratio in the DCH was low because of increasing hunting pressure and declining recruitment (Appendix B). The bull:cow ratio recovered rapidly after the onset of wolf control and cessation of hunting in 1975, and then slowly declined as harvest was resumed in 1980. A rapid decline in the bull:cow ratio also occurred after 1986, even though harvest and fall calf:cow ratio did not change appreciably. It is therefore likely that this decline was largely caused by increasing natural mortality (Appendix B). From the late 1980s to the mid 1990s, the bull:cow ratio in the DCH remained low and did not recover appreciably until 1996. The hunting season was closed after 1991, and, though we did not measure natural mortality of bulls, most of the bulls in the DCH were in the prime age classes where natural mortality is relatively low. Even though recruitment increased only moderately after 1994 (Table 1), the bull:cow ratio increased despite the resumption of limited hunting. The limited permit hunting in the DCH after 1996 has probably had only a small influence on the bull:cow ratio.

One of the reasons that hunting does not influence bull:cow ratios more is that much of the hunting of bulls that occurs is compensatory. This is especially true in herds like the DCH where aircraft access is good, and hunters can be selective. Given the choice, most hunters select large bulls, and these are the animals most likely to die within a few months from the stress of the rut and predation. Evidence for the compensatory nature of hunting in the DCH comes primarily from modeling. When modeling the DCH, in order to mimic observed bull:cow ratios, it was necessary to reduce model inputs for male natural mortality almost to zero when hunting was heavy (Appendix B). Also, when the bull:cow ratio in a herd is high, as it was in the Mulchatna Herd before the late 1990s, it is not uncommon to see severely wounded bulls during the rut. In herds where the bull:cow ratio was low, rut-wounded bulls were rarely seen.

NATALITY RATE IN THE DCH

We were able to accurately measure natality rates of known-aged female caribou in the DCH for about 20 years (Table 2). During this period, there was considerable variation (67–96%) in natality of females ≥3 years of age. In the one particularly unusual year of 1993, natality was only 29%. Most of the variation in natality occurred in 3-year-old females, whose natality rates averaged 82% but varied from 0% to 100%. Although the relatively small sample sizes accentuated the range of variation, it is clear that in the good years, virtually all 3-year-old females produced calves, and in the bad years, very few did. In females older than 3 years, natality averaged about 88%, and varied only from about 75% to 100%, except in 1993. There was little evidence that very old females had reduced natality rates, but sample sizes of caribou older than 10 years were small. We found several cases where old females produced calves, but then died during the winter, leaving the calf orphaned. Natality in 2-year-old females was uncommon in the DCH, except in 1980, when a majority of 2-year-old females were pregnant. Any natality in 2-year-olds seems to be an indication that herd nutrition in summer is exceptionally good, but even when natality in 2-year-olds is relatively high, their contribution to recruitment is insignificant because almost all of the calves produced by these females die (Adams and Dale 1998).

Despite the considerable variation in natality rates, natality had only a minor influence on recruitment and population dynamics in the DCH. This was because most females were in the older age classes where variation in natality was less, and because predators killed most DCH calves during the summer in most years. In addition, low natality rates occurred when caribou were in poorer condition and more vulnerable to predation. During these times, wolf numbers also tended to be high, and predation on calves during summer was higher than normal. Thus by fall, no matter how many calves were produced, few remained by the time composition counts were done in early October. For example, when natality reached a record low of 29% in 1993 fall calf:cow ratio was 5 calves:100 cows (Tables 1 and 2). The previous year, the DCH had one of the highest natality rates recorded, but there were only 11 calves:100 cows in early October, and the population was still declining.

We found that mean weight of female calves in early October was a reasonably good predictor of natality rate the following May (Fig 2). This relationship was expected because it is now clear that summer nutrition affects natality and autumn calf weights (c.f. Skogland 1984).

NATALITY RATE IN OTHER HERDS

Natality of Nelchina caribou was consistently lower than in the DCH during the period for which comparable data were available, except during the unusual year of 1993 (Tables 2 and 3). This was true for all age classes, even for females that were ≥6 years of age. No 2-year-olds produced calves, and natality of 3-year-olds averaged only 28% from 1997 to 2001 (Table 3). Natality rates were particularly low in 1999 and 2000 (50% and 60% respectively). These data on natality in the Nelchina Herd and data on calf weights in early October lead us to conclude that summer nutrition of Nelchina caribou was relatively poor, at least from 1996 to 2000 (Table 3 and Appendix A).

RECRUITMENT IN THE DCH

Davis et al. (1991) concluded that fall composition counts yielded good estimates of recruitment because mortality of calves after their first summer appeared to be similar to mortality of older caribou. Although this was a valid conclusion during the 1980s in the DCH, it was certainly not true from 1991 to 2001 (Table 5). During these years, mortality of calves from 4 months to 16 months of age averaged 41% whereas mortality of older caribou averaged 13%. Modeling further substantiated these conclusions, because fall calf:cow ratios could be successfully used as inputs for recruitment prior to 1989, but had to be reduced during the 1990s to make the model population accurately track census data. Bergerud (1971) reached similar conclusions during work on caribou in Newfoundland, and he advocated using April composition counts rather than fall counts as an index to recruitment (Bergerud 1978). For many years, we also used April composition counts when monitoring Alaskan caribou herds (c.f. Davis et al. 1980; Davis et al. 1991). Although these counts may often be better than fall counts because they include the periodically high winter mortality of calves, obtaining representative samples of herd composition is much more problematic in April because many calves have left their mothers, and adult females often have a different distribution than males, yearlings, and most calves. It is not uncommon to find higher calf:cow ratios in April than during the previous October (Tables 1 and 4). However, April counts are usually sufficient to detect large losses of calves during the winter, and thus can be very useful in foretelling an imminent population decline (Tables 1 and 4). In the DCH after 1991, and in many Interior caribou herds where calves are large enough to carry an adult-sized radio collar, we usually tried to collar calves in October and were thus able to obtain an independent estimate of overwinter calf survival. We abandoned April composition counts after 1991 in the DCH and other Interior herds.

HARVEST

Reasonably accurate harvest data were available from the range of the DCH since 1968 when the harvest ticket system was implemented and computerized. However, it was necessary to include a factor for non-reporting during years when permits were not required and harvests were reported through the quasi-required (i.e. there is no enforcement) harvest ticket report cards. During 1968–1973, biologists estimated that about 72–85% of the caribou taken were reported, but it was not clear how this proportion was calculated. Later, during the late 1980s we estimated unreported harvest by casually interviewing hunters in the field, determining if they had been successful, and later checking to see if their caribou were reported. Results of these interviews indicated that only about 63% of the caribou taken were reported (Davis et al. 1991:40). We also estimated that hunters contributed an additional 10–20% of the reported harvest to mortality from wounding loss. To estimate hunter harvest for the purposes of this report we divided reported harvests by 0.63 to obtain the estimated total harvest when hunting was not under registration or drawing permits. We did not include estimates for wounding loss, and during modeling exercises, wounding loss was included in estimates of natural mortality. From a population dynamics and management perspective, wounding loss would only be significant when harvest of females is high. With most Interior Alaskan caribou herds, this is seldom the case because predation usually limits allowable harvests to small numbers of bulls and very few cows.

Prior to 1983, biologists made no attempt to limit herd size in the DCH through harvest, although during 1971 and 1972, harvests, combined with declining recruitment, probably contributed to a significant population decline (Appendix A). From 1983 to 1986, however, managers deliberately tried to stabilize the herd. During these years of high recruitment, it was necessary to harvest 15–18% of the herd annually to prevent the population from growing. After 1986 the director of the Division of Wildlife Conservation overruled managers and decided to allow the herd to continue to grow. From a research perspective, this was an attractive idea because we were interested in determining at what point the herd would begin to be limited by density-dependent factors. After 1986, harvest of females was insignificant to population growth, and harvest of males had only a minor effect on population size. Harvest was eliminated in 1992 after the population crashed and the bull:cow ratio had declined to below 30:100. After a closure of 4 years, hunting resumed with a limited permit drawing hunt for bulls only. During 1996–2001, harvest ranged from 22 to 50 bulls annually (1–2% of the herd), and had very little effect on herd growth or the bull:cow ratio. As mentioned in the previous section on mortality, much of the harvest of bull caribou appears to be compensatory.

DETERMINING WEIGHT AND SIZE OF CALVES IN APRIL AND TESTING A MODEL THAT PREDICTS RECRUITMENT BASED ON CALF WEIGHTS

Soon after we began collecting data on weights of DCH calves in April, a close correlation between 10-month-old calf weights and fall calf:cow ratio became apparent (Fig 2; Table 9). How close this relationship will continue to be remains to be seen, but there are many reasons to believe there are real biological factors that drive this model. Weights of calves in April are primarily determined by their weight gain the previous summer (i.e., summer nutrition), and to a lesser extent by weight loss during winter. Summer nutrition has been shown also to affect natality the following May, and winter nutrition of females has been shown to affect the survival of calves after birth (c.f. Skogland 1985). Together, natality and postnatal calf survival affect the number of calves present in fall. In addition, when weights of calves are low in April, it probably also means that caribou are generally in poor condition; the population is therefore more vulnerable to predation, and wolf numbers are likely to be relatively high (c.f. Dale et al. 1994; Valkenburg et al. 1996; Mech et al. 1998). Because wolves have consistently been shown to be one of the 2 most important causes of calf mortality in summer, the number of calves surviving to fall would be expected to be low when wolf numbers are high. In summary, it appears that 10-month-old calf weights integrate several factors that all influence numbers of calves present in the herd in fall. At the present time mean weight of female calves in April in the DCH predicted about 58% of the variation in the calf:cow ratio in October (Table 9). However, the currently close relationship between April calf weight and autumn calf:cow ratio could be a coincidence and might deteriorate over time. In the Nelchina Herd, there was no relationship. This could be because calf:cow ratios have not shown the same degree of variability as they have in the DCH, and/or because they are not as dramatically influenced by predation in the Nelchina Herd.

DETERMINING IF WEATHER IS A FACTOR IN THE GROWTH OF THE DCH

Snow Depth

The significant negative correlation between snow depth and autumn calf:cow ratio is consistent with the hypothesis that snow depth influences weight of newborn calves, and subsequent calf survival (c.f. Skogland 1984; 1985; Adams et al. 1995; Reimers 1997; Mech et al. 1998). It is also likely that with more data a significant inverse relationship between snow depth and 10-month and newborn calf weight would also eventually be found (Table 9). Within the DCH, the effects of snow depth may be magnified because it appears that winter range is not abundant, caribou frequently search for new wintering areas (Table 13), and the proportion of mosses in the winter diet was relatively high, particularly after 1990 (Table 11). A deep, extensive, or dense snow cover at the present time would likely cause significant nutritional stress in the DCH.

July Temperature and Rainfall

Although neither July temperature nor July rainfall were significantly related to any of the caribou condition or population variables, they were correlated with snow depth (temperature positively and rainfall negatively), and snow depth was correlated with autumn calf:cow ratios. This relationship between snow depth and July temperature is likely due to oscillations in Pacific weather patterns. We hypothesize that these short-term (i.e., decadal) weather cycles are likely to influence caribou, at least in the Interior Alaskan herds. When snow is deep and July temperatures are relatively high, summer caribou calf survival, autumn calf weights and calf:cow ratios, and the following year’s natality tend to be low. Wolves prosper during these conditions, and the Interior caribou herds decline as a result. We will continue to research and refine our measures of summer weather in an effort to explore the influence of short-term summer weather patterns on caribou dynamics.

Shading Experiments

The initial shading experiments we did in the early 1990s and the work of Lenart et al. (2002) with the Chisana Herd may provide clues to why caribou calves gain more weight in some summers compared to others and less weight when their population density is higher. During cloudy summers, leaves of *Salix pulchra* probably remain lower in tannin content longer than during sunny summers. During sunny and dry summers, many plants also senesce earlier. Although in our experiments there were no clear differences in in vitro digestibility between shaded and unshaded plots, the primary effects of tannin would be to bind proteins and make them unavailable to caribou. This effect might not be apparent with the in vitro method. In other shading experiments, Lenart (1997) found that nitrogen content was higher in a variety of caribou forage plants under shaded conditions in the range of the Chisana Herd. Similar results were reported for willows in Norway by Bo and Hjeljord (1991). Lenart (1997) thoroughly discussed the potential effects of varying summer precipitation and sunlight on biomass, digestibility, and plant senescence, and she also reviewed available literature on the subject.

Summer feeding ecology of caribou is complicated, however, and they may switch to eating other foods in summers if willows become less palatable. There are also a multitude of other factors that could also influence summer weight gain in caribou. Some of these include length of the growing season (Boertje et al. 1996), the abundance of mushrooms and blueberries (Boertje 1981; J Wright, personal communication), insect abundance (Morschel and Klein 1997), and vegetation senescence due to summer drought. With so many variables to control for, it is an exceedingly difficult task to determine which factors are most important in any given year. The relatively poor correlations between weight of female caribou calves in October and the various weather variables tested (Table 9), probably indicate that July temperature and rainfall do not adequately reflect summer feeding conditions for caribou. The fact that weights of female calves at 4 months of age are variable from year to year in many herds (Appendix A) while population density remains constant (Table 18) indicates that variability in summer nutrition is, to a high degree, independent of population density. Further investigation of caribou summer nutrition during cloudy versus sunny summers would require long-term research on a variety of plant species and a detailed knowledge of annual variation in the summer food habits of caribou. The sampling problems inherent in this approach are daunting, and for management purposes, it may be sufficient to simply monitor female calf weights in autumn if the desire is to predict future herd performance and determine if population size objectives should be changed.

FOOD HABITS

Spring and Summer

For the caribou herds in Interior and Arctic Alaska, the flower buds of *Eriophorum vaginatum* are the first new green food to which caribou have access. *Eriophorum* buds are unusually high in digestible protein (Boertje 1981; William Collins, personal communication), but the timing of bud growth and their abundance varies greatly from year to year. The timing of bud growth depends a great deal on temperatures in April. We observed caribou in the DCH feeding on *Eriophorum* buds around 20 April in years when temperatures were unusually warm. In Southwest Alaska, we also observed Mulchatna caribou with noses covered with yellow *Eriophorum* pollen on 7 April 1995. In some years *Eriophorum* buds begin to grow under the snow, but in other years, growth can be delayed or arrested by a return to colder weather. In Southwest Alaska, *Eriophorum vaginatum* occurs only as far south as about Port

Heiden, so the caribou of the Alaska Peninsula and Unimak Island are without this important food (Hulten 1968).

The importance of lichens as summer food for caribou in the Interior herds remains largely unknown. There is reason to believe lichens are an important energy source in some herds. In particular, in the Nelchina Herd, lichens became depleted on the summer range during the 1990s when we observed autumn condition of calves to be chronically poor.

Winter

On all of the caribou ranges where we obtained fecal samples, lichens usually made up the majority of discerned plant fragments in the winter diet (Tables 11 and 12). There were some exceptions to this, however, especially in the Delta Herd, where lichens made up only 20–50% of discerned fragments during some years. Typically, when the proportion of lichens found in fecal pellets declined, the proportion of mosses, shrubs, sedges, and grasses increased. On some winter ranges of the DCH, mosses composed 30–50% of plant fragments.

MONITORING MOVEMENTS AND DISPERSAL OF DCH CARIBOU

History of Winter Range Use

The frequent shifts in winter ranges used by the DCH probably indicate that the herd has a shortage of high quality winter range. Since 1990 the 2 most consistently used winter ranges were the lower Yanert River drainage and Nenana River Valley north from Windy Pass to the Denali Park Road, and the area between Iowa Ridge and the Tanana River between Dry Creek and the Little Delta River. Other areas were either used by relatively small numbers of caribou or for short periods of time. Proportions of lichens in the winter diet of the DCH after 1990 were consistently lower than in other herds. Now that herd size is once again below 3000, it appears that winter range use may be stabilizing. In 2001–2002 radiocollared DCH caribou did not cross the Delta River for the first time in 5 years (although 2 collared caribou did winter near the Brushkana Campground along the Denali Highway).

History of Calving Area Use

In addition to the weather-related shifts in calving areas that appear to occur in most caribou herds, DCH caribou also shifted their major calving area in a progressive manner beginning in about 1987. By 1992 most caribou were calving in the Wells Creek drainage of Unit 13. From 1999 to 2001 calving distribution of the DCH continued shifting south and east to the Monahan Flats and upper Susitna River. In all of these 3 years, lingering snow and cold temperatures caused the Wells Creek calving area to be snow covered into early June. It is unclear whether this latest shift in use of calving areas is progressive behavioral geographic shift or if it is weather related. However, DCH caribou are now beginning to calve in an area that has traditionally been used for calving by Upper Susitna caribou. Interaction between Delta and Upper Susitna caribou now occurs on all seasonal ranges.

History of Summer Range Use

Summer range use by the DCH was relatively stable during 1976–2001, except for a few cases where groups of caribou spent most of June in the mountains of the south side of the Yanert drainage above Louis Creek. Even the collared DCH caribou that have calved as far to the east as the Upper Susitna have returned to the normal DCH summer ranges on the north side of the Alaska Range. However, beginning in 2000, some DCH caribou returned to the Wells Creek/Denali Highway/Butte Lake area as early as 1 October, and there has undoubtedly been some interaction of Upper Susitna and DCH caribou during the rut.

Unusual Movements

Aside from the dramatic shift in the main calving area that occurred from 1987 to 1992, the most unusual movements of the DCH occurred in fall 1992, and appeared to be associated with highly unusual weather. Unusual movements were seen in all Interior herds in response to this unusual weather system. In addition, the pioneering movements of small numbers of DCH caribou across the Delta River during 1997–2000 were also unexpected. In all of these cases, caribou returned to their traditional summer ranges.

Although we observed unusual movements of individual radiocollared caribou outside the normal range of the DCH, in only 3 cases since 1979 was a radio collared DCH caribou observed with a calf in areas outside the normal range of the herd or away from the calving distribution. One radiocollared DCH cow was observed with a calf near Lower Tangle Lake in 2000. One additional cow that was born in the DCH in 1997 took up residence in Denali Park between the Teklanika River and the east fork of the Toklat in 1999, and she calved in the park near the Teklanika Bridge in 2002. We were unable to determine if she calved there in 2001. One DCH cow also calved on the calving area of the Nelchina Herd near the Oshetna River in 2002. Since we began radiocollaring caribou in the DCH in 1979 we have found no evidence that unusual movements of groups or individuals affect population size estimates in the DCH or other Interior caribou herds.

MONITORING MORTALITY IN THE DCH

Mortality of Caribou from Birth to 4 Months

Summer mortality of DCH caribou calves was likely lower during the 1980s than during the 1990s, even immediately after the wolf control program in 1994 and 1995. In most years in the DCH, it was likely that wolves killed more caribou calves than any other predator. This was also generally true in the Denali Herd and in the Fortymile Herd, although in some years grizzly bears were documented to have killed more collared calves in the Denali Herd than wolves (Adams et al. 1995; Boertje and Gardner 2001). Golden eagles were the only other significant predator of caribou calves in these 3 Interior herds. In some years and in some herds (e.g., Chisana), it is likely that coyotes may also be a significant predator of caribou calves. Coyotes were abundant on the calving area of the Chisana Herd in the early to mid 1990s following the decline of snowshoe hares in the western Yukon (Gardner, personal communication). A major difference between coyotes and eagles, and the larger predators like bears and wolves is that female caribou will defend their calves against coyotes and golden eagles (and even wolverines [*Gulo gulo*]). It is therefore unlikely that coyotes and eagles will ever kill more caribou calves than bears and wolves. In contrast to Newfoundland, lynx have not been shown to be a major predator of newborn caribou calves in Alaska (Bergerud 1971).

Mortality of caribou calves is likely to be related to their size and condition at birth (Skogland 1985; Adams et al. 1995; Mech et al. 1998). Because we did not begin weighing newborn calves until 1995, it was not possible to determine if weight and condition of calves affected survival in the DCH. However, it is likely that newborn calf weights were low in the DCH, during the early 1990s because condition and size of older female calves was low during that period and because newborn calf weights were low in the adjacent Denali Herd (Adams et al. 1995). In addition, DCH caribou consistently lost weight over winter during the 1990s and it is therefore likely that winter nutrition was suboptimal (Valkenburg et al. 2002a, in press). However, newborn calf weights in the DCH have been increasing and are now as high as they were in the Denali Herd during the mid 1980s (Table 19).

Mortality of Radiocollared Female Calves 4–16 Months of Age

Mortality of calves 4–16 months of age was variable in the DCH, and wolves continued to be the greatest mortality factor. Judging from changes in calf:cow ratios in the 1980s, it appeared that mortality in this age group was similar to that of older females. However, during the 1990s, after we began radiocollaring calves at 4 months of age, mortality of these caribou was high, and it was no longer possible to use fall calf:cow ratios as a recruitment input in the population model (Appendix B). We suspect that mortality in this age group depends upon condition and size of calves in fall, the areas that are available for winter range, and snow conditions. For example, if relatively heavy calves winter in areas where snow is shallow and the terrain is open so that caribou can see wolves coming, their mortality rates will be low. On the other hand, in forested situations where snow is deep and wolves have the element of surprise, the relative inexperience of calves and their shorter legs probably put them at a significant disadvantage compared with older, larger caribou. During declines in numbers of snowshoe hares, caribou in this age group are also occasionally preyed upon by lynx, and probably by grizzly bears. Although we documented mortality from lynx predation in the DCH during the early 1990s and in the Fortymile Herd during the early 1990s and in 2001–2002 (Valkenburg 1993:8; Boertje, ADF&G, personal communication), lynx predation in Alaska has never been found to be as high as it can be in Newfoundland (Bergerud 1971). During 1991–2002, no collared caribou in this age group were documented to have died of disease or starvation in the DCH, even during years of record deep snow in the early 1990s.

Mortality of Radiocollared Females 16–30 Months of Age

During all of the years of this study, despite the tendency of some caribou in this age group to inhabit the periphery of the DCH range, these caribou consistently had the lowest mortality rates. These are relatively experienced animals in their physical prime of life. Wolves continued to be the greatest cause of mortality, although 1 radiocollared male yearling was killed by a lynx during the early 1990s.

Mortality of Radiocollared Females Older than 30 Months of Age

Mortality of caribou in this age group was variable. In years of population decline, mortality sometimes exceeded 20%. Older females (i.e., older than 10 years) contributed most to mortalities in this age group and wolves were the main cause of death. Wolves killed a majority of these caribou, and snow depth was a significant contributing factor. Breached births, resulting in the deaths of both mother and calf were also occasionally seen.

EXPERIMENTAL DIVERSIONARY FEEDING TO REDUCE CALF MORTALITY

Effects of Diversionary Feeding on the Number of Calves Killed by Wolves

Diversionary feeding had no measurable effects on the numbers of caribou calves surviving to October in the DCH, most likely because not all calves were born on the Wells Creek calving area where diversionary feeding occurred, and because wolves continued to kill calves when they moved to summer ranges on the north side of the Alaska Range. In addition, there appeared to be a limit to how long wolves in Wells Creek were content to stay near the den despite the abundance of food presented to them. In both years that diversionary feeding occurred, wolves continued to hunt on the calving area to some degree, and when they encountered nursery bands of caribou, they killed many calves.

Effects of Diversionary Feeding on Hunting Behavior of the Wells Creek Pack

Diversionary feeding significantly affected the behavior of the Wells Creek Pack and largely restricted their movements to the immediate vicinity of the den during the last 2 weeks of May. However, it appears that wolves will continue to hunt despite the provision of abundant food at the den. Ingliss et al. (1997, 2001) theorize that there is an adaptive advantage to exploring and assessing resources that overrides the drive to forage optimally, except when hunger is great. This theory is used to explain why animals will pass up abundant, easily accessed food in favor of food that is more difficult to obtain.

RECOLLARING ADULT FEMALES AND MAINTAINING COHORTS OF COLLARED KNOWN-AGED FEMALES

Female calves collared as either 4-month-olds or 10-month-olds showed no obvious ill effects when fitted with adult-sized radio collars. During the early 1990s when winter mortality of calves was exceptionally high, we were concerned that radio collars may have been predisposing them to mortality. However, when we switched to smaller, lighter collars with no visual collar attached, mortality rates continued to be high. However, because we did not handle the same calves at 4 months and 10 months of age, we did not determine if radiocollared calves lost more weight over winter than uncollared calves in the DCH. There was some evidence from the Nelchina Herd that collared caribou calves gained less weight or lost more weight during winter than uncollared calves. In the DCH, radio collars were changed when a caribou reached 5 years of age. Over the 20+ years of the study, we found no instances where radio collars had become too tight or resulted in infection or even skin irritation.

During this study, although recruitment varied, we attempted to collar about 15 caribou calves each year regardless of the strength of each cohort. Our sample of radiocollared caribou was therefore not weighted by cohort strength (i.e., not age-justified). In practice, however, because we collared calves at 4-months after 1990, varying winter mortality resulted in varying numbers of collared calves being recruited into the herd. During years when recruitment was low and the herd was declining, the number of radio collars in the herd also declined. From 1985 to 1991 the number of radiocollared females older than 2 years in the DCH varied from a low of 24 during the period of severe population decline to a high of 42 during years of population growth.

MONITORING DENSITY, MORTALITY, BODY CONDITION, AND WEATHER IN ALASKAN CARIBOU HERDS OTHER THAN THE DCH

Nelchina Herd

Population size of the Nelchina Herd increased to over 50,000 and then declined to 30,000 the mid-to-late 1990s. During this period, there were clear indications that population density of caribou on the summer range compromised condition, natality, and probably recruitment. It is likely that the effects of density were exacerbated by dry summer weather in some years. In contrast, winter weather and quality of the winter range used by the Nelchina Herd during the 1990s did not appear to be limiting the herd. Data on weights of calves during October 2000 may indicate that summer range of the herd is recovering, and we predict higher natality rates in 2002.

The Nelchina Herd contrasts nicely with the Delta Herd, because it appeared that summer nutrition was most limiting in the former, whereas winter nutrition was most limiting in the latter (Valkenburg et al. 2002a). In addition, predation appeared to be a much stronger influence in the DCH both in summer and in winter, due primarily to herd size. The DCH was more productive (i.e., had higher natality) than the Nelchina Herd but had chronically lower fall calf:cow ratios, despite the fact that calves were in better condition in October.

Northern and Southern Alaska Peninsula and Unimak Island Herds

The NAP declined during 1995–2001, condition of calves and adults was relatively poor, and mortality was high. Mean body weights of some cohorts of female calves declined below 45 kg (100 lb), and pneumonia may have influenced calf survival. Although poor summer nutrition was probably the most important limiting factor, NAP caribou may also have been short of high quality winter range. These caribou crossed the Naknek River and were apparently searching for new winter range during the 1990s. It is clear now that the population management goal of maintaining the NAP at around 20,000, although successful for about 10 years, was overly optimistic. In contrast, caribou on Unimak Island and in the SAP were recovering from population lows after the mid 1990s and were in relatively good condition (Valkenburg et al. 2002b).

Nushagak Herd

This transplanted herd erupted after introduction in 1988 and showed every indication of being in optimal nutritional condition (Hinkes and Van Daele 1996). However, in contrast to caribou transplanted from the Nelchina Herd to the Kenai Peninsula, mean body weights of Nushagak caribou calves at 4 and 10 months of age remained at only moderate levels (57 kg) even after several generations. It is possible that body size in these caribou is genetically constrained. After about 10 years of rapid growth, the Nushagak Herd appeared to be declining in condition. By April 2002, calf weights were down to 49.5 kg, and condition of calves was relatively poor. During 1999–2002 Nushagak caribou also began ranging away from the Nushagak Peninsula in larger numbers (Collins et al. 2002; Aderman, personal communication).

Mulchatna Herd

The Mulchatna Herd experienced one of the most spectacular periods of population growth of any herd in Alaska in recent times (Valkenburg et al. 2002b). The herd also produced high numbers of trophy bulls, and by 1999, these bulls composed about 30% of the top 100 barren-ground caribou in the records maintained by the Boone and Crockett Club (Boone and Crockett Club 1999). Until the late 1990s, there were spectacular numbers of trophy bulls in the herd, but numbers of these bulls apparently declined rapidly thereafter. We suspect the primary reason for the decline in numbers of trophy bulls was related primarily to poorer nutrition that resulted in reduced antler growth and higher natural mortality of older bulls. Selective hunting of bulls may also have played a role. Size and condition of calves in the herd also declined in the herd after 1995. Although the herd expanded both its summer and winter ranges, these range expansions were apparently insufficient to maintain body size and condition of caribou.

Small Interior Herds (Chisana, Macomb, Ray Mountains, and White Mountains Herds)

Chisana Herd. As the Chisana Herd peaked in size in the late 1980s, condition and size of calves declined. There were also some years when pregnancy rates were relatively low (Gardner and Farnell, personal communication). Subsequently, however, body size and condition of calves increased to very high levels but numbers of calves remained very low. It appears that the present low recruitment is related to high levels of predation.

Macomb Herd. Like the Chisana Herd, caribou calves in the Macomb Herd were small and in poor condition during the late 1980s as the herd declined from about 800 to less than 500. During the late 1990s, condition and size of calves had recovered to high levels and the herd increased again to over 600 caribou. The summer range of this herd is apparently quite limited but there seems to be an abundance of suitable winter range north of the Tanana River.

Ray Mountains Herd. During the early 1980s when we first surveyed caribou in the Ray Mountains, this herd appeared to be an example of a small, very low density Interior herd that was being held at a low density by predation. However, the herd increased steadily and numbered about 1800 by 1999. Mean weights of calves was high and their condition was exceptionally good in October 1995 when we radiocollared 20 calves. Many of these females produced their first calf at age 2, and we expected condition of these caribou to remain high because density of the herd remained relatively low. However, in late March 2002, after a very mild winter, calf weights were relatively low and calves were only in moderately good condition. In addition, in comparison to previous years, few large trophy bulls were seen during fall composition counts after 1997 (hunters took less than 5 caribou per year). Because weather conditions did not appear to be exceptional either in summer or winter, it appears this herd may also be constrained by increasing density.

White Mountains Herd. In contrast to the other 3 small Interior herds mentioned above, the White Mountains Herd has probably remained relatively stable in size (although it was not counted continuously), and condition of calves has remained good. The herd has largely abandoned winter ranges west of Beaver Creek in favor of those in the Preacher Creek drainage in recent years, but this change has not been associated with a change in population size or condition.

IMPROVING AND DEVELOPING TECHNIQUES FOR MONITORING BODY CONDITION IN CARIBOU

A large number of techniques have been found to be useful in determining condition of caribou and other ungulates (Riney 1955; Klein and Strandgaard 1972; Kistner et al. 1980; Allye–Chan 1991; Gerhart et al. 1996). Most biologists also agree that monitoring population condition should be an integral part of management programs where humans have the ability to regulate the size of an ungulate population. However, to be useful for monitoring the condition of ungulate populations over time, data must be consistently collected, and preferably, collected annually. Annually collected, consistent data makes it possible for biologists to separate short-term weather-related trends from trends in body size and condition that are related to density-dependent factors. Until the 1990s, condition data on Alaskan caribou were not consistently collected, primarily because biologists relied on specimens and measurements from hunter-killed samples of caribou taken at checkstations or at concentrated hunting areas. Although collections were adequate in some years (or could have been), changing caribou movements, varying seasons and bag limits, differing methods that hunters use in processing carcasses, and the expensive and time-consuming nature of the checkstation approach resulted in very little useful condition data being collected in Alaska from the 1950s to 1990s. Despite relatively large sample sizes in some years (e.g., at Anaktuvuk Pass and the Kobuk River in the late 1960s, and from checkstations on the Taylor and Denali Highways during the late 1960s and early 1970s) after data were segregated by sex and age, sample sizes were often too small to be useful. Furthermore, although carcass weight (one of the most useful measures of condition) could have been collected, it often was not, because hunters do not field dress caribou in a consistent manner. Some large collections of mandibles did prove to be useful, but the utility of the data was often not recognized until long after it was collected (Valkenburg et al. 1991; Eberhart and Pitcher 1992; Ver Hoef et al. 2001).

Samples of weights and measurements of female calves obtained either during collaring programs or from collections have proven to be much more useful than the haphazard samples of various ages and sexes of caribou obtained from hunters. In the more high-profile caribou herds like the DCH, Fortymile, and Nelchina, it has proven to be relatively simple and inexpensive to obtain samples of newborn calf weights, and measurements and weights of 4-month-old and 10-month-old female caribou calves. Although in other herds (e.g., Northern and Southern Alaska Peninsula, Mulchatna, and Nushagak) this kind of sampling protocol was constrained by the availability of reasonably priced helicopters, we were still able to obtain enough samples to reasonably monitor trends in body weight and condition.

GENETICS OF ALASKAN CARIBOU

Genetic comparisons of Alaskan caribou remain incomplete. We hope to finish work with microsatellite DNA in 2002 or 2003. So far, however, work has shown that most caribou in Interior and eastern Arctic Alaska are closely related (i.e., Nelchina, Mentasta, Macomb, Fortymile, White Mountains, Porcupine, and Central Arctic), except for the Chisana Herd which appears to be from woodland (i.e., *R. t. caribou*) stock. It appears likely that the genetic constitution of caribou in the Denali and Delta herds and other Alaska Range herds also will be similar to caribou in the other Interior herds. However, caribou in southwestern Alaska are relatively distinct from Interior caribou, and calves of caribou in southwestern Alaska have not been shown to achieve the same large body sizes, even when translocated to pristine range. Despite their smaller body size, caribou in southwestern Alaska are capable of growing very large antlers, and the current world record barren-ground bull is from the Mulchatna Herd. A remaining mystery is the Western Arctic Herd, which has very small caribou, and bulls that seldom grow large antlers. In 1999 there were fewer than a half dozen Western Arctic bulls in the Boone and Crockett records (Boone and Crockett Club 1999). The largest 4- and 10-month-old calves in the Western Arctic Herd weighed less than the smallest calves from other Alaskan herds (i.e. about 45 kg) (Appendix A). Whether these diminutive animals result from the herd's genetic constitution or a long-term adaptation to a less productive range remains to be determined.

CONCLUSIONS

POPULATION REGULATION IN INTERIOR ALASKAN CARIBOU

Although it is now clear that although density-dependent feedback mechanisms may constrain the upper bounds of caribou herd sizes in many cases, in the absence of hunting, sizes of Interior Alaskan caribou herds can be expected to fluctuate with unpredictable amplitudes and periods or remain relatively stable. Few, if any, of the older proposed theoretical models of population regulation (i.e., single stable equilibrium—"balance of nature," multiple equilibria [Haber and Walters 1980], stable limit cycles [Caughley 1981], chaos theory [Gleick 1987], or conventional carrying capacity theories [e.g., McCullough 1979; Caughley 1970, 1976, 1979]) have been supported by empirical data from caribou herds.

In considering the DCH data set, it is difficult to even think in terms of "carrying capacity," except perhaps as discussed by Sinclair (1981) where he states, "A population at carrying capacity should not be thought of as one with a stable or constant level. Rather, it is one that is fluctuating, often extensively, between certain boundaries." Even most of the newer ideas about carrying capacity (e.g., Caughley and Gunn 1993) appear to be of limited usefulness to caribou managers because, as others have pointed out previously, almost every population is unique in many important ways. In a similar discussion of population regulation in moose, Van Ballenberghe (1980) opined that much of the theory on population regulation is contrived because of "people trying to force ecological events into the conceptual framework of classical physics and systems theory." Our research on the dynamics of caribou in Alaska over the last 20 years has lead us to conclusions similar to those reached by Hamlin and Mackie (1989) for mule deer (*Odocoileus hemionis*) in the Missouri Breaks. That is, environmental variation and stochastic factors are often likely to obscure and override density-dependent factors. Hamlin and Mackie (1989) did such an excellent review of the subject, and there has been so much written about population regulation in ungulates, that we saw no point in elaborating on the discussion as it relates to caribou.

Although it is possible to generalize broadly about limiting and regulating factors in caribou herds, our conclusions are that caribou ranges are so different and environmental variation is so pervasive that herd-specific information will continue to be critical for management. The importance of collecting long-term population data (periodic census and annual composition data) and information on the condition and movements of animals cannot be overemphasized. Over time, this will allow managers to compare current information with past performance of the herd under similar circumstances.

Long-term monitoring, comparative study, and the development of case histories of caribou herds have been very efficient methods for determining mechanisms involved in the dynamics of these populations. This work should continue in as many of the high-profile herds as possible.

NATALITY AND MORTALITY

Contrary to earlier ideas that natality in caribou is relatively fixed (e.g., Bergerud 1978), we have found that it is, in fact, quite variable (in 2- to 4-year-old females). We found also that in the larger caribou herds (i.e., Nelchina) this variation has a significant influence on population growth. However, in most smaller (herds less than 20,000) Interior Alaskan herds, predation is usually so overriding that the influence of variable natality is negligible.

Most changes in population trajectory of Alaskan caribou herds are caused by changes in mortality. In the Interior herds, mortality was almost always a result of predation, although weather-caused declines in body condition were a predisposing factor. In Southwest Alaska we documented that disease is also likely to be a significant mortality factor.

Hunting of bull caribou is to a significant degree, compensatory. Therefore, it is seldom necessary to completely eliminate all harvest, even in small, declining herds. Elimination of harvest is only justified if bull:cow ratios fall to unacceptably low levels, or where other management objectives (besides harvest) are important.

OPTIMUM HERD SIZE FOR THE DCH, NELCHINA, AND NORTHERN ALASKA PENINSULA HERDS

For caribou herds in which it may be possible for managers to control herd size with hunting, it is necessary to establish population objectives or guesses about optimum population size. To do this, it is very useful to know the history of population fluctuations. In fact, this may be one of the best clues to how herds may react in the future. With knowledge of past population history and annual collection of population and condition data, managers can make reasonable guesses about the optimum population size for a given herd. By optimum population size, we mean the size at which it is most likely that harvest can be maximized in the long-term (i.e., decades). For several of Alaska’s 32 or 33 herds, it may now be reasonable to estimate optimum herd size. These herds include the NAP, SAP, DCH, and the Nelchina Herd. For the NAP, SAP, DCH, and Nelchina herds, we currently believe the most appropriate population goals are about 10,000, 3000, 3000, and 35,000, respectively.

CARIBOU HERDS ARE POPULATIONS

The last 20 years of data from radiocollaring and radiotracking caribou indicate that caribou herds can be considered as closed populations for the purposes of population management. Although interchange of caribou between herds occurs enough so that most adjacent herds are very closely related genetically (although there are exceptions), the number of dispersing caribou is so small that it has no influence on population dynamics.

NUTRITION CAN EXPLAIN VIRTUALLY THE ENTIRE RANGE OF BODY SIZES IN ALASKAN CARIBOU

Nutrition has far more influence on the body size of Alaskan caribou than any other factor. However, cause(s) for the very small size of Western Arctic caribou remain a mystery.

IN THE DCH RECRUITMENT OF CALVES TO AUTUMN CAN BE PREDICTED FROM WEIGHT OF CALVES IN APRIL

April calf weights appear to integrate many factors that eventually affect recruitment of calves. Whether this relationship will hold for other herds is unknown.

MONITORING BODY CONDITION OF ALASKAN CARIBOU

We conclude that live weight of 4- and 10-month-old female calves is likely to be the best measure of condition of Alaskan caribou, especially where historical weight data for herds are available. However, unless herds are known to be closely related genetically, comparisons of live weight across herds will be confusing.

DIVERSIONARY FEEDING OF WOLVES TO IMPROVE CARIBOU CALF SURVIVAL

Diversionary feeding could be a successful method of helping to reduce predation in some cases but it has limitations, primarily because wolves continue to hunt even when they are not hungry, and because they are such efficient predators of caribou calves. Diversionary feeding might be cost-effective if combined with surgical or chemical sterilization of dominant pairs, translocation, or trapping and other lethal control of wolf numbers.

EFFECTS OF WOLF CONTROL ON THE DCH

Snaring, trapping, and ground shooting of wolves during 1994–1995 was effective in reversing the decline of the DCH. Declines in adjacent caribou herds without wolf control also stopped, but in contrast to the DCH, these herds did not grow subsequently. The wolf control program in the DCH was more difficult to implement than expected, and it was inefficient, costly, and controversial. In addition, it did not produce the dramatic population increase in the DCH that accompanied the aerial shooting program a decade earlier, and it did not allow a return to the higher caribou harvests of the 1980s. The program would undoubtedly have been more effective if it had been allowed to continue and/or if it had been expanded slightly to include the main calving area of the DCH. Immediately after the program was over, wolves remained the most significant cause of death of caribou calves and adults in the DCH.

MANAGEMENT IMPLICATIONS

The main thrust of this research project was to determine which factors are most important in driving caribou population fluctuations, particularly in the small-to-moderately sized herds that occur in Alaska’s Interior. Our working hypothesis during the latter part of the study was that population fluctuations are primarily caused by the interaction of population density (i.e., intraspecific competition for food), weather, and predation. Data collected over the last 20 years are consistent with this hypothesis and indicate that both winter and summer food shortages influence caribou nutrition, body condition, and population dynamics. Winter food limitation appears to be most limiting in the Delta Herd, but summer nutrition appears to be most limiting in the Nelchina Herd. Variation in summer nutrition due to weather also seems to occur regardless of population size and density. When poor summer weather occurs where herds are also experiencing suboptimal nutrition due to high population size, natality can be significantly reduced (e.g., Delta Herd in 1993 and Nelchina Herd in 1999 and 2000). In most of the Interior herds, however, natality seldom influences population growth. In the smaller Interior herds (i.e., those less than about 20,000), the primary factors that influence caribou dynamics are predation and weather.

During the course of this study, it has not been difficult to document the occurrence of density-dependent effects on body size and natality, but documenting population regulation is another matter. However, it is reasonable to believe that the effects of high population density would eventually contribute in some way to cause a population to decline. Thus, it appears that the amplitude and period of population fluctuations in Interior caribou herds, although constrained within certain upper limits by habitat, are likely to be rather unpredictable, and herd trajectories would be unlikely to follow any of the proposed theoretical models of population regulation.

As a practical matter, for managers of the DCH whose goal it is to regulate population size to provide for optimum and somewhat predictable harvests, it is probably more useful to estimate the optimum population size for management rather than trying to estimate “carrying capacity” in any theoretical sense. If the term “carrying capacity” is used in relation to Interior caribou, we recommend a return to the original definition discussed by Leopold (1948). That is, the maximum number of animals that can be indefinitely maintained in a given area (i.e., herd) in a reasonably healthy condition. We suggest that this approach will be the most useful concept for management and will approximate an optimum population size that will provide the greatest harvest over long periods of time. With historical data on population size and annually or periodically collected data on population parameters and body condition, managers will be able to make reasonable estimates of “carrying capacity” in the few important caribou herds where we have the ability to control the upper limits of herd size through harvest.

Even though it is currently difficult for wildlife biologists at ADF&G or the Alaska Board of Game to manage predation, the DCH may eventually increase to the point where harvest could be used to limit population growth. It would therefore be useful to have a target population in mind. At the present time and population size, besides predation, the DCH appears more strongly influenced by a shortage of high quality winter range than by summer range. Based on the past history of population fluctuations, and the tendency of the herd to explore for new seasonal ranges at population sizes above 4000, we recommend maintaining the herd at about 3500. With good recruitment and survival, even a herd of this relatively small size could provide an annual sustainable harvest of about 300–400 caribou.

ACKNOWLEDGMENTS

The long-term study of caribou population dynamics in the DCH was started largely by J Davis, and his contributions in designing the first 10 years of research and in training those involved in the later years of the study are immeasurable. Area management biologists C Gardner, L Van Daele, D Kelleyhouse, M McNay, R O'Connor, T Osborne, R Pegau, T Spraker, D Young, J Whitman, and J Woolington all willingly contributed their time, energy, and ideas to the project. With the limited finances and staffing that were available to the research program, it would not have been possible to conduct this work without the help and willing cooperation of the area biologists and their assistants. While we were conducting this study on the DCH and other Alaskan caribou herds, L Adams, S Arthur, R Boertje, C Gardner, B Dale, K Jolly, and W Collins were also conducting related work on caribou in other herds. We all shared ideas and data, and these biologists deserve thanks for their particularly positive attitudes and their cooperation in trying to find ways to better manage caribou in Alaska. We also thank R Boertje, J Larrivee, D Miller, D Reed, J Selinger, B Scotton, R Swisher, and S Gibbons for help with fieldwork, flying, data analysis, or lab work. J Ver Hoef provided help with analysis of weather and caribou population data. L McCarthy provided technical help and editorial review with this report and with the many manuscripts that have been generated from the research program over the last 12 years.

LITERATURE CITED

ADAMS LG AND BW DALE. 1998. Reproductive performance of female Alaskan caribou. Journal of Wildlife Management 62:1184–1195.

———, FJ SINGER, AND BW DALE. 1995. Caribou calf mortality in Denali National Park, Alaska. *Journal of Wildlife Management* 59(3):584–594.

ALLYE–CHAN A. 1991. Physiological and ecological determinants of nutrient partitioning in caribou and reindeer. Dissertation, University of Alaska Fairbanks.

ARTHUR S. 2002. Effects of oil field development on calf production and survival in the Central Arctic Caribou Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Performance Report. Grant W-27-5. Study 3.46. Juneau, Alaska.

BERGERUD AT. 1964. A field method to determine annual parturition rates for Newfoundland caribou. *Journal of Wildlife Management* 28(3):477–480.

———. 1971. The population dynamics of Newfoundland caribou. *Wildlife Monographs* 25.

———. 1978. Caribou. Pages 83–101 *in* JL Schmidt and DL Gilbert, editors. Big Game of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

BO S AND O HJELJORD. 1991. Do continental moose ranges improve during cloudy summers? *Canadian Journal of Zoology* 69:1875–1879.

BOERTJE RD. 1981. *Nutrition ecology of the Denali Caribou Herd*. Thesis, University of Alaska Fairbanks.

——— AND CL GARDNER. 1999. Reducing mortality on the Fortymile Caribou Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Performance Report. Grant W-27-2. Study 3.43. Juneau, Alaska.

——— AND CL GARDNER. 2000. Reducing mortality on the Fortymile Caribou Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Performance Report. Grant W-27-3. Study 3.43. Juneau, Alaska.

——— AND CL GARDNER. 2001. Reducing mortality on the Fortymile Caribou Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Performance Report. Grant W-27-4. Study 3.43. Juneau, Alaska.

———, P VALKENBURG, AND ME MCNAY. 1996. Increases in moose, caribou, and wolves following wolf control in Alaska. *Journal of Wildlife Management* 60(3):474–489.

BOONE AND CROCKETT CLUB. 1999. *Records of North American Big Game, 11th Edition*. Boone and Crockett Club, Missoula, MT.

BRYANT JP, FS CHAPIN III, AND DR KLEIN. 1993. Carbon nutrient balance in boreal plants in relation to vertebrate herbivory. *Oikos* 40:357–368.

CAUGHLEY G. 1970. Eruption of ungulate populations with emphasis on the Himalayan Thar in New Zealand. *Ecology* 51:53–70.

———. 1976. Wildlife management and the dynamics of ungulate populations. Pages 183–246 *in* TH Coaker, editor. Applied biology, Volume I. Academic Press, London.

———. 1979. What is this thing called carrying capacity? Pages 2–8 *in* MS Boyce and LD Hayden-Wing, editors. *North American elk: ecology, behavior, and management*. University of Wyoming Press. Laramie.

———. 1981. Comments on natural regulation of ungulates (what constitutes a real wilderness?). *Wildlife Society Bulletin* 9:232–234.

——— AND A GUNN. 1993. Dynamics of large herbivores in deserts: kangaroos and caribou. *Oikos* 67:47–55.

COLLINS GH, MT HINKES, AR ADERMAN, AND JD WOOLINGTON. 2002. Population growth, movements, and status of the Nushagak Peninsula Caribou Herd following reintroduction, 1988–2000. *Rangifer*, Special Issue (in press).

DALE BW, LG ADAMS, AND RT BOWYER. 1994. Function response of wolves preying on barren-ground caribou in a multi-prey ecosystem. *Journal of Animal Ecology* 63:644–652.

DAVIS JL AND P VALKENBURG. 1985. Demography of the Delta Caribou Herd under varying rates of natural mortality and harvest by humans. Alaska Department of Fish and

Game. Federal Aid in Wildlife Restoration. Research Final Report. Projects W-21-2, W-22-1, W-22-2, W-22-3, and W-22-4. Job 3.27. Juneau, Alaska.

———, P VALKENBURG, AND HV REYNOLDS. 1980. Population dynamics of Alaska's Western Arctic Caribou Herd. Pages 595–604 *in* E Reimers, E Gaare, and S Skjenneberg, editors. Proceedings 2nd International Reindeer/Caribou Symposium, Roros, Norway. Direktoratet for Vilt og Ferskvannsfisk, Trondheim.

———, ———, ME MCNAY, RM BEASLEY, AND VL TUTTERROW. 1991. Demography of the Delta Caribou Herd under varying rates of natural mortality and human harvest and assessment of field techniques for acquiring demographic data. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Projects W-22-5, W-23-1, W-23-2, and W-23-3. Job 3.33. Juneau, Alaska.

EAGAN RM. 1993. Unit 20A caribou. Pages 122-147 in SM Abbott, editor. Caribou management report of survey-inventory activities, 1 July 1990-30 June 1992. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Projects W-23-5 & W-24-1. Study 3.0. Juneau, Alaska, USA.

EBERHART LL AND KW PITCHER. 1992. A further analysis of the Nelchina caribou and wolf data. *Wildlife Society Bulletin* 20(4):385–395.

GASAWAY WC, RO STEPHENSON, JL DAVIS, PEK SHEPHERD, AND OE BURRIS. 1983. Interrelationships of wolves, prey, and man in Interior Alaska. *Wildlife Monographs* 84.

GERHART KL. 1995. Nutritional and ecological determinants of growth and reproduction in caribou. Dissertation, University of Alaska Fairbanks.

———, RG WHITE, RD CAMERON, AND DE RUSSELL. 1996. Body composition and nutrient reserves of arctic caribou. *Canadian Journal of Zoology* 74:136–146.

GLEICK J. 1987. Chaos. Viking Penguin, Incorporated. New York.

HAMLIN KL AND RJ MACKIE. 1989. Mule deer in the Missouri Breaks, Montana. Montana Department of Fish and Wildlife. Federal Aid in Wildlife Restoration Final report, Project W-120-R-7-18. Missoula, Montana.

HEMMING JE. 1971. The distribution and movement patterns of caribou in Alaska. Alaska Department of Fish and Game. Technical Bulletin 1. Juneau, Alaska.

——— AND LP GLENN. 1968. Caribou project annual segment report. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. W-15-R-2. Juneau, Alaska.

HINKES MT AND LJ VAN DAELE. 1996. Population growth and status of the Nushagak Peninsula caribou herd in Southwest Alaska following reintroduction, 1988–1993. *Rangifer*, Special Issue 9:301–309.

Hulten E. 1968. *Flora of Alaska and neighboring territories*. Stanford University Press. Stanford, California, USA.

Ingliss IR, B Forkman, and J Lazarus. 1997. Free food or earned food? A review and fuzzy model of contrafreeloading. *Animal Behavior* 53:1171–1191.

———, S Langton, B Forkman, and J Lazarus. 2001. An information primacy model of exploratory and foraging behavior. *Animal Behavior* 62:543–557.

Jenkins KJ. 1996. Population dynamics of the Mentasta Caribou Herd, Wrangell–St Elias National Park and Preserve: Progress Report and Preliminary Assessment. WRST Research and Management. Report 95-1. US National Park Service, Anchorage, Alaska.

Kistner TP, CE Trainer, and NA Hartmann. 1980. A field technique for evaluating physical condition in deer. *Wildlife Society Bulletin* 8:11–17.

Klein DR and H Strandgaard. 1972. Factors affecting growth and body size of roe deer. *Journal of Wildlife Management* 36:64–79.

Langvatn R. 1977. Criteria of physical condition, growth and development in Cervidae, suitable for routine studies. Nordic Council for Wildlife Research, Stockholm.

Lenart EA. 1997. Effects of weather on caribou forage productivity and nutrition within the range of the Chisana Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Grants W-24-3, W-24-4, and W-24-5. Study 3.41. Juneau, Alaska.

———, RT Bowyer, J Ver Hoef, and RW Ruess. 2002. Climate change and caribou: effects of summer weather on forage. *Canadian Journal of Zoology* 80:664–678.

Leopold A. 1948. Game management. Charles Scribner’s Sons. New York.

Magoun AJ. 1976. Summer scavenging activity in northeastern Alaska. Thesis, University of Alaska Fairbanks, Fairbanks, Alaska.

McCullough DR. 1979. The George Reserve deer herd, population ecology of a K-selected species. University of Michigan Press. Ann Arbor.

McNay ME. 2000. Investigation of wolf population response to intensive trapping in the presence of high ungulate biomass. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Performance Report. Grant W-27-3. Study 14.17. Juneau, Alaska.

Mech LD, LG Adams, TJ Meier, JW Burch, and BW Dale. 1998. *The wolves of Denali*. University of Minnesota Press, Minneapolis.

MORSCHEL FM. 1996. *Effects of weather and parasitic insects on summer ecology of caribou of the Delta Herd*. Thesis, University of Alaska Fairbanks.

——— AND DR KLEIN. 1997. Effects of weather and parasitic insects on the behavior and group dynamics of caribou of the Delta herd. *Canadian Journal of Zoology* 75:1659–1670.

REIMERS E. 1997. *Rangifer* population ecology: a Scandinavian perspective. *Rangifer* 17:105–118.

RINEY T. 1955. Evaluating condition of free-ranging red deer (*Cervus elaphus*), with special reference to New Zealand. *New Zealand Journal of Science and Technology* 36:429–463.

ROBINSON SR. 1984. Status of the Ray Mountains Caribou Herd. Unpublished report. Bureau of Land Management, Fairbanks

ROED KH AND KR WHITTEN. 1986. Transferrin variation and evolution of Alaskan caribou and reindeer and caribou, *Rangifer tarandus* L. *Rangifer*, Special Issue 1:247–251.

SELLERS RA. 1999. Northern Alaska Peninsula Herd caribou management progress report of survey–inventory activities. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-24-5 and W-27-1. Study 3.0. Juneau, Alaska.

———, P VALKENBURG, RL ZARNKE, AND RC SQUIBB. 1998a. Natality and early calf mortality of Northern Alaska Peninsula caribou, 1998. Alaska Department of Fish and Game. US Fish and Wildlife Service, Anchorage. Final Report. Cooperative Agreement 98-079. Juneau, Alaska.

———, P VALKENBURG, BW DALE, RC SQUIBB, AND M ROY. 2000. Fall sex/age composition, genetic screening and collaring of Northern and Southern Alaska Peninsula herds, 1999. Alaska Department of Fish and Game. US Fish and Wildlife Service, Anchorage. Final Report. Cooperative Agreement 00-020. Juneau, Alaska.

———, P VALKENBURG, R SQUIBB, BW DALE, AND R ZARNKE. 2002. Natality and early calf mortality in the Northern Alaska Peninsula and Southern Alaska Peninsula caribou herds. *Rangifer*, Special Issue (in press).

———, P VALKENBURG, RL ZARNKE, RC SQUIBB, AND M ROY. 1998b. Fall sex/age composition, body condition, disease screening, and collaring of Northern and Southern Alaska Peninsula caribou herds, 1998. Alaska Department of Fish and Game. US Fish and Wildlife Service, Anchorage. Final Report. Cooperative Agreement 99-014. Juneau, Alaska.

SINCLAIR ARE. 1981. Environmental carrying capacity and the evidence for overabundance. Pages 247–257 *in* PA Jewell and S Holt, editors, Problems in management of locally abundant wild mammals. Academic Press, New York.

SKOGLAND T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. *Rangifer* 4(2):39–46.

———. 1985. The effects of density-dependent resource limitation on the demography of wild reindeer. *Journal of Animal Ecology* 54:359–374.

SKOOG RO. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Dissertation, University of California, Berkeley.

TOBEY RW. 1993. Nelchina caribou herd management progress report of survey–inventory activities. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-23-5 and W-24-1. Study 3.0. Juneau, Alaska.

———. 1999. Nelchina caribou herd management progress report of survey–inventory activities. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-24-5 and W-27-1. Study 3.0. Juneau, Alaska.

VALKENBURG P. 1993. Investigation of limiting and regulating factors in the Delta Caribou Herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Progress Report. Grant W-24-1. Study 3.37. Juneau, Alaska.

———. 1997. Investigation of regulating and limiting factors in the Delta caribou herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Grant W-24-5. Study 3.42. Juneau, Alaska.

———. 1998. Herd size, distribution, harvest, management issues, and research priorities relevant to caribou herds in Alaska. *Rangifer,* Special Issue 10:125–130.

———. 2002. Stumbling towards enlightenment: understanding caribou dynamics. *Alces* 37(2):457–474.

———, JL DAVIS, AND DJ REED. 1988. Distribution of radiocollared caribou from the Delta and Yanert herds during calving. Proceedings third North American caribou workshop. Alaska Department of Fish and Game, Technical Bulletin 8:14–25.

———, RW TOBEY, AND D KIRK. 1999. Velocity of tranquilizer darts and capture mortality of caribou calves. *Wildlife Society Bulletin* 27(4):894–896.

———, RW TOBEY, BW DALE, BD SCOTTON, AND JM VER HOEF. 2002a. Body weight of female calves and natality rate of adults as indicators of summer and winter limitation in two Alaskan caribou herds. *Rangifer* (In press).

———, RA SELLERS, RC SQUIBB, JD WOOLINGTON, AR ADERMAN, AND BW DALE. 2002b. Population dynamics of caribou herds in southwestern Alaska. *Rangifer* (in press).

———, TH SPRAKER, MT HINKES, LH VAN DAELE, RW TOBEY, AND RA SELLERS. 2000. Increases in body weight and nutritional status of transplanted Alaskan caribou. *Rangifer*, Special Issue 12:133–138.

———, KW PITCHER, DJ REED, EF BECKER, JR DAU, DN LARSEN, AND JL DAVIS. 1991. Density-dependent responses in mandible length, calving date, and recruitment in three Alaskan caribou herds. Pages 288–299 *in* CE Butler and SP Mahoney, editors. Proceedings 4th North American Caribou Workshop. Newfoundland and Labrador Wildlife Division, St. John's, Newfoundland, Canada.

———, JL DAVIS, JM VER HOEF, RD BOERTJE, ME MCNAY, RM EAGAN, DJ REED, CL GARDNER, AND RW TOBEY. 1996. Population decline in the Delta caribou herd with reference to other Alaskan herds. *Rangifer,* Special Issue 9:53–62.

VAN BALLENBERGHE V. 1980. Utility of multiple equilibrium concepts applied to population dynamics of moose. Proceedings of the North American moose conference and workshop 16:571–586.

VER HOEF JM, P VALKENBURG, AND JR DAU. 2001. Modeling growth in mandibles in the Western Arctic caribou herd. *Rangifer* 21(1):29–34.

WHITTEN KR. 1995a. Influence of body condition on productivity of adult female caribou in the Porcupine caribou herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Grants W-24-1, W-24-2, and W-24-3. Study 3.39. Juneau, Alaska.

———. 1995b. Antler loss and udder distention in relation to parturition in caribou. *Journal of Wildlife Management* 59:273–277.

———, GW GARNER, FJ MAUER, AND RB HARRIS. 1992. Productivity and early calf survival in the Porcupine Caribou Herd. *Journal of Wildlife Management* 56:201–212.

ZARNKE RL. 1996. Serologic survey of Alaska wildlife for microbial pathogens. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Grants W-23-5 and W-24-1 through W-24-4. Study 18.70. Juneau, Alaska.

———. 2000. Alaska wildlife serologic survey, 1975–2000. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Grants W-24-5 and W27-1 through W-27-4. Study 18.71. Juneau, Alaska. (available on CD).

ZITTLAU K, J COFFIN, R FARNELL, G KUZYK, AND C STROBECK. 2000. Genetic relationships of three Yukon caribou herds determined by DNA typing. *Rangifer,* Special Issue 12:59–62.

XI. PREPARED BY:

Patrick Valkenburg
Wildlife Biologist IV

SUBMITTED BY:

David D James
Regional Supervisor

Laura A McCarthy
Publications Technician II

APPROVED BY:

Tom Paul
Federal Aid Coordinator
Division of Wildlife Conservation

Wayne L Regelin, Director
Division of Wildlife Conservation

APPROVAL DATE: __________________

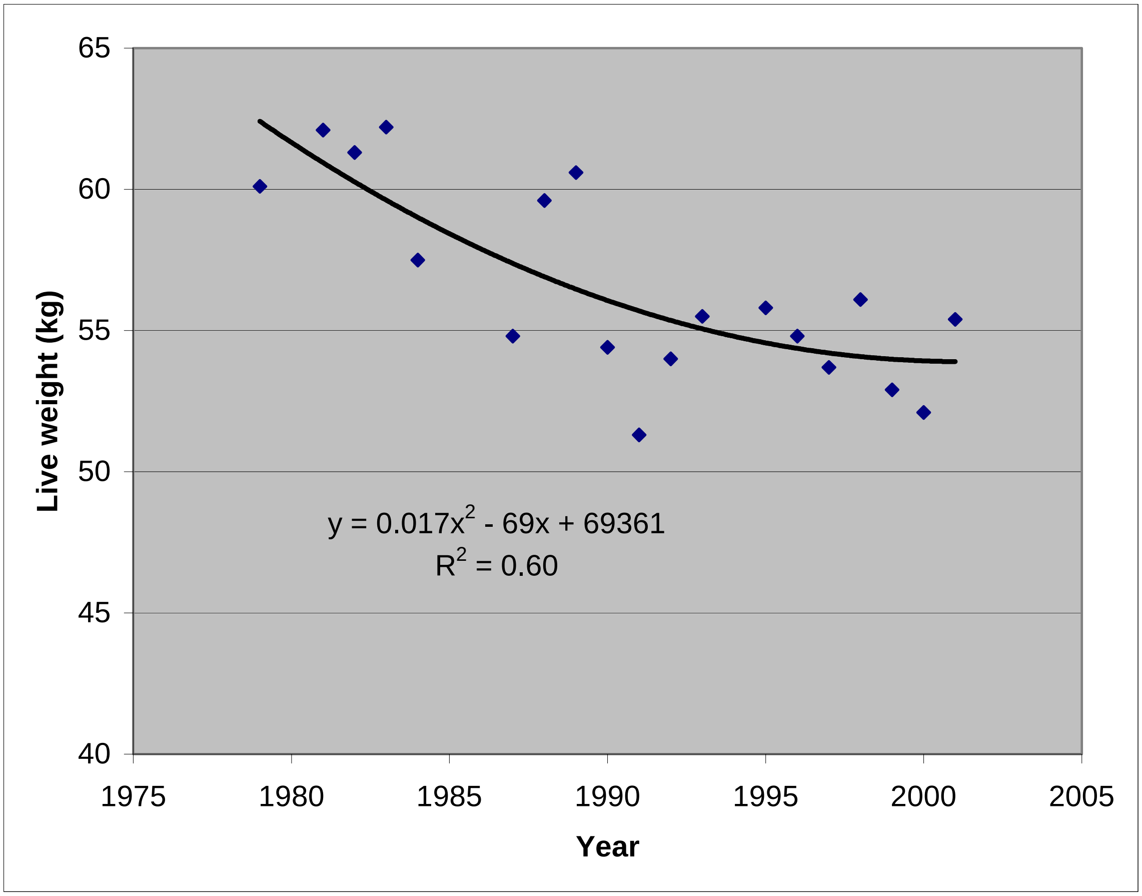

Figure 1 Trend in weight of 10-month-old female calves in the Delta caribou herd

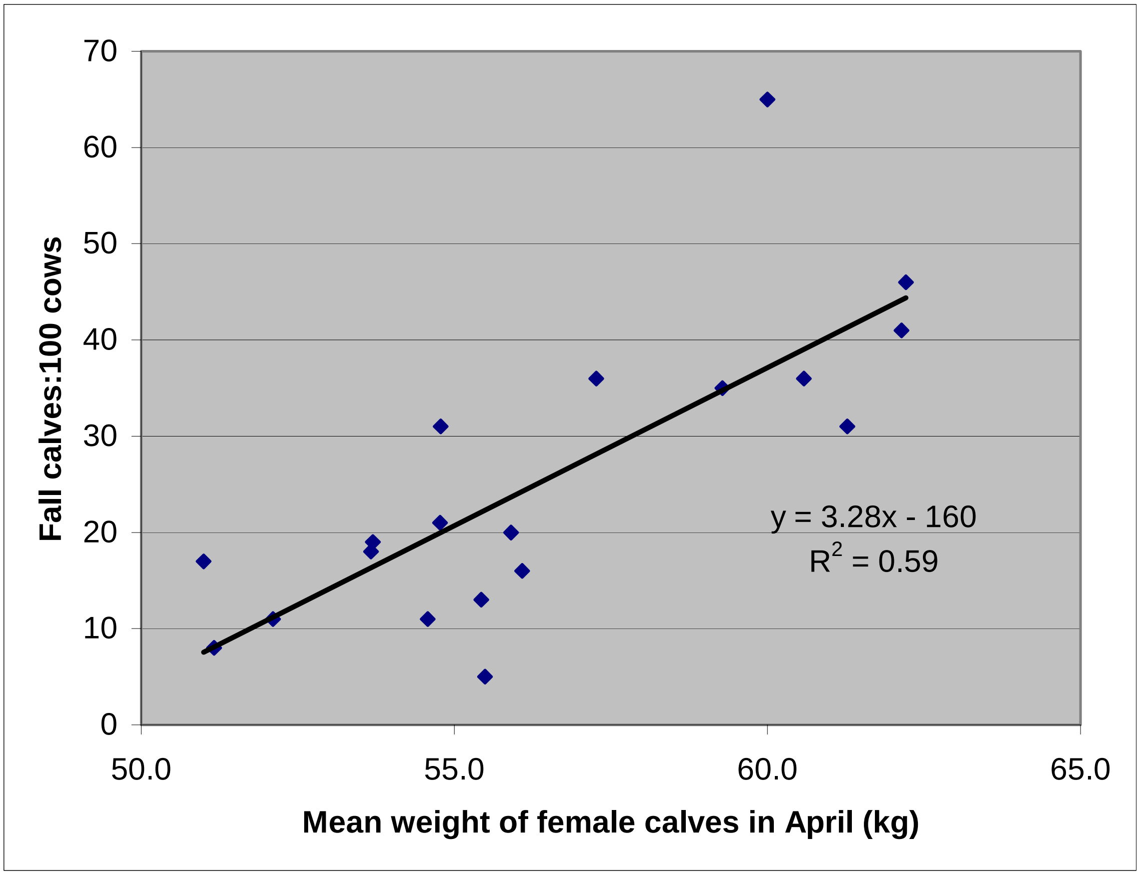

Figure 2 Relationship between April calf weight and October calf:cow ratio in the Delta caribou herd, 1979–2001

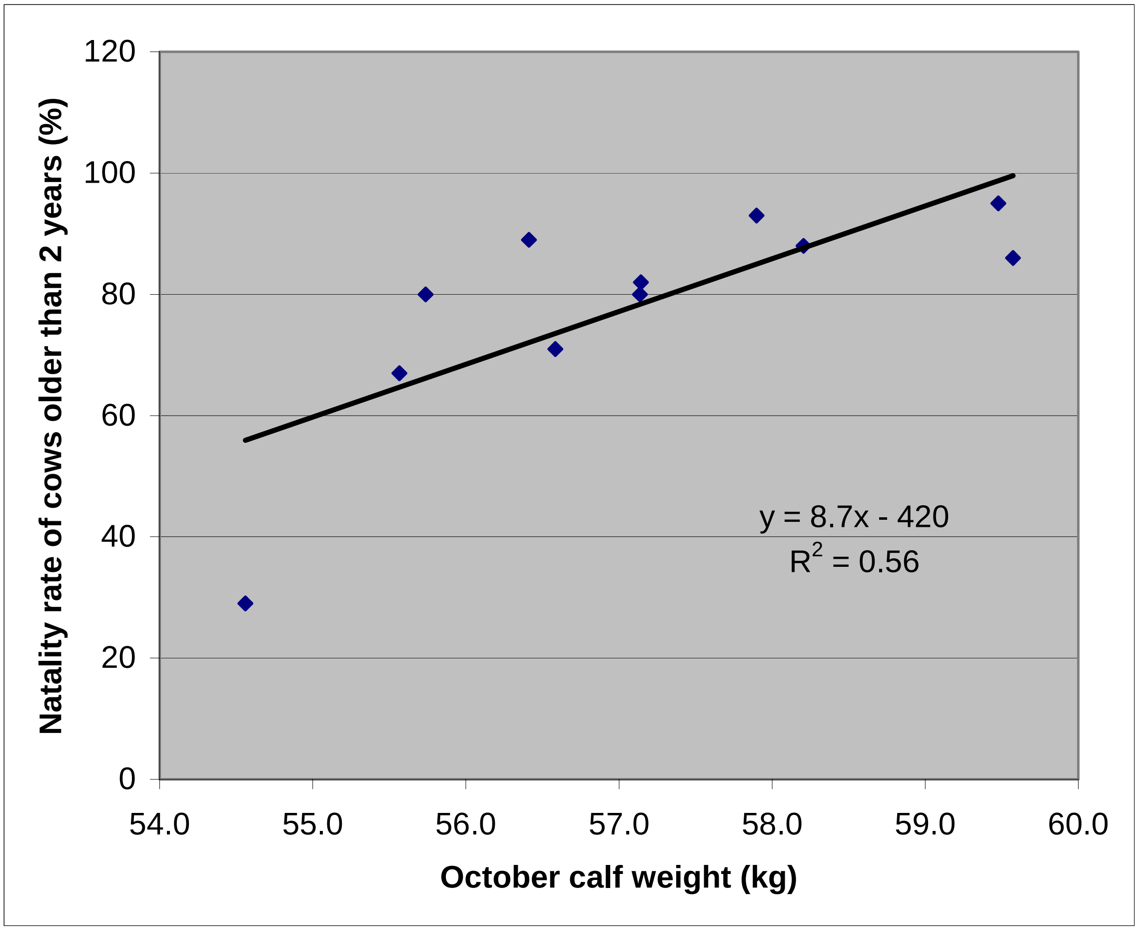

Figure 3 Relationship between mean weights of female calves in fall and natality rate of females ≥ 3-years old the following May in the DCH, 1991–2001

Table 1 Fall composition counts and size of Delta Herd caribou, 1969–2001

Approximate survey date	Bulls:100 Cows	3-Yr Avg	Calves:100 Cows	Calves %	Cows %	Small bulls % of bulls	Medium bulls % of bulls	Large bulls % of bulls	Total bulls %	Composition sample size	Count of herd size[a]
13–15 Oct 1969	40	49	28	15	53	--	--	--	21	777	
21–23 Oct 1970	77		34	14	43	--	--	--	33	896	
29–31 Oct 1971	29		15	10	65	--	--	--	19	1139	
27–31 Oct 1972	33	30	11	7	67	--	--	--	22	1185	
23–24 Oct 1973	29		10	7	70	--	--	--	20	1050	2804
23–25 Oct 1974	28		2	1	76	--	--	--	21	1141	
29–31 Oct 1976	38	49	45	24	54	--	--	--	21	1055	
26–31 Oct 1977	33		42	23	55	--	--	--	18	1365	
26 Oct 1978	75		39	17	45	--	--	--	33	725	3200
7 Dec 1979	39	57	65	32	49	--	--	--	19	361	4191
25 Oct 1980	85		49	21	43	--	--	--	36	1369	4478
2 Oct 1981	46		41	22	53	47	3	50	25	1451	4962
8 Oct 1982	42	40	31	18	58	48	4	48	24	1565	7335
4 Oct 1983	35		46	25	55	59	6	36	20	1208	6969
17 Oct 1984	42		36	20	56	28	32	40	24	1093	6260
9–12 Oct 1985	49	41	36	20	54	57	24	19	26	1164	8083
22 Oct 1986	41		29	17	59	49	30	21	24	1934	7804
5 Oct 1987	32		31	19	61	53	23	24	20	1682	8380
14 Oct 1988	33	33	35	21	60	50	38	12	20	3003	8535
10 Oct 1989	27		36	22	62	64	28	7	16	1965	10,690
4 Oct 1990	38		17	11	65	45	39	16	24	2411	8700
1 Oct 1991	29	30	8	6	73	55	29	16	21	1705	5755
28 Sep 1992	25		11	8	74	46	43	11	19	1240	5877
25 Sep 1993	36		5	3	72	45	33	22	25	1525	3661
3–4 Oct 1994	25	26	23	16	68	33	29	39	17	2131	4341
3 Oct 1995	24		20	14	69	41	19	40	17	1567	4646
3 Oct 1996	30		21	14	66	51	20	29	20	1532	4019
27 Sep 1997	27	38	18	13	69	48	20	32	18	1598	3699
1 Oct 1998	44		16	10	62	31	49	20	27	1519	3829
1 Oct 1999	44		19	11	62	37	40	23	27	674	3227
3–4 Oct 2000	46	45	11	7	64	41	37	22	30	1010	3227
30 Sep 2001	39		13	8	66	46	30	24	26	1378	2950
28 Sep 2002	50		25	14	57	43	23	34	29	924	

[a] Includes Yanert Herd caribou.

Table 2 Natality rates of radiocollared known-aged Delta Herd caribou[a] females observed in late May 1980–2001

Year	Proportion parturient (%) in late May						
	Yearlings	2-year-olds	3-year-olds	4-year-olds	5-year-olds	≥6-year-olds	All cows 3 years and older
1980		7/11 (64)					
1981	0/7 (0)	1/1 (100)	10/13 (77)				10/13 (77)
1982	0/10 (0)	0/7 (0)	2/2 (100)	5/8 (63)			7/10 (70)
1983	0/12 (0)	1/8 (13)	7/7 (100)		6/8 (75)		13/15 (87)
1984	0/12 (0)	0/11 (0)	8/9 (89)	6/6 (100)	1/1 (100)	6/7 (86)	21/23 (91)
1985		1/9 (11)	9/10 (90)	6/7 (86)	6/6 (100)	7/8 (88)	28/31 (90)
1986			8/9 (89)	9/9 (100)	3/4 (75)	8/9 (89)	28/31 (90)
1987	0/6 (0)	0/2 (0)		8/8 (100)	8/9 (89)	9/11 (82)	25/28 (89)
1988	0/11 (0)	0/5 (0)	1/1 (100)		8/8 (100)	15/16 (94)	24/25 (96)
1989	0/10 (0)	0/11 (0)	3/5 (60)	2/2 (100)		21/23 (91)	26/30 (87)
1990		0/4 (0)	6/10 (60)	5/6 (83)	0/1 (0)	17/17 (100)	28/34 (82)
1991	0/4 (0)		2/7 (29)	8/10 (80)	3/3 (100)	11/14 (79)	24/34 (71)
1992	0/16 (0)	0/5 (0)	0/1 (0)	6/7 (86)	8/8 (100)	12/12 (100)	26/28 (93)
1993	0/11 (0)	0/10 (0)	0/5 (0)	0/1 (0)	1/3 (33)	6/15 (40)	7/24 (29)
1994	0/10 (0)	0/12 (0)	2/9 (22)	4/5 (80)	1/1 (100)	13/15 (87)	20/30 (67)
1995	0/13 (0)	0/7 (0)	7/11 (64)	8/8 (100)	4/5 (80)	13/13 (100)	32/37 (86)
1996	0/16 (0)	1/11 (9)	5/5 (100)	9/10 (90)	6/6 (100)	15/16 (94)	35/37 (95)
1997	0/12 (0)	0/11 (0)	5/10 (50)	3/4 (75)	8/9 (89)	16/17 (94)	32/40 (80)
1998	0/17 (0)	1/8 (13)	9/10 (90)	7/7 (100)	3/3 (100)	18/22 (80)	37/42 (88)
1999	0/10 (0)	1/13 (8)	6/7 (86)	5/7 (71)	7/7 (100)	16/17 (94)	34/38 (89)
2000	0/9 (0)	0/10 (0)	8/12 (66)	5/5 (100)	6/6 (100)	14/18 (78)	33/41 (80)
2001	0/15 (0)	1/7 (14)	2/8 (25)	8/10 (80)	4/6 (67)	15/17 (88)	29/41 (71)
2002	0/9 (0)	2/11 (18)	3/6 (50)	8/9 (89)	11/11 (100)	11/13 (85)	33/39 (85)
1980–2002	0/210 (0)	16/174 (9)	154/257 (60)	114/129 (88)	94/105 (90)	243/280 (87)	552/671 (82)

---

[a] Figures may differ slightly from previous reports because only Delta caribou herd females were considered here (no Yanert females or those whose age was not known were used in this analysis).

Table 3 Natality rates of radiocollared known-aged female caribou in the Nelchina caribou herd, 1993–2001

	Proportion parturient (%) in late May						
Year	Yearlings	2-year-olds	3-year-olds	4-year-olds	5-year-olds	≥6-year-olds	All cows 3 years and older
1993							19/29 (66)
1994							NA
1995							18/20 (90)
1996		0/7 (0)					10/15 (66)
1997		0/2 (0)	3/6 (50)	NA	NA	5/6 (83)	8/12 (66)
1998		0/2 (0)	5/11 (45)	6/8 (75)	NA	6/7 (86)	17/26 (65)
1999		NA	3/12 (25)	6/9 (66)	2/6 (33)	6/7 (86)	17/34 (50)
2000		NA	0/8 (0)	6/10 (60)	4/10 (40)	5/5 (100)	15/25 (60)
2001		0/5	1/6 (10)	6/6 (100)	7/8 (75)	9/14 (64)	23/34 (68)
1993–2001		0/16 (0)	12/43 (28)	24/33 (73)	13/24 (54)	31/39 (79)	127/195 (65)

Table 4 Spring sex and age composition counts of Delta Herd caribou, 1983–1991

Date	Bulls:100 Cows	Calves:100 Cows	Calves %	Number of calves	Cows %	Number of cows	Bulls %	Number of bulls	Total caribou counted
4/20/83	23	29	19	205	66	708	15	166	1079
4/10/84	10	49	31	194	63	396	6	38	628
4/20/86	21	29	19	302	67	694	14	145	1041
4/6/88	22	29	19	285	66	976	14	212	1473
4/18/90	15	17	13	129	76	781	11	116	1026
4/18/91	20	8	7	96	78	1074	16	217	1387

Table 5 Annual total mortality of radiocollared known-aged female Delta Herd[a] caribou, 1979–2001

	Proportion dying (%) (cause of death) by age class			
Year[b]	Calves (4–16 mo old)	Yearlings (16–30 mo old)	Older than yearlings (>30 mo old)	Yearlings and older (>16 mo old)
1979–1980		0/11 (0)		0/11 (0)
1980–1981		0/2 (0)	0/11 (0)	0/13 (0)
1981–1982		0/7 (0)	0/11 (0)	0/18 (0)
1982–1983		2/10 (20) (2 unk)	0/18 (0)	2/28 (7)
1983–1984		0/12 (0)	2/24 (8) (1 unk, 1 hunting)	2/36 (6)
1984–1985		0/11 (0)	2/21 (10) (1 grizzly, 1 unk)	2/32 (6)
1985–1986			7/39 (18) (4 wolf, 1 hunting, 1 poached, 1 unk)	7/39 (18)
1986–1987			3/32 (9) (2 unk, 1 poached)	3/32 (9)
1987–1988		1/6 (17) (1 poached)	1/32 (3) (1 unk pred)	2/38 (5)
1988–1989		1/11 (9) (1 unk pred)	5/32 (16) (5 unk)	6/43 (14)
1989–1990		1/8 (13) (1 wolf)	5/41 (12) (4 unk, 1 wolf)	6/49 (12)
1990–1991			9/41 (22) (5 unk, 2 wolf, 2 unk pred)	9/41 (22)
1991–1992	5/12 (42) (2 wolf, 2 unk pred, 1 unk)	0/4 (0)	5/31 (16) (3 wolf, 1 unk pred, 1 unk)	5/35 (14)
1992–1993	8/15 (53) (3 lynx, 3 unk pred, 2 unk)	1/11 (9) (1 unk)	5/30 (17) (4 wolf, 1 coyote)	6/41 (15)
1993–1994	7/10 (70) (5 wolf, 1 unk, 1 poached)	0/7	4/32 (13) (3 unk, 1 wolf)	4/39 (10)
1994–1995	5/15 (33) (3 wolf, 2 unk pred)	2/7 (1 grizzly, 1 hunting)	5/41 (12) (3 wolf, 1 unk pred, 1 breached birth)	7/48 (15)
1995–1996	4/14 (29) (3 wolf, 1 unk)	1/11 (9) (1 wolf)	4/39 (10) (3 wolf, 1 unk pred)	5/50 (10)
1996–1997	6/13 (46) (2 wolf, 3 unk pred, 1 unk)	3/14 (21) (3 wolf)	3/42 (7) (2 wolf, 1 unk)	6/56 (11)
1997–1998	3/17 (18) (2 wolf, 1 unk)	1/19 (5) (1 wolf)	5/49 (10) (1 wolf, 1 avalanche, 1 poached, 2 unk)	6/68 (9)
1998–1999	6/15 (47) (5 wolf, 2 unk)	0/15 (0)	5/49 (10) (3 wolf, 2 unk)	5/64 (8)

	Proportion dying (%) (cause of death) by age class			
Year[b]	Calves (4–16 mo old)	Yearlings (16–30 mo old)	Older than yearlings (>30 mo old)	Yearlings and older (>16 mo old)
1999–2000	8/13 (62) (6 wolf, 2 unk)	3/10 (30) (1 unk pred, 2 unk)	7/55 (13) (2 wolf, 1 unk pred, 4 unk)	10/65 (16)
2000–2001	3/14 (21) (2 wolf, 1 grizzly)	0/9 (0)	8/56 (14) (3 wolf, 5 unk)	8/65 (12)
Totals	56/138 (41)(30 wolf, 12 unk pred, 9 unk, 3 lynx, 1 grizzly, 1 poached)	16/185 (9) (5 unk, 6 wolf, 2 unk pred, 1 grizzly, 1 poached, 1 hunting)	85/726 (12) (37 unk[c], 32 wolf, 7 unk pred, 2 hunting, 3 poached, 1 grizzly, 1 coyote, 1 breached birth, 1 avalanche)	101/911 (11)

[a] Mortality rates differ slightly from previous reports because only DCH caribou are considered here (no Yanert caribou are included).

[b] Mortality rate was calculated from 1 Oct to 30 Sep each year.

[c] Most of these died in summer when it was difficult to determine cause of death. Wolves and grizzly bears are the most likely cause of death.

Table 6 Hunting seasons, bag limits, and harvest for Delta Herd caribou, 1991–1992 to 2001–2002[a]

Year	Area, season, and bag limit
1991–1992	Ferry Trail Management Area, 10 Aug–10 Sep, 1 caribou by drawing permit (up to 200 permits issued); or 1–15 Feb, 1 caribou by registration permit (up to 75 permits issued in Nenana)[b]
1991–1992	Yanert Controlled Use Area, 1–15 Sep, 1 bull; or 1–15 Jan, 1 caribou[b]
1991–1992	Remainder of Unit 20A, 1–10 Sep, 1 bull; or 16 Feb–1 Mar, 1 antlered caribou by registration permit (up to 175 permits issued in Nenana)[b]
1992–1993	Unit 20A, no open season
1993–1994	Unit 20A, no open season
1994–1995	Unit 20A, no open season
1995–1996	Unit 20A, no open season
1996–1997	Unit 20A, 1 bull by drawing permit (up to 100 permits issued)
1997–1998	Unit 20A, 1 bull by drawing permit (up to 100 permits issued)
1998–1999	Unit 20A, 1 bull by drawing permit (up to 100 permits issued)
1999–2000	Unit 20A, 1 bull by drawing permit (up to 100 permits issued)
2000–2001	Unit 20A, 1 bull by drawing permit (up to 100 permits issued)
2001–2002	Unit 20A, 1 bull by drawing permit (up to 100 permits issued)

[a] For a summary of season and bag limits prior to 1991, see Davis et al. 1991.

[b] All winter seasons were closed by emergency order (No. 3-11-91).

Table 7 Harvest of Delta Herd[a] caribou, 1968–1969 through 2001–2002

Regulatory year	Reported harvest			Estimated total harvest
	Males	Females	Total	
1968–1969	119	25	147	205
1969–1970	169	54	225	324
1970–1971	198	68	275	428
1971–1972	387	226	624	740
1972–1973	372	132	517	700
1973–1974	158	67	233	301
1974–1975[b]				
1975–1976[b]				
1976–1977[b]				
1978–1979[b]				
1979–1980[b]				
1980–1981	104	0	104	104
1981–1982	191	73	268	268
1982–1983	193	77	274	274
1983–1984	616	110	748	1187[c]
1984–1985	335	175	534	848[c]
1985–1986	304	74	381	605[c]
1986–1987	404	110	520	841[c]
1987–1988	391	38	430	522[c]
1988–1989	415	22	441	555[c]
1989–1990	459	18	480	686[c]
1990–1991	275	83	361	549[c]
1991–1992	277	22	302	456[c]
1992–1993[b]				
1993–1994[b]				
1994–1995[b]				
1995–1996[b]				
1996–1997	22	0	22	22
1997–1998	44	0	44	44
1998–1999	49	1	50	50
1999–2000	38	0	38	38
2000–2001	34	0	34	34
2001–2002	32	0	32	32

[a] Includes Yanert Herd harvest during years the 2 herds could be separated.

[b] No open season.

[c] Estimated by dividing reported general harvest by 0.63 (estimated proportion of successful hunters that report).

Table 8 Mean weight of samples of 4- and 10-month-old female calves from the Delta caribou herd, 1979–2001

	10-month-olds				4-month-olds			
Year	$\bar{x}$ (lb)	$\bar{x}$ (kg)	$s_{\bar{x}}$ (lb)	n	$\bar{x}$ (lb)	$\bar{x}$ (kg)	$s_{\bar{x}}$ (lb)	n
1979	132.3	60.1	2.4	11				
1981	137.0	62.1	7.4	5				
1982	135.1	61.3	3.9	11				
1983	137.2	62.2	3.3	13				
1984	126.9	57.5	1.3	14				
1987	120.8	54.8	2.8	9				
1988	131.3	59.6	2.9	12				
1989	133.6	60.6	2.7	9				
1990	119.9	54.4	3.3	9				
1991	113.1	51.3	2.3	9	127.6	57.9	2.6	14
1992	119.1	54.0	2.6	17	119.1	54.0	2.6	17
1993	122.3	55.5	2.9	12	122.9	55.8	3.0	11
1994[a]					131.4	59.6	3.0	15
1995	123.1	55.8	2.7	15	131.1	59.5	2.7	15
1996	120.8	54.8	3.3	15	123.0	55.8	3.0	14
1997	118.3	53.7	2.5	14	128.3	58.2	2.2	20
1998	123.7	56.1	3.0	12	124.4	56.4	2.6	16
1999	116.7	52.9	2.6	13	126.0	57.1	2.9	14
2000	114.9	52.1	2.6	12	124.7	56.6	4.0	14
2001	122.2	55.4	3.2	11	126.0	57.1	2.4	14

[a] There were too few calves to obtain a sample of 10-mo-olds in April 1994.

Table 9 Matrix of Spearman correlation coefficients (r), significance level (P), and number of observations (N) in correlations of 13 variables from the DCH data set (significant correlations are shaded)

		July temp	July rain	Winter snow	Natality rate	Natality rate year + 1	Birth weight	Birth weight year + 1	4-mo weight	4-mo weight year +1	Calf/cow ratio	Calf/cow ratio year + 1	10-mo weight	10-mo weight year + 1
July temp	r	1												
	P	0												
	N	22												
July rain	r	-0.40	1											
	P	0.06	0											
	N	22	22											
Winter snow	r	0.44	-0.37	1										
	P	0.04	0.09	0										
	N	22	22	32										
Natality rate	r	0.01	0.11	-0.29	1									
	P	0.98	0.63	0.21	0									
	N	21	21	21	21									
Natality rate year +1	r	-0.17	0.20	-0.21	0.14	1								
	P	0.45	0.39	0.35	0.55	0								
	N	21	21	21	20	21								
Birth weight	r	-0.21	0.14	-0.43	-0.34	0.70	1							
	P	0.64	0.76	0.34	0.45	0.12	0							
	N	7	7	7	7	6	7							
Birth weight year + 1	r	0.00	-0.14	0.43	-0.50	-0.34	-0.89	1						
	P	1.00	0.76	0.34	0.25	0.45	0.02	0						
	N	7	7	7	7	7	6	7						
4-mo weight	r	-0.07	-0.28	-0.20	-0.37	0.72	0.68	-0.14	1					
	P	0.84	0.41	0.56	0.26	0.02	0.9	0.76	0					
	N	11	11	11	11	10	7	7	11					
4-mo weight year + 1	r	0.54	-0.40	-0.15	-0.27	-0.37	-0.84	0.68	-0.15	1				
	P	0.08	0.22	0.65	0.42	0.26	0.04	0.09	0.69	0				
	N	11	11	11	11	11	6	7	10	11				
Calf/cow ratio	r	-0.21	0.03	-0.33	0.33	0.23	0.11	-0.21	0.51	0.20	1			
	P	0.34	0.91	0.07	0.14	0.32	0.82	0.64	0.11	0.55	0			
	N	22	22	31	21	21	7	7	11	11	32			
Calf/cow ratio year + 1	r	-0.29	0.15	-0.29	0.08	0.33	0.26	0.11	0.22	0.51	0.80	1		
	P	0.21	0.51	0.12	0.72	0.14	0.62	0.82	0.54	0.11	0.00	0		
	N	21	21	30	20	21	6	7	10	11	30	31		
10-mo weight	r	-0.10	0.34	-0.36	0.02	0.12	0.39	-0.03	-0.15	0.43	0.76	0.77	1	
	P	0.69	0.17	0.13	0.93	0.65	0.38	0.96	0.68	0.21	< 0.01	< 0.01	0	
	N	18	18	19	18	17	7	6	10	10	19	18	19	
10-mo weight year + 1	r	-0.24	0.03	-0.40	-0.22	0.02	-0.20	0.39	0.39	-0.15	0.66	0.76	0.50	1
	P	0.34	0.90	0.09	0.41	0.93	0.70	0.38	0.30	0.68	<0.01	<0.01	0.06	0
	N	18	18	19	17	18	6	7	9	10	19	19	15	19

Table 10 Results of shading experiments on *Salix pulchra* in the upper Wood River in 1993 and 1994

Sampling date	Crude protein (%)[a]				IVDMD (%)				Tanin (ug/ml)[a]			
	Control	Shaded	Grazed-control	Grazed-shaded	Control	Shaded	Grazed-control	Grazed-shaded	Control	Shaded	Grazed-control	Grazed-shaded
6/3/93	22				41				70			
6/21/93	16	18			39	36			210	80		
7/12/93	15	17			41	34			400	180		
7/29/93	14	16	16	15	38	35	37	35	280	70	190	280
6/1/94	29				51				138			
6/23/94	18	20			47	54			380	310		
7/8/94	16	18			41	43			500	380		
7/25/94	14	17			41	41			480	240		

[a] Difference in protein and tannin levels between years may be due to method of analysis (different labs were used).

Table 11 Proportions of discerned plant fragments in fecal pellets from winter ranges of Delta Herd caribou, 1985–1999

Sample #	Mo/Year	Location	Proportions (%) of discerned plant fragments							
			Lichens	Mosses	Shrubs	Grass/sedge	Equisetum	Forbs	Other	Total
103104	11/1985	Rex Dome	89	3	3	1	4	0		100
103105	11/1985	Yanert River	94	2	2	0	2	0	0	100
103106	11/1985	Yanert River	92	1	3	2	0	1	1	100
103108	12/1985	Yanert River	87	4	4	2	3	0	0	100
103107	12/1985	Lignite Creek	90	3	4	1	1		1	100
103109	10/1986	Rex Dome	90	4	3	0	2	0	1	100
103110	10/1988	Yanert River	84	2	3	3	8	0	0	100
103111	11/1988	Benches (Fish Creek)	78	7	8	5	2	0	0	100
103645	2/1988	Rex Dome	82	6	7	2	0	0	3	100
103646	2/1988	Rex Dome	87	6	6	0	0	0	1	100
103648	5/1988	Dick Creek	71	11	4	6	5	2	1	100
103650	10/1989	Totatlanika Canyon	89	4	5	1	0	1	0	100
103653	3/1989	Coady Creek	75	14	6	3	1	0	1	100
103654	3/1989	Coady	79	12	6	2	1	0	0	100
103655	3/1989	Iowa	78	13	8	0	1	0	0	100
103656	3/1989	Gold King	72	19	8	1	0	0	0	100
103659	3/1989	Fish Creek	93	2	2	0	1	0	2	100
103662	3/1989	Fish Creek	81	4	7	0	4	0	4	100
103950	10/1992	Yanert	74	15	10	0	0	0	1	100
103953	3/1992	Little Del Forks	43	34	17	1	1	0	4	100
103971	3/1993	Iowa Ridge	24	39	27	6	0	0	4	100
104200	3/1993	Totatlanika	85	5	4	1	4	0	1	100
104200	3/1993	Liberty Bell Mine	40	38	13	4	3	1	1	100
104202	3/1993	UAF	66	3	11	3	11	1	5	100
104205	3/1993	Eielson AFB	63	23	8	0	5	1	0	100
104206	3/1993	Little Del Forks	61	15	21	1	1	1	0	100
104210	3/1993	Granite Tors	78	11	4	2	1	1	3	100
104778	4/1995	Kansas Creek	63	11	4	11	5	1	5	100
104779	4/1995	Upper Delta Creek	70	11	14	5	0	0	0	100
105704	2/1999	Jumbo Dome	46	29	8	4	10	2	1	100

Sample #	Mo/Year	Location	Proportions (%) of discerned plant fragments							
			Lichens	Mosses	Shrubs	Grass/sedge	Equisetum	Forbs	Other	Total
105705	2/1999	Donnelly Dome	29	50	6	5	3	5	2	100
106184	3/1999	Moose Creek	38	40	12	6	0	0	4	100
106185	3/1999	Carlo Creek	50	35	8	3	0	4	0	100
106186	3/1999	Revine Creek	33	49	10	2	4	1	1	100

Table 12 Proportions of discerned plant fragments in fecal samples from selected Interior and Southwest Alaska caribou herds

Sample			Proportions (%) of discerned plant fragments							
#	Mo/Year	Herd/Location	Lichens	Mosses	Shrubs	Grass/sedge	Equisetum	Forbs	Other	Total
103961	4/1992	WMH[a]/VABM Beaver	79	13	4	2	0	0	2	100
103962	4/1992	WMH/N VABM Beaver	72	3	14	7	0	1	3	100
103963	4/1992	WMH/Noodor Dome	61	6	3	9	2	17	2	100
103964	4/1992	WMH/VABM Duncan	72	4	22	1	1	0	0	100
103965	4/1992	WMH/VABM Beaver	76	11	10	2	0	1	0	100
103969	4/1992	NCH[b]/Northway	83	1	3	0	10	0	3	100
103970	4/1992	NCH/Gardiner Creek	88	2	3	1	5	0	1	100
103967	4/1992	NCH/Lake Louise Flats	62	5	16	0	6	0	11	100
103960	3/1992	NCH/Cantwell	78	10	9	3	0	0	0	100
103972	3/1993	NCH/Western Denali Hwy	89	3	7	0	0	0	1	100
104211	4/1993	NCH/Eastern Denali Hwy	63	19	9	5	1	3	0	100
104789	1/1995	NCH/Jatahmund Lake	76	4	3	10	6	0	1	100
104790	2/1995	NCH/Mansfield Lake	77	2	1	1	18	0	1	100
104776	4/1996	NCH/Suslota Lake	39	14	10	32	5	0	0	100
104777	4/1996	NCH/Suslota Lake	34	17	5	40	3	0	1	100
104772	4/1995	NAP[c]/Pilot Station	38	1	9	32	18	1	1	100
104773	4/1995	NAP/6 S of King Salmon	55	2	22	17	4	0	0	100
104773	4/1995	NAP/6 N of King Salmon	48	8	35	7	2	0	0	100
104797	4/1996	KMCH[d]/Kenai Mountains	89	1	5	4	0	1	0	100
104798	4/1996	KMCH/Kenai Mountains	91	1	3	4	0	1	0	100
104799	4/1996	KRCH[e]/Killey River	88	1	2	8	0	1	0	100
104775	4/1995	MCH[f]/Kaktuli River	41	0	26	18	10	3	2	100
103954	3/1992	RMH[g]/Kilo Hot Springs	81	8	9	1	0	0	1	100
103951	4/1992	WACH[h]/Pah Flats	54	3	11	24	1	1	6	100
104203	4/1993	WACH/Indian River Flats	59	11	23	1	0	0	6	100
104207	4/1993	WACH/Indian River Flats	74	2	21	3	0	0	0	100
104212	3/1993	Farewell-Big River/Submarine Lake	62	18	10	1	5	0	4	100

[a] White Mountains Herd.
[b] Nelchina Herd.
[c] Northern Alaska Peninsula Herd.
[d] Kenai Mountains Herd.
[e] Killey River Herd.
[f] Mulchatna Herd.
[g] Ray Mountains Herd.
[h] Western Arctic Herd.

Table 13 Winter ranges of radiocollared Delta Herd caribou during 1978–1979 through 2001–2002

Winter	Primary winter ranges during Nov–Apr (estimated proportion of the herd in the area)
1978–1979	Gold King Benches (GKB) (80), flats north of Iowa Ridge (20)
1979–1980	GKB (80), Iowa Ridge-Buchanan Creek (20)
1980–1981	GKB (50), Iowa Ridge-Buchanan Creek (50)
1981–1982	Tatlanika drainage (90), GKB (10)
1982–1983	Iowa Ridge-Little Delta drainages (90), GKB (10)
1983–1984	Slide Creek/Newman Creek/Iowa Ridge (75), Wood River—Mystic to Snow Mtn (25)
1984–1985	GKB (50), Wood River—Mystic to Snow Mtn (25), upper Little Delta (25)
1985–1986	Tatlanika/Totatlanika foothills (33), GKB (33), Slide Creek/Little Delta (33)
1986–1987	Iowa Ridge/Buchanan Creek (50), GKB (25), Tatlanika foothills (25)
1987–1988	GKB (40), Tatlanika/Totatlanika foothills (50), flats north of Iowa Ridge (10)
1988–1989	Fish Creek/Tatlanika flats (75), Tatlanika/Totatlanika foothills (25)
1989–1990	Fish Creek/Tatlanika flats (60), Tatlanika/Totatlanika foothills (20), GKB (20)
1990–1991	Tatlanika/Totatlanika flats (50), Tatlanika/Totatlanika foothills (25), lower Yanert (25)
1991–1992	Tatlanika/Totatlanika foothills (40), lower Yanert (40), upper Delta Creek (20)
1992–1993	Eielson AFB (15), Chatanika/pipeline (15), Tatlanika/Totatlanika flats (15), Tatlanika/Totatlanika foothills (15), White Mountains (10), upper Chena R. (10), Jack River (10), Dinosaur/Iowa Ridge and flats to north (10)
1993–1994	Yanert (30), Flats n or Iowa Ridge (30), 100-Mile Creek (30), GKB (10)
1994–1995	100-Mile Creek (30), Kansas Creek/Coady Creek (40), Yanert (30),
1995–1996	Tatlanika/Totatlanika foothills (15), Little Delta foothills (15), 100-mile Creek (10), Iowa Ridge (10), Flats n or Iowa Ridge (10), Donnelly Dome/Granite Mtns (10), upper Delta Creek (10), Upper Buchanan Creek (10), lower Yanert (10)
1996–1997	Tatlanika/Totatlanika foothills (30), upper Delta Creek (20), Yanert (15), GKB (15), Iowa Ridge (10), 100-Mile Creek (10)
1997–1998	Lower Yanert (40), GKB (15), Tatlanika/Totatlanika foothills (15), Donnelly Dome/Granite Mtns (10), 100-Mile Creek (10), Upper Little Delta (10)
1998–1999	Lower Yanert (20), Tatlanika/Totatlanika foothills (20), Donnelly Dome/Granite Mtns (15), GKB (15), 100-Mile Creek (10), Iowa Ridge (10), upper Little Delta (10)
1999–2000	Lower Yanert (30), Tatlanika/Totatlanika foothills (30), Donnelly Dome/Granite Mtns (10), 100-Mile Creek (10), Wells Creek/Chulitna Mtns (10), Upper Little Delta (10)
2000–2001	Lower Yanert (30), Tatlanika/Totatlanika foothills (15), Donnelly Dome/Granite Mtns (15), Monahan Flats (10), GKB (10), Flats n Iowa Ridge (10), upper Little Delta (10)
2001–2002	Delta Creek, flats north of Iowa Ridge, upper Little Delta, Yanert

Table 14 Location of calving areas used by Delta Herd caribou in late May, and relative timing of snowmelt, 1979–2001

Year	Major calving areas used (proportion of parturient females estimated to be in the area)	Snowmelt
1979	Upper Delta Creek (80), Upper Buchanan Creek (10)	Average
1980	Upper Delta Creek (80), Upper Buchanan Creek (10)	Average
1981	Upper Delta Creek (80), Upper Buchanan Creek (10)	Average
1982	Flats between Molybdenum and Dinosaur ridges (80), Portage Creek/lower Buchanan (10)	Late
1983	Flats between Molybdenum and Dinosaur ridges (70), upper Delta Creek (20)	Late
1984	Upper Delta Creek (45), upper Buchanan Creek (45)	Average
1985	Upper Delta Creek (45), upper Buchanan Creek (45)	Average
1986	Upper Delta Creek (50), upper Buchanan Creek (40)	Average
1987	Upper Delta Creek (45), upper Wood River (45)	Early
1988	Dick Creek (60), upper Wood River (30)	Early
1989	Upper Delta Creek (30), upper Wood River (30), Little Delta/Buchanan (10), Dick Creek (10)	Average
1990	Dick Creek (45), Wells Creek (45)	Early
1991	Wells Creek (40), Dick Creek (20), upper Delta Creek (10), Buchanan Creek (10)	Average
1992	Upper Yanert (45), Delta Creek impact area (45)	Very late
1993	Wells Creek (60), Dick Creek (15), Upper Wood River (15)	Average
1994	Wells Creek (60), upper Yanert/Dick Creek/Dean Creek (30)	Average
1995	Wells Creek (65), upper Yanert/Dick Creek/Dean Creek (25)	Very early
1996	Wells Creek (65), upper Yanert/Dick Creek/Dean Creek (25)	Average
1997	Wells Creek (60), upper Yanert/Dick Creek/Dean Creek (25)	Average
1998	Upper Nenana/Monahan Flats (25), Yanert/Dick Creek/Dean Creek (25), Wells Creek (20), upper Delta Creek (15)	Late
1999	Upper Nenana/Monahan Flats (40), Yanert/Dick Creek/Dean Creek (30), Wells Creek (20)	Late
2000	Yanert/Dick Creek/ Dean Creek (35), Upper Nenana/Monahan Flats (15), Wells Creek (15), upper Little Delta/Buchanan Creek (15), Gold King Benches (15)	Very late
2001	Upper Nenana/Monahan Flats (40), upper Yanert/Dick Creek/Dean Creek (25), Buchanan Creek (10), flats north of Molybdenum Ridge (10)	Very late

Table 15 Mortality of radiocollared calves and calves of radiocollared females by cause in the Delta caribou herd from birth to 30 September 1995–1997

		Proportion dying (%)							
	Year	Neonatal[a]	Wolf	Grizzly bear	Golden eagle	Coyote	Unk	Total	Capture-induced
All radiocollared calves	1995	na	13/43 (30)	9/43 (21)	7/43 (16)	0/43 (0)	0/43 (0)	29/43 (67)	2/45 (4)
	1996	na	9/50 (18)	11/50 (22)	6/50 (12)	1/50 (2)	4/50 (8)	31/50 (62)	0/50 (0)
	1997	na	19/73 (26)	13/73 (18)	11/73 (15)	2/73 (3)	0/73 (0)	45/73 (62)	1/74 (1)
Total			41/166 (25)	33/166 (20)	24/166 (14)	3/166 (2)	4/166 (2)	105/166 (63)	3/169 (2)
All calves of known-aged radiocollared cows	1995	7/31 (23)[b]	5/31 (16)	5/31 (16)	3/31 (10)	0/31 (0)	1/31 (3)	21/31 (68)	1/32 (3)
	1996	4/33 (12)	5/33 (15)	8/33 (24)	3/33 (9)	0/33 (0)	1/33 (3)	21/33 (64)	0/33 (0)
	1997	3/31 (10)	5/31 (16)	7/31 (19)	1/31 (3)	2/31 (6)	0/31 (0)	15/31 (48)	0/31 (0)
Total		14/95 (15)	15/95 (16)	20/95 (21)	7/95 (7)	2/95 (2)	2/95 (2)	57/95 (60)	1/96 (1)

[a] These calves died before we could radiocollar them.

[b] Includes 1 due to breached birth where both cow and calf died.

Table 16 Amount and type of prey provided during diversionary feeding of the Wells Creek Pack in 1996 and 1997

Date of delivery	Prey item	Distance and direction from den	Estimated weight (lb)	Method of acquisition and transport	Handled by humans?	Time until item was found by wolves	Time until item was fed on by wolves	Time until item was ≥75% consumed	Other large predators that came
5/15/96	bull caribou	½ mile E	350	shot in place	no	4 days	4 days	13	
5/17/96	bull caribou	1/3 mile E	300	shot in place	no	2 days	2 days	4	
5/19/96	bull caribou	1/3 mile E	300	shot in place	no	<1 day	<1 day	2–5	
5/21/96	bull caribou	1½ miles E	325	shot in place[a]	no	4[a] days	4[a] days	1[a]	
5/21/96	cow moose	1/3 mile E	900	shot in place	no	<1 day	<1 day	<1	1 grizzly
5/24/96	cow moose	1 mile E	650	shot in place	no	4 days	4 days	>10	1 grizzly
5/28/96	bull caribou	¼ mile E	300	shot, slung in[b]	no	>1 day	<1 day	<1	
5/28/96	bull caribou	¼ mile E	250	shot, slung in	no	<1 day	<1 day	2	
5/30/96	bull caribou	¼ mile E	300	shot, slung in	no	7 hr	7 hr	16 hr	2 grizzlies
6/1/96	bull caribou	¼ mile E	300	shot, slung in	no	6 hr	6 hr	10 hr	
6/3/96	bull caribou	¼ mile E	300	shot, slung in	no	6 hr	6 hr	<10 hr	
6/5/96	bull caribou	¼ mile E	300	shot in place	no	6–12 hr	6–12 hr	15 hr	
5/15/97	bull caribou	¼ mile E	350	shot, slung in	no	10 hr	22 hr	36 hr	
5/17/97	bull caribou	¼ mile E	300	shot, slung in	no	4 hr	14 hr		
5/17/97	8 beavers	¼ mile E	180	slung in	yes	4 hr	48 hr	3 days[c]	2 grizzlies[c]
5/19/97	24 beavers	¼ mile E	550	slung in	yes	<4 hr	4 hr	4 days[c]	2 grizzlies[c]
5/21/97	bull caribou	¼ mile E	400	shot, slung in	yes	<4 hr	bears ate		2 grizzlies
5/21/97	20 beavers	¼ mile E	475	slung in	yes	<4 hr	2 days	cached[c]	2 grizzlies
5/21/97	dog food	¼ mile E	50	slung in	yes?	<4 hr	4 days	>4 days?	
5/25/97	bull caribou	¼ mile E	275	shot, slung in	no	3 hr	12 hr	14 hr	
5/25/97	8 beavers	¼ mile E	180	slung in	yes	2 hr			
5/26/97	cow moose[d]	¼ mile E	600	slung in	yes	3 hr	16 hr	4 days	
5/30/97	bull caribou	¼ mile E	350	shot, slung in	no	<3 hr	3–6 hr	10 hr	grizzly[e]
6/1/97	bull caribou	¼ mile E	300	shot, slung in	no	4 hr	22 hr	48 hr	
6/3/97	bull caribou	¼ mile E	275	shot, slung in	no	3 hr	9 hr	14 hr	
6/4/97	bull caribou	¼ mile E	300	shot, slung in	no	12 hr	14 hr	18 hr	2 grizzlies

[a] Moved to open area ¼ mile east of den after 4 days.

[b] Shot >1 mi away and slung in with R-22 helicopter.

[c] Two grizzlies arrived on 20 May at about 1300 hr and ate most of the 2 piles of beaver, which the wolves were still reluctant to eat. Bears remained until 23 May and eat virtually the entire caribou delivered on 21 May. Pile debris on the piles of beaver and ate some. The bears may have eaten some of the dog food. Wolves were not interested in the bag of dog food but appear to eat some loose dog food after about 4 days.

[d] A cow moose and newborn twin calves were all found dead at the mouth of Wells Creek. They were slung in 2 loads.

[e] A single grizzly bear came to carcass pile area again on 31 May but only stayed for 4 hr. On 4 June, a sow and yearling arrived but wolves chased them away.

Table 17a Estimates of herd size for Alaskan caribou herds, 1970–1985

	Year															
Herd	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Adak	214	230	347	230			223	214	233	276	297	381	274	177	360	460
Beaver Mtns	1100													1200		1000
Central Arctic					5000				6000			9000		13,000		
Chisana											1000	1000				
Delta				2804					3200	4191	4478	4962	7335	6969	6260	8083
Denali			1250	1250						1250	1350		1350	1050	2250	
Farewell-Big R														700	750	
Fortymile				5312	4000	4000						7900		12,350	13,731	
Fox R																
Galena Mtn																
Kenai Lowlands		27								70	70		80	80		85
Kenai Mtns	119										250	256	266	276		400
Kilbuck Mtns													50	75		65
Killey R																
Macomb												700				
Mentasta							2000	2300	2800		2400	2700	2800		2800	3150
Mulchatna	14,250						9500		7500			20,500		30,000		43,000
Nelchina			7900	6500	10,500		8100	14,000	19,000		19,000	21,750	21,250	24,850	24,100	
N Peninsula						10,500	11,500					17,000	17,000	18,000	19,000	19,000
Nushagak																
Porcupine			100,000					105,000		110,000			125,000	135,000		
Rainy Pass				1000										1500		
Ray Mtns																
S Peninsula												6000	7000	10,200		
Sunshine Mtns	700									500				600		550
Teshekpuk															12,000	
Tonzona														1100		
Twin Lakes																
Unimak Island																
Western Arctic	242,000						75,000	83,000	105,000	113,000	140,000		175,000			
White Mtns														800		
Wolf Mtn																
Yanert												550		930		

Table 17b Estimates of herd size for Alaskan caribou herds, 1986–2001

Herd	Year															
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Adak				475	535	437		827								
Beaver Mtns					1050			550	600	400				150		150
Central Arctic						19,050	23,400			18,100		20,000			27,000	
Chisana		1100	1350	1660	1200	1285	1235	935	800	775		600		350	425	375
Delta	7804	8380	8535	10,690	8700	5755	5877	3661	4341	4646	4019	3699	3829	3625	3227	2965
Denali		2650	2850	3250	3740	2960	2810	1890	2130	2300	2060	2070	1930	1925		1900
Farewell-Big R																
Fortymile	15,500		19,975		22,800		21,900		22,100	22,600	23,500	27,000	31,000	36,300	35,000	
Fox R				32		40		57	83	85		81	70		70	70
Galena Mtn						400		400								100
Kenai Lowlands		100	125	125	125	130	75	75	85	90		98	130	150		
Kenai Mtns					325	350	410	425				460	450			
Kilbuck Mtns		300	1600	1400		2600		3700	4250[a]						100	
Killey R				91		197		281		290		376	530		640	650
Macomb			800		775	600	600	500	550	500	600	600	600	700	675	600
Mentasta	3100	3160	2480	2600		1940	1430	970	880	850	780	610	540	430	470	390
Mulchatna		52,500	60,500		82,000		115,000		180,000		210,000			175,000		
Nelchina		30,300		36,000	36,900	45,000	45,500	40,400	44,100	50,300	44,300	35,000	38,600	33,000	29,500	33,800
N Peninsula	15,300	16,500	25,000		17,000				12,500	12,000	11,500	10,500	9000	9000	7000	
Nushagak[b]			146	268	383	561	734	1007			1304	1429	1381	1159	1037	1000
Porcupine		165,000		178,000			160,000		152,000				130,000			123,000
Rainy Pass											1200					
Ray Mtns		600								1750			1800			
S Peninsula	4600	4100	4000		3750	3000	3000		2200	1550		2000		3600	3500	3000
Sunshine Mtns					800			700	700	500				100		
Teshekpuk				17,000				27,700		26,000				29,000		
Tonzona	400		1200		1600	1400										
Twin Lakes										50		73			65	67
Unimak Island					200							650			1000	
Western Arctic	229,500		343,000		416,000			450,000			463,000			430,000		
White Mtns				930			1000								700	
Wolf Mtn						500	675									500
Yanert	600[c]															

[a] Assimilated by the Mulchatna Herd after 1994.

[b] Data from Collins et al. (2002).

[c] Assimilated by the Delta Herd after 1986.

Table 18 Caribou density on summer range in 1990 and 1997 by herd

	Density on summer range (caribou/km^2)	
Herd	1990	1997
Adak	1.3	3.6[a]
Beaver Mountains	0.3	0.2
Central Arctic	1.0	1.2
Chisana	0.4	0.1
Delta	1.2	0.4
Denali	0.5	0.4
Farewell-Big River	0.1	0.2[b]
Fortymile	1.0	1.2
Fox River	0.4	1.0
Galena Mountain	0.1	0.1
Kenai Lowlands	0.3	0.2
Kenai Mountains	0.3	0.4
Kilbuck Mountains[c]	0.2	
Killey River	0.3	1.0
Macomb	0.3	0.3
Mentasta	0.5	0.1
Mulchatna	4.1	6.3
Nelchina[d]	3.1	2.3
N Peninsula	1.3	0.7
Nushagak	0.3	0.8
Porcupine	1.5	1.3
Rainy Pass	0.2	0.1
Ray Mountains	0.1	0.2
S Peninsula[e]	1.1	0.6
Sunshine Mountains	0.1	0.5
Teshekpuk	0.9	2.1
Tonzona[f]	0.5	
Twin Lakes[g]		0.3
Unimak Island	0.1	0.2
Western Arctic	1.7	2.3
White Mountains	0.2	0.2
Wolf Mountain	0.1	0.1

[a] Assumes no population increase since 1993 census.
[b] Assumes same population as in 1984.
[c] Summer range inundated by Mulchatna caribou after 1994.
[d] Nelchina Herd peaked in 1995 at a summer density of 3.8/km^2.
[e] A peak in summer density (2.9/km^2) occurred in 1983.
[f] No data since 1991.
[g] Herd established in 1995.

Table 19 Weights of newborn caribou calves from selected Alaskan herds

	Males			Females		
Herd and Year	Weight (kg)	$s_{\bar{x}}$ [a]	*n*	Weight (kg)	$s_{\bar{x}}$	*n*
Central Arctic 2001	--	--	--	6.19	0.37	65
Delta 1995	8.72	0.29	26	8.31	0.24	19
Delta 1996	8.39	0.23	22	7.40	0.19	28
Delta 1997	8.33	0.21	40	7.99	0.20	35
Delta 1998	8.41	0.22	15	7.70	0.29	15
Delta 1999	8.86	0.32	26	7.89	0.19	35
Delta 2000	7.82	0.28	25	7.76	0.32	16
Delta 2001	9.56	0.61	8	8.70	0.32	10
Denali 1986–1987[b]	9.00	0.11	67	7.80	0.11	60
Denali 1998[c]	9.40	0.30	15	8.40	0.32	14
Fortymile 1994	7.71	0.20	22	7.55	0.27	22
Fortymile 1995	8.65	0.16	24	7.94	0.19	25
Fortymile 1996	8.54	0.24	26	8.09	0.17	32
Fortymile 1997	8.52	0.25	24	7.97	0.21	32
Fortymile 1998	8.43	0.14	30	8.00	0.15	39
Fortymile 1999	8.54	0.18	35	7.71	0.17	40
Fortymile 2000	8.30	0.17	27	7.64	0.18	39
Fortymile 2001	8.10	0.14	34	7.53	0.17	26
Mentasta 1993[d]	8.90	0.23	15	7.91	0.20	23
Mentasta 1994[d]	8.83	0.21	18	8.09	0.19	23
Mentasta 1998[c]	8.66	0.27	15	7.98	0.32	12
Nelchina 1996	8.26	0.24	23	7.19	0.19	17
Nelchina 1997	8.43	0.18	30	7.91	0.21	30
Nelchina 1998	8.97	0.20	30	8.57	0.18	30
Nelchina 1999	9.17	0.23	26	8.14	0.21	27
Nelchina 2000	7.66	0.19	25	7.02	0.15	31
Nelchina 2001	8.25	0.21	25	7.72	0.19	25
NAP 1998	8.44	0.24	19	7.17	0.30	20
NAP 1999	8.35	0.25	22	7.41	0.24	22
SAP 1989	6.70	0.67	9	5.40	0.57	9
SAP 1999	7.70	0.28	25	7.14	0.16	29
Porcupine 1983[e]	7.40	0.19	24	6.60	0.16	28
Porcupine 1984[e]	7.30	0.22	33	6.70	0.18	23
Porcupine 1985[e]	7.70	0.23	27	7.30	0.20	26
Porcupine 1993[f]	--	--	--	6.20	0.70	68

[a] With standard errors of about 0.2 kg, a difference in means of 0.6 kg would be significant at the 0.05 level.

[b] Denali data is corrected for calf age; uncorrected weights would be 0.3–0.5 kg higher (Adams et al. 1995).

[c] Unpublished data from L Adams.

[d] Unpublished data from Jenkins (1996).

[e] Data from Whitten et al. (1992).

[f] Data from Whitten (1995a).

Table 20 Causes and timing of mortality of caribou calves that were radiocollared as newborns in early June in the Northern and Southern Alaska Peninsula herds

	Number of caribou calves radiocollared as newborns that died during June							
Herd and Year	Brown bear	Wolf	Eagle	Wolverine	Drowning	Disease (pneumonia?)[a]	Unknown	Total dying (%)
NAP 1998	3[b]	none[b]	1	none	1	2	6[b]	13/37 (35)
SAP 1999	3	6	1	1	2	none	9	22/49 (45)

[a] Two calves were found dead in late June. There were no visible subcutaneous marks on them. Lungs and liver were sent to Washington Animal Disease Diagnostic Laboratory and pneumonia was diagnosed.

[b] Two calves included as unknown were killed either by bears or wolves.

Table 21 Genetic distances in 10 Alaskan caribou herds

Herd	MACH	MECH	MCH	NAP	NCH	NPCH	PCH	SAP	UNI	WHITE
Macomb	0.00									
Mentasta	0.14	0.00								
Mulchatna	0.24	0.23	0.00							
Northern Alaska Peninsula	0.32	0.28	0.32	0.00						
Nelchina	0.17	0.13	0.28	0.31	0.00					
Nushagak	0.31	0.30	0.26	0.14	0.32	0.00				
Porcupine	0.14	0.14	0.23	0.23	0.16	0.25	0.00			
Southern Alaska Peninsula	0.51	0.48	0.51	0.23	0.57	0.33	0.42	0.00		
Unimak	0.68	0.65	0.71	0.35	0.83	0.53	0.58	0.22	0.00	
White Mountains	0.39	0.40	0.50	0.57	0.44	0.56	0.39	0.71	0.86	0.00

Table 22 Assignment tests of 218 samples of DNA from 10 Alaskan caribou herds

Herd	MAC	MENT	MU	NAP	NEL	NUSH	PORC	SAP	UNI	WHITE	Total samples
Macomb	10	2	1	0	4	0	2	1	0	0	20
Mentasta	4	19	2	3	2	0	2	0	0	0	32
Mulchatna	3	1	12	0	0	1	1	0	0	1	19
Northern Alaska Peninsula	0	0	2	7	3	3	1	3	1	0	20
Nelchina	5	5	1	3	4	0	1	1	0	0	20
Nushagak	0	2	3	8	0	4	0	2	1	0	20
Porcupine	8	4	6	5	5	3	13	0	0	1	45
Southern Alaska Peninsula	0	0	0	3	0	0	0	16	1	0	20
Unimak	0	0	0	0	0	0	0	1	15	0	16
White Mountains	0	1	0	0	1	0	1	0	0	3	6
										Grand total:	218

APPENDIX A Means of weights and measurements (cm), standard errors, and sample sizes of cohorts of female Alaskan caribou calves handled during 1979–2001

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Chisana	1990	Fall	114.1	51.7	35.4	89.1	154.1		1.46
			3.8	1.8	0.3	1.3	2.4		0.05
			13	13	13	13	13		13
Chisana	1998	Fall	147.1	66.7	38.0	99.8	171.3	23.0	1.75
			2.6	1.2	0.6	2.2	3.7	0.2	0.01
			3	3	3	3	3	3	3
Chisana	1999	Fall	139.9	63.5	37.2	99.3	164.1	22.0	1.71
			3.4	1.5	0.7	0.3	0.1	0.1	0.03
			8	8	8	8	8	8	8
Chisana	2000	Fall	136.7	62.0	36.8	101.0	165.5	22.5	1.68
			3.2	1.4	0.3	1.2	1.9	0.3	0.03
			8	8	8	8	8	8	8
Delta	1979	Spring	132.3	60.0	37.8	102.9	168.5		1.58
			2.4	1.1	0.4	1.4	1.9		0.03
			11	11	12	12	12		11
Delta	1981	Spring	137.0	62.1	39.5	105.0	174.5		1.68
			7.4	3.4	0.5	2.9	2.7		0.08
			5	5	4	6	6		3
Delta	1982	Spring	135.1	61.3	38.1	96.9	165.0		1.62
			3.9	1.7	0.3	1.5	2.7		0.04
			11	11	10	9	7		10
Delta	1983	Spring	137.2	62.2	38.1	97.8	168.3		1.64
			3.3	1.5	0.4	1.6	2.0		0.03
			13	13	12	12	12		12
Delta	1984	Spring	126.3	57.3	37.9	97.6	164.0		1.51
			1.4	0.6	0.2	1.0	2.3		0.02
			12	12	10	10	10		10

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Delta	1987	Spring	120.8	54.8	36.8	94.4	163.1	23.6	1.48
			2.8	1.3	0.4	1.1	2.3	0.4	0.03
			9	9	10	10	9	7	9
Delta	1988	Spring	130.7	59.3	38.0	101.7	171.4	24.1	1.56
			2.2	1.0	0.2	0.7	1.6	0.3	0.02
			16	16	16	17	17	16	15
Delta	1989	Spring	133.6	60.6	37.9	98.2	171.6	24.3	1.59
			2.7	1.2	0.5	1.5	1.9	0.3	0.02
			9	9	10	10	10	10	9
Delta	1990	Spring	112.4	51.0	37.1	96.0	167.6		1.37
			2.9	1.3	0.5	1.1	1.4		0.03
			14	14	14	14	14		14
Delta	1991	Spring	112.8	51.2	36.9	92.1	164.6		1.38
			2.3	1.1	0.3	1.0	2.3		0.03
			10	10	11	11	11		10
Delta	1991	Fall	127.6	57.9	35.6	94.6	162.2	21.9	1.63
			2.6	1.2	0.2	0.8	2.0	0.2	0.03
			14	14	14	14	14	14	14
Delta	1992	Spring	120.3	54.6	36.3	91.5	163.8	22.5	1.50
			2.9	1.3	0.3	0.7	2.0	0.2	0.04
			16	16	16	16	16	16	16
Delta	1992	Fall	120.3	54.6	35.3	90.8	158.8	21.5	1.55
			3.1	1.4	0.2	1.1	2.3	0.2	0.03
			14	14	15	14	14	15	14
Delta	1993	Spring	122.3	55.5	36.9	92.8	165.6	23.1	1.50
			2.9	1.3	0.3	0.8	1.7	0.3	0.03
			12	12	12	11	11	12	12

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Delta	1993	Fall	122.5	55.6	35.1	91.4	161.1	21.3	1.58
			3.2	1.4	0.2	1.3	2.3	0.2	0.04
			14	14	14	14	14	13	14
Delta	1994	Fall	131.3	59.6	36.1	96.5	167.9	22.2	1.65
			3.0	1.3	0.2	1.0	1.7	0.2	0.03
			15	15	15	15	15	15	15
Delta	1995	Spring	123.3	55.9	37.2	96.1	169.5	23.3	1.50
			2.7	1.2	0.2	0.9	1.2	0.1	0.03
			15	15	14	15	15	14	14
Delta	1995	Fall	131.1	59.5	35.7	93.8	169.4	22.2	1.66
			2.6	1.3	0.3	0.6	1.8	0.1	0.03
			13	13	12	12	12	12	12
Delta	1996	Spring	120.8	54.8	37.0	95.0	167.6	23.5	1.48
			3.3	1.5	0.2	1.2	2.1	0.2	0.04
			15	15	15	15	15	15	15
Delta	1996	Fall	122.9	55.7	35.8	94.1	161.1	22.1	1.56
			3.0	1.4	0.2	1.1	1.7	0.2	0.03
			14	14	14	14	14	14	14
Delta	1997	Spring	118.3	53.7	37.8	96.0	166.1	23.4	1.43
			2.5	1.1	0.4	0.7	2.1	0.2	0.03
			14	14	8	14	14	13	8
Delta	1997	Fall	128.3	58.2	36.0	95.0	159.4	22.4	1.60
			2.2	1.0	0.3	0.9	2.0	0.2	0.03
			20	20	15	20	20	20	15
Delta	1998	Spring	123.7	56.1	36.7	98.4	168.9	23.3	1.53
			3.0	1.4	0.5	1.1	1.9	0.3	0.04
			12	12	12	12	12	11	12

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Delta	1998	Fall	124.4	56.4	35.7	95.2	159.1	21.6	1.58
			2.6	1.2	0.2	1.2	2.3	0.3	0.03
			16	16	16	16	16	16	16
Delta	1999	Spring	118.3	53.7	37.2	92.3	161.7	22.9	1.44
			2.9	1.3	0.2	0.9	12.1	0.3	0.03
			14	14	14	14	13	14	14
Delta	1999	Fall	126.0	57.1	35.7	91.9	160.6	22.1	1.58
			2.9	1.3	2.7	1.2	2.1	0.2	0.12
			14	14	13	14	14	14	13
Delta	2000	Spring	114.9	52.1	36.6	89.0	159.6	22.9	1.42
			2.6	1.2	0.3	3.4	2.0	0.2	0.02
			12	12	12	12	12	12	12
Delta	2000	Fall	124.7	56.6	35.7	95.6	162.4	22.2	1.58
			4.0	1.8	0.3	1.1	2.6	0.2	0.0
			14	14	14	14	14	14	14
Delta	2001	Spring	122.2	55.4	37.7	94.4	166.8	23.7	1.47
			3.2	1.4	0.3	0.9	3.2	0.2	
			11	11	11	11	11	11	11
Delta	2001	Fall	126.0	57.1	35.5	93.6	163.6	22.0	1.61
			2.4	1.1	0.3	0.9	2.0	0.2	
			14	14	14	14	14	14	14
Denali[a]	1987	Spring	131.0	59.4	37.7	97.5	163.5	23.6	1.57
			7.4	3.3	0.3	1.1	3.9	0.2	0.08
			5	5	6	6	6	7	5
Denali	1988	Spring	130.6	59.2	37.3	97.3	167.0	23.4	1.58
			5.3	2.4	0.3	2.0	2.3	0.5	0.06
			9	9	8	8	8	8	8

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Denali	1989	Spring	131.3	59.5	36.9	96.8	169.2	24.9	1.61
			3.7	1.7	0.1	1.0	1.5	0.9	0.05
			13	13	13	13	13	14	13
Denali	1990	Spring	126.3	57.3	36.8	95.2	165.4	24.1	1.56
			2.7	1.2	0.3	1.0	2.0	0.3	0.03
			15	15	16	16	16	16	15
Denali	1991	Spring	111.7	50.7	36.1	91.5	157.2	23.6	1.40
			3.1	1.4	0.4	1.1	2.5	0.8	0.03
			15	15	14	14	14	14	14
Denali	1992	Spring	123.5	56.0	37.4	94.2	165.7	24.3	1.50
			2.6	1.2	0.2	0.8	1.3	0.4	0.03
			16	16	16	16	16	16	16
Denali	1993	Spring	125.4	56.9	37.1	93.5	164.7	23.1	1.53
			4.3	2.0	0.3	1.1	2.7	0.4	0.05
			9	9	9	8	9	9	9
Denali	1994	Spring	125.5	56.9	37.3	95.7	167.5	23.8	1.53
			3.3	1.5	0.3	0.9	1.7	0.3	0.04
			11	11	11	11	11	11	11
Denali	1995	Spring	132.3	60.0	37.2	95.7	168.0	23.8	1.61
			6.0	2.7	0.4	2.4	3.2	0.2	0.07
			6	6	6	6	6	6	6
Denali	1996	Spring	132.6	60.1	37.7	94.9	165.4	23.6	1.59
			4.7	2.1	0.5	1.6	3.9	0.3	0.04
			7	7	7	7	7	7	7
Denali	1997	Spring	134.5	61.0	37.5	102.3	167.0	24.3	1.63
			4.6	2.1	0.3	2.9	3.2	0.5	0.05
			3	3	4	3	4	4	3

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Fortymile	1990	Fall	116.3	52.7	35.8	93.0	157.9		1.47
			2.5	1.2	0.2	1.2	1.5		0.03
			14	14	14	14	14		14
Fortymile	1991	Fall	118.9	53.9	35.2	94.1	157.0	22.0	1.53
			3.0	1.4	0.2	1.4	2.1	0.2	0.03
			14	14	14	13	14	14	14
Fortymile	1992	Spring	110.6	50.2	36.8	89.7	158.5	22.2	1.31
			5.1	2.3	0.5	2.1	4.4	0.3	0.03
			7	7	6	6	6	5	6
Fortymile	1992	Fall	121.5	55.1	35.0	96.7	154.5	21.4	1.57
			3.7	1.7	0.3	1.2	2.6	0.2	0.05
			14	14	13	13	13	13	13
Fortymile	1993	Fall	123.7	56.1	35.3	93.9	158.5	21.3	1.59
			1.9	0.9	0.2	1.1	1.7	0.1	0.02
			15	15	14	14	14	15	14
Fortymile	1994	Fall	120.0	54.4	36.0	94.1	159.5	22.4	1.53
			2.7	1.2	0.4	0.8	1.8	0.2	0.05
			14	14	11	13	13	13	11
Fortymile	1995	Fall	125.0	56.7	35.4	94.1	163.6	22.1	1.60
			2.6	1.2	0.3	0.9	2.2	0.2	0.03
			15	15	15	14	14	15	15
Fortymile	1996	Fall	121.4	55.1	35.5	94.5	156.9	22.0	1.55
			3.0	1.4	0.3	1.4	2.1	0.2	0.03
			15	15	15	15	15	15	15
Fortymile	1997	Fall	130.8	59.3	36.3	96.5	158.7	22.2	1.63
			2.8	1.3	0.2	0.8	2.2	0.2	0.03
			15	15	15	15	15	15	15

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Fortymile	1998	Fall	116.9	53.0	35.8	91.8	152.1	21.7	1.48
			2.9	1.3	0.3	1.4	3.5	0.3	0.03
			17	17	17	17	17	17	17
Fortymile	1999	Fall	120.5	54.7	36.2	95.9	158.5	21.9	1.51
			2.1	1.0	0.3	1.2	1.6	1.5	0.02
			15	15	15	15	15	14	15
Fortymile	2000	Fall	125.0	56.7	35.6	95.6	157.6	21.4	1.59
			2.5	1.1	0.2	0.6	2.0	0.2	0.03
			15	15	15	15	15	15	15
Fortymile	2001	Fall	119.3	54.1	35.2	92.5	160.8	21.6	1.55
			2.5	1.1	0.2	1.6	1.5	0.2	0.03
			17	17	17	17	17	17	17
Galena Mtn	1993	Fall	146.5	66.5	36.5	96.3	170.3	22.4	1.82
			7.0	3.2	0.6	2.3	6.7	0.4	0.06
			4	4	4	4	3	4	4
Galena Mtn	1994	Fall	144.6	65.6	35.9	99.2	177.3	23.5	1.83
			2.9	1.3	0.1	1.4	2.1	0.2	0.03
			9	9	9	9	9	9	9
Kenai Mtns	1996	Spring	126.9	57.6	38.2	97.6	166.6	23.4	1.48
			3.3	1.5	0.3	0.9	2.5	0.1	0.03
			11	11	11	11	11	11	11
Kenai Mtns	2000	Fall	133.0	60.3		101.0	164.4		
			2.2	1.0		1.1	1.7		
			14	14		13	7		
Kenai Mtns	2001	Fall	131.2	59.5		100.2	161.0		
			4.2	1.9		1.3	3.3		
			11	11		7	8		

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Killey River	1996	Spring	144.8	65.7	39.4	102.4	174.4	24.6	1.66
			1.4	0.6	0.3	1.4	2.0	0.2	0.02
			10	10	9	7	8	9	9
Killey River	2001	Fall	134.5	61.0		102.0	166.8		
			4.2	1.9		1.3	2.7		
			13	13		10	10		
Macomb	1988	Spring	116.8	53.0	37.0	99.3	164.8	23.1	1.43
			1.3	0.6	0.4	0.6	2.6	0.3	0.02
			4	4	4	4	4	4	4
Macomb	1990	Spring	107.3	48.7	36.3	94.3	166.0	23.0	1.34
			2.6	1.2	0.5	1.0	2.4	0.4	0.03
			12	12	12	12	12	6	12
Macomb	1994	Spring	118.8	53.9	37.4	97.0	162.5	23.1	1.44
			3.1	1.4	0.3	1.6	2.2	0.2	0.03
			10	10	10	9	10	10	10
Macomb	1996	Fall	128.8	58.4	36.1	96.8	165.4	21.9	1.62
			5.6	2.6	0.4	2.0	2.1	0.3	0.06
			8	8	8	8	8	8	8
Macomb	1998	Fall	132.8	60.2	36.1	96.4	165.7	22.7	1.67
			3.1	1.4	0.2	1.4	2.2	0.2	0.04
			12	12	12	12	12	12	12
Macomb	1999	Fall	128.2	58.1	35.4	94.8	158.3	23.0	1.64
			9.8	4.4	0.7	2.1	4.6	0.5	0.09
			4	4	4	4	4	4	4
Mulchatna	1995	Spring	110.6	50.1	36.9	93.9	156.0	22.4	1.36
			3.0	1.4	0.3	1.5	2.1	0.2	0.03
			10	10	10	10	10	10	10

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Mulchatna	1998	Fall	106.9	48.3	34.3	92.1	151.6	20.8	1.4
			4.8	2.6	0.4	1.3	3.1	0.3	0.1
			14	10	14	14	14	13	10
Mulchatna	2000	Spring	103.5	46.9	35.6	91.0	158.0	22.0	1.31
			2.6	1.2	0.3	0.9	3.1	0.2	0.03
			11	11	10	11	10	10	10
Mulchatna	2000	Fall	112.9	51.2	35.2	91.8	154.4	21.2	1.45
			4.1	1.8	0.2	1.3	2.5	0.4	0.05
			10	10	10	10	10	9	10
Mulchatna	2001	Spring	109.8	49.8	35.9	92.4	153.7	22.0	1.39
			1.9	0.9	0.2	0.9	2.5	0.5	0.03
			13	13	13	12	12	11	13
Nelchina	1994	Spring	107.7	48.9					
			4.2	1.9					
			11	11					
Nelchina	1995	Spring	105.0	47.6	36.7	92.2	159.8	22.6	1.30
			1.9	0.8	0.2	0.8	1.3	0.1	0.02
			29	29	29	29	29	29	29
Nelchina	1995	Fall	118.0	53.5	35.6	94.1	160.2	21.4	1.50
			3.4	1.5	0.3	1.2	1.7	0.2	0.03
			15	15	15	15	15	15	15
Nelchina	1996	Spring	117.1	53.1	37.2	94.0	167.4	22.7	1.42
			2.7	1.2	0.3	1.0	2.1	0.2	0.02
			16	16	16	16	16	16	16
Nelchina	1996	Fall	106.5	48.3	35.5	88.3	149.5	21.2	1.36
			4.7	2.1	0.3	1.6	1.9	0.2	0.05
			10	10	10	10	10	9	10

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Nelchina	1997	Spring	108.3	49.1	36.8	93.9	159.9	23.0	1.32
			2.3	1.0	0.2	1.0	2.0	0.1	0.02
			23	23	18	23	23	23	18
Nelchina	1997	Fall	122.3	55.5	35.9	92.1	156.6	21.8	1.55
			3.9	1.8	0.3	1.5	2.0	0.5	0.05
			10	10	10	10	10	10	10
Nelchina	1998	Spring	125.7	57.0	37.5	94.4	168.6	23.1	1.52
			2.5	1.1	0.1	0.9	1.4	0.2	0.03
			15	15	15	15	15	15	15
Nelchina	1998	Fall	111.6	50.6	35.4	93.0	153.8	20.9	1.43
			1.9	0.9	0.2	0.7	1.6	0.2	0.02
			25	25	25	25	25	25	25
Nelchina	1999	Spring	117.0	53.1	37.1	92.1	163.7	22.9	1.43
			2.7	1.2	0.3	0.9	1.6	0.2	0.03
			15	15	15	15	15	15	15
Nelchina	1999	Fall	114.7	52.0	35.9	91.3	154.6	21.7	1.45
			1.8	0.8	0.2	0.6	1.0	0.1	0.02
			38	38	38	38	38	38	38
Nelchina	2000	Spring	107.1	48.6	37.5	91.7	159.5	23.4	1.3
			1.7	0.8	0.2	0.9	1.4	0.1	0.0
			27	27	28	27	28	27	27
Nelchina	2000	Fall	118.0	53.5	35.5	92.4	154.9	21.6	1.51
			2.4	1.1	0.2	0.9	1.4	0.2	0.03
			37	37	36	37	36	37	36
Nelchina	2001	Spring	115.5	52.5	37.2	91.2	162.3	23.6	1.42
			2.0	0.9	0.2	0.8	1.6	0.2	0.02
			26	26	25	25	25	25	25

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Nelchina	2001	Fall	129.0	58.5	36.4	96.1	160.3	22.5	1.60
			2.1	0.9	0.2	0.8	1.1	0.1	0.02
			40	40	40	40	40	40	40
Nelchina (12)	1992	Spring	124.4	56.4					
			2.7	1.2					
			9	9					
Nelchina (12)	1993	Spring	125.7	57.0	36.9	93.6	162.7	23.7	1.55
			4.0	1.8	0.3	1.3	3.4	0.9	0.04
			7	7	7	7	7	7	7
Nelchina (13)	1992	Spring	109.4	49.6					
			2.8	1.6					
			7	7					
Nelchina (13)	1993	Spring	118.7	53.8	36.9	93.6	156.7	22.6	1.46
			3.1	1.4	0.4	1.3	1.7	0.2	0.03
			12	12	12	11	12	12	11
Northern AK Peninsula	1995	Spring	113.3	51.4	35.8	92.6	161.1	22.5	1.43
			3.0	1.3	0.3	1.1	2.1	0.2	0.03
			19	19	19	19	19	19	19
Northern AK Peninsula	1995	Fall	98.6	44.7	34.2	88.6	145.1	20.2	1.31
			3.6	1.6	0.3	0.9	1.6	0.2	0.04
			10	10	10	10	10	10	10
Northern AK Peninsula	1996	Fall	101.5	46.0	34.2	89.1	143.5	20.3	1.34
			5.3	2.4	0.3	2.3	2.6	0.4	0.06
			10	10	10	10	10	10	10
Northern AK Peninsula	1997	Spring	106.6	48.4	35.6	91.8	157.4	22.2	1.36
			3.0	1.4	0.2	0.9	1.5	0.2	0.03
			14	14	14	14	14	14	14

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Northern AK Peninsula	1997	Fall	106.6	48.3	34.0	92.9	152.8	20.3	1.42
			4.7	2.1	0.2	1.4	3.2	0.3	0.06
			10	10	10	10	10	10	10
Northern AK Peninsula	1998	Fall	109.0	49.4	33.9	90.9	151.4	20.6	1.46
			2.8	1.3	0.2	0.9	1.6	0.2	0.03
			29	29	29	29	29	29	29
Northern AK Peninsula	1999	Fall	114.3	51.9	34.9	93.6	154.0	21.4	1.48
			2.9	1.3	0.3	1.5	2.3	0.3	0.04
			11	11	11	11	11	10	11
Northern AK Peninsula	2001	Spring	119.8	54.3	36.0	96.7	158.4	22.4	1.51
			2.1	0.9	0.3	1.1	2.2	0.2	0.02
			21	21	20	19	19	19	20
Nushagak Peninsula	1995	Spring	125.8	57.1	36.9	98.3	167.5	23.4	1.55
			2.9	1.3	0.3	0.9	2.7	0.2	0.03
			15	15	15	15	15	15	15
Nushagak Peninsula	1997	Spring	112.2	50.9	37.5	96.8	151.9	22.8	1.36
			4.3	1.9	0.5	1.5	3.0	0.3	0.04
			10	10	13	13	13	13	10
Nushagak Peninsula	1998	Fall	123.0	55.8	35.3	94.8	156.2	21.7	1.58
			3.5	1.6	0.3	0.9	3.0	0.2	0.03
			5	5	5	5	5	5	5
Nushagak Peninsula	2000	Spring	108.4	49.2	35.3	95.0	165.9	22.3	1.39
			1.5	0.7	0.2	0.9	2.0	0.2	0.02
			10	10	10	10	10	10	10
Nushagak Peninsula	2001	Spring	113.1	51.3	37.1	93.6	156.7	23.1	1.43
			3.5	1.6	0.6	1.5	1.5	0.5	0.05
			10	10	9	11	11	9	9

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Rainy Pass	1999	Fall	140.1	63.6	37.0	102.8	170.8	22.8	1.72
			5.4	2.5	0.5	2.0	1.7	0.4	0.05
			5	5	5	5	5	5	5
Ray Mtns	1994	Fall	134.4	60.9	35.5	96.7	170.7	22.3	1.72
			2.9	1.3	0.3	0.6	1.5	0.2	0.03
			20	20	20	20	20	17	20
Unimak	1997	Spring	106.8	48.4	35.1	93.0	157.6	21.7	1.38
			6.5	3.0	0.8	2.0	3.1	0.3	0.06
			5	5	5	5	5	5	5
Unimak	1999	Fall	123.4	56.0	34.5	96.1	166.2	21.4	1.62
			3.4	1.5	0.3	0.9	2.0	0.3	0.05
			12	12	12	12	12	12	12
Southern AK Peninsula	1997	Spring	107.7	48.9	35.6	93.6	153.9	22.3	1.37
			2.2	1.0	0.2	1.0	2.1	0.1	0.03
			13	13	13	13	13	13	13
Southern AK Peninsula	1998	Fall	115.2	52.2	33.9	91.9	153.9	20.9	1.54
			2.7	1.2	0.3	0.8	1.7	0.2	0.03
			13	13	13	13	13	13	13
Western Arctic	1992	Spring	87.0	39.5					
			2.0	0.9					
			16	16					
Western Arctic	1992	Fall	89.2	40.4					
			3.9	1.8					
			13	13					
Western Arctic	1993	Spring	82.1	37.2					
			2.1	1.0					
			14	14					

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
Western Arctic	1994	Spring	88.3	40.1					
			2.8	1.3					
			15	15					
Western Arctic	1994	Fall	71.5	32.4					
			2.8	1.3					
			15	15					
Western Arctic	1995	Fall	81.1	36.8					
			2.6	1.2					
			9	9					
White Mtns	1988	Fall			36.0	103.9	166.5	22.4	
					0.5	1.5	2.5	0.4	
					10	8	10	9	
White Mtns	1991	Fall	128.9	58.5	35.9	95.4	164.8	22.2	1.63
			4.7	2.1	0.4	1.5	2.0	0.4	0.05
			9	9	9	9	9	9	9
White Mtns	1995	Spring	130.1	59.0	37.6	98.5	172.5	24.4	1.56
			3.0	1.4	0.4	1.3	1.7	0.2	0.03
			8	8	7	8	8	8	7
White Mtns	1995	Fall	133.6	60.6	36.4	96.2	170.0	23.0	1.66
			4.7	2.1	0.5	1.3	3.5	0.3	0.04
			6	6	6	6	6	6	6
White Mtns	1997	Fall	135.8	61.6		98.3	164.8	22.7	
			2.4	1.1		1.0	3.2	0.4	
			6	6		6	6	6	
White Mtns	2000	Spring	118.9	53.9	37.5	94.3	167.5	23.1	1.44
			4.2	1.9	0.6	2.3	1.8	0.1	0.1
			4	4	4	4	4	4	4

Herd	Year	Season	Weight (lb)	Weight (kg)	Metatarsus	Girth	Total length	Mandible length	Weight: metatarsus ratio
White Mtns	2001	Fall	135.0	61.2	36.1	100.2	166.8	22.3	1.70
			3.0	1.4	0.2	1.3	2.4	0.1	0.04
			9	9	9	9	9	9	9
Wolf Mtn	1995	Fall	131.4	59.6	35.7	97.0	166.1	22.7	1.67
			4.7	2.1	0.3	1.1	2.2	0.3	0.05
			8	8	8	8	7	8	8

[a] Denali data provided by L Adams (unpublished).

APPENDIX B Spreadsheet computer simulation of the DCH, 1969–2001, with projection to 2004. The model was constructed by manipulating female and male survival rates to make the population track census data.

Year	Cows	Calves	Bulls	Posthunt total	***Cow[a] harvest***	***Bull harvest***	Cow survival	Bull survival	Calves: 100 Cows	Bulls: 100 Cows	λ	***Census***	***Fall Calf: Cow***	***Fall Bull: Cow***	***Adult female mortality rate***
1969	**3000[b]**	840	1200	5040	**86**	**271**	**0.88**	**0.95**	**28**	**40**			28	40	
1970	2932	997	1178	5106	**115**	**321**	**0.88**	**0.95**	**34**	40	1.01		34	77	
1971	2696	404	921	4022	**366**	**624**	**0.88**	**0.95**	**15**	34	0.79		15	29	
1972	2349	258	447	3055	**219**	**601**	**0.88**	**0.95**	**11**	19	0.76		11	33	
1973	2089	209	269	2567	**104**	**266**	**0.85**	**0.95**	**10**	13	0.84	2804	10	29	
1974	1873	37	345	2255	**0**	**0**	**0.85**	**0.95**	**2**	18	0.88		2	28	
1975	1609	193	344	2146	**0**	**0**	**0.95**	**0.95**	**12**	21	0.95				
1976	1630	733	409	2773	**0**	**0**	**0.95**	**0.95**	**45**	25	1.29		45	38	
1977	1932	811	702	3445	**0**	**0**	**0.95**	**0.95**	**42**	36	1.24		42	33	
1978	2259	881	1014	4154	**0**	**0**	**0.93**	**0.95**	**39**	45	1.21	3200	39	75	
1979	2551	1021	1340	4912	**0**	**0**	**0.92**	**0.95**	**40**	53	1.18	4191	65	39	0
1980	2864	1403	1605	5872	**0**	**104**	**0.92**	**0.95**	**49**	56	1.20	4478	49	85	0
1981	3272	1341	1857	6470	**73**	**268**	**0.92**	**0.95**	**41**	57	1.10	4962	41	46	0
1982	3612	1120	2063	6795	**77**	**274**	**0.91**	**0.97**	**31**	57	1.05	7335	31	42	7
1983	3613	1662	1188	6463	**234**	**1302**	**0.91**	**0.97**	**46**	33	0.95	6969	46	35	6
1984	3929	1414	1371	6714	**191**	**507**	**0.91**	**0.98**	**36**	35	1.04	6260	36	42	6
1985	4166	1500	1353	7019	**117**	**614**	**0.95**	**0.98**	**36**	32	1.05	8083	36	49	18
1986	4558	1322	1147	7027	**183**	**841**	**0.97**	**0.98**	**29**	25	1.00	7804	29	41	9
1987	5089	1578	1063	7729	**38**	**644**	**0.97**	**0.98**	**31**	21	1.10	8380	31	32	5
1988	5756	2015	1182	8953	**22**	**555**	**0.97**	**0.98**	**35**	21	1.16	8535	35	33	14
1989	6640	1062	1366	9068	**18**	**681**	**0.80**	**0.98**	**16**	21	1.01	10,690	36	27	12
1990	5654	509	1307	7470	**83**	**552**	**0.80**	**0.98**	**9**	23	0.82	8700	17	38	22
1991	4705	235	1074	6014	**22**	**456**	**0.75**	**0.90**	**5**	23	0.81	5755	8	29	14
1992	3617	181	1073	4870	**0**	**0**	**0.78**	**0.75**	**5**	30	0.81	5877	11	25	15
1993	2887	144	867	3898	**5**	**5**	**0.93**	**0.78**	**5**	30	0.80	3661	5	36	10
1994	2745	467	739	3950	**0**	**0**	**0.93**	**0.80**	**17**	27	1.01	4341	23	25	15
1995	2743	411	791	3946	**5**	**5**	**0.91**	**0.85**	**15**	29	1.00	4646	20	24	10
1996	2665	346	843	3854	**0**	**22**	**0.86**	**0.90**	**13**	32	0.98	4091	21	30	11
1997	2441	244	870	3555	**0**	**44**	**0.93**	**0.90**	**10**	36	0.92	3699	18	27	9
1998	2383	191	843	3417	**0**	**50**	**0.91**	**0.90**	**8**	35	0.96	3829	16	44	8

Year	Cows	Calves	Bulls	Posthunt total	***Cow*[a] *harvest***	***Bull harvest***	Cow survival	Bull survival	Calves: 100 Cows	Bulls: 100 Cows	λ	***Census***	***Fall Calf: Cow***	***Fall Bull: Cow***	***Adult female mortality rate***
1999	2255	180	807	3243	**0**	**38**	**0.91**	**0.90**	**8**	36	0.95	3227	19	44	23
2000	2135	213	773	3121	**0**	**34**	**0.90**	**0.90**	**10**	36	0.96	3227	11	46	14
2001	2017	202	767	2986	**0**	**32**	**0.90**	**0.90**	**10**	38	0.96	2950	13	39	
2002	1906	286	741	2933	**0**	**40**[c]	**0.90**	**0.90**	**15**	39	0.98				
2003	1844	277	756	2876	**0**	**40**[c]	**0.90**	**0.90**	**15**	41	0.98				
2004	1784	268	765	2816	**0**	**40**[c]	**0.90**	**0.90**	**15**	43	0.98				

[a] Figures in columns with italicized headings represent actual data collected in the field.

[b] Bolded figures are model inputs.

[c] Harvest projected after 2001.