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Investigation and Improvement of Techniques for Monitoring Recruitment, Population Trend, and Nutritional Status in the Western Arctic Caribou Herd

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FINAL RESEARCH REPORT

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SUMMARY

From 1991 to 1995 we investigated more efficient and economical techniques for monitoring recruitment and body condition in the Western Arctic Caribou (*Rangifer tarandus granti*) Herd (WACH). To assess recruitment, we used a relatively inexpensive Robinson R-22 (2 place) helicopter, along with a fixed-wing aircraft, to conduct composition counts during the prerut period in fall. The fixed-wing aircraft was used to determine the distribution of radiocollared caribou in the herd and carry extra fuel for the helicopter. Helicopter costs averaged about $6000 annually, and we sampled from one-third to two-thirds of the distribution of collared caribou. One disadvantage in using the R-22 helicopter is that in-the-field training of counters is difficult.

Based on a review of the literature on caribou body condition and ongoing work in Interior Alaska, we established a simple protocol to monitor the condition of WAH caribou in spring and fall by collecting samples of 10-15 female calves. Because this was a pilot project, we collected 10 female calves in the Pah Flats by helicopter in April 1992. Thereafter, samples were collected by cooperating local residents who were paid $50-$100 per processed calf. Additional samples were collected by Department of Fish and Game (ADF&G) biologists and cooperating nonlocal hunters. Calves were weighed, and the presence or absence of fat was recorded for 4 depos: rump, brisket, mesenteries, and heart. Cooperators were asked to collect whole jaws and femurs for analysis of fat content and determination of dried jaw length. Although 2 local cooperators were successful in collecting samples of female calves, the unpredictable nature of caribou movements, difficult conditions for ground travel during spring and fall, and time conflicts of cooperators resulted in missing data. Samples were not obtained in fall 1993 or spring

1995. Nevertheless, mean calf weight and marrow fat content varied among some collections and were particularly low preceding a winter die-off of caribou in fall 1994.

A review of the literature on body condition in caribou and ongoing studies in Interior Alaska indicates that calf weight and marrow fat content can be reliable indicators of herd nutrition. Calf weight in September reflects nutrient availability over the preceding summer and winter, and calf weight in April reflects nutrient availability over the previous 2 winters and intervening summer. Recent studies have shown that femur marrow water, marrow fat weight, and percent femur fat in September and April accurately reflect body fat over a wide range of values, especially in calves. Inexpensive, quantitative annual data on body weight and fatness in calves could be collected in conjunction with fall composition counts or fall collaring activities on the Kobuk River. Local residents should be involved in these activities, but supervision by biologists is essential.

Collaring 15 bulls in fall 1992 did not significantly increase the number of caribou found during the census of 1993. Only about 2000 additional caribou were found. However, confidence in census results was improved.

Body size of male WAH caribou (i.e., jaw length) was significantly smaller during the late 1960s when the herd was high and declining than in the 1980s when it was growing. Jaws of male calves collected incidentally during this study were intermediate in size compared with jaws of male calves from the previous 2 collections. However, the most recent jaws were collected in April, whereas previous ones were collected primarily in fall, and there is some growth of bones in calf caribou over winter. Western Arctic caribou are probably again becoming smaller. Data from jaw collections are most valuable from a historical perspective, and it will be several years before the trend in body size is confirmed by jaw measurements.

We present a summary of results from the disease monitoring program in the WACH from 1985 to 1994. There is no indication the prevalence of disease has increased in the WACH in recent years as herd size has increased.

Although there was no controversy about this research project, work was suspended because collectors could not reliably collect all calves needed, and a new policy established by the regional supervisor (Region V) precluded use of aircraft, nonlocal collectors, and department biologists in the collection program. Similar work will continue on the Nelchina, Northern Alaska Peninsula, and Mulchatna herds.

As the WACH grows in size or remains large, annual data on recruitment and animal condition will become more critical. These data will be particularly useful for monitoring population trend and explaining biological processes to interested users. In addition to being one of Alaska's most important game resources, the WACH is one of the largest caribou herds in the world and is politically and logistically one of the easiest of all the large herds to study. Data from the WACH could contribute significantly to our understanding of the population dynamics of large herds.

Key words: body condition, body size, body weight, diastema, mandible length, marrow fat, movements, natality, nutrition, *Rangifer*.

CONTENTS

BACKGROUND

The Western Arctic Caribou (*Rangifer tarandus granti*) Herd (WACH) was recognized as a distinct population by about 1950 (Scott et al. 1950), based on the exclusive and traditional use of a calving area in northwestern Alaska. The calving area has been used for at least a century and probably much longer (Lent 1966), but the population has fluctuated considerably in size (Skoog 1968). The herd remained at a low level from the 1880s to the 1930s probably because of overexploitation including unregulated commercial hunting by Europeans and Eskimos (Sonnenfeld 1960, Lent 1966). Around the turn of the century, the inland Nunamiut Eskimos were forced to abandon the Brooks Range and move to the coast, and they did not return until around 1930 (Gubser 1965). Reindeer (*Rangifer tarandus tarandus*) were introduced in 1892 to help provide an alternative food source to the caribou, walrus (*Odobenus rosmarus*), and bowhead whales (*Balena mysticetus*) that were all seriously depleted (Lantis 1950). Moose (*Alces alces*) and beaver (*Castor canadensis*) were also extremely rare in the range of the WACH until after the 1930s (Huntington 1994; A Cleveland, pers commun). By 1930, reindeer were herded throughout coastal western Alaska from the Yukon Delta to the McKenzie Delta (Lantis 1950). However, the WACH began to recover significantly during the 1920s and reinvaded populated areas in the Kobuk Valley during the 1940s (Lent 1966; A Cleveland, pers commun). The herd continued to increase during the 1950s and once again became a mainstay of the subsistence economy in northwestern Alaska (Skoog 1968). Partly because of losses to the WACH, reindeer herding largely died out by 1960, except on the Seward Peninsula (Lantis 1950, Sonnenfeld 1959, Skoog 1968). From the 1950s to 1976, local residents harvested about 25,000 caribou annually for personal consumption, barter, dog food, trap bait, and limited local sale in Kotzebue and Barrow (Skoog 1968, Davis et al. 1985). The caribou census of 1975 revealed a sudden, unexpected decline in the WACH, probably from a combination of high overwinter calf mortality, high harvests, heavy predation, and unfavorable weather (Doerr 1980, Davis et al. 1980, Davis and Valkenburg 1985). The decline was probably a natural event that may have begun during the mid-1960s, accelerating rapidly during the early 1970s. The annual harvest of 20,000-30,000 could not be sustained, and harvest restrictions were implemented. Fortunately, the harvest restrictions were effective and harvest in 1976-1977 was estimated at only 2700-3500 caribou (Davis and Valkenburg 1978). The decline was immediately reversed in 1977 with about 75,000 caribou remaining. The recovery was rapid, and the herd increased by about 13% annually between 1977 and 1990, when it reached about 415,000.

Presently, caribou from the WACH are a significant source of food for about 20,000 people from 36 villages and 4 regional centers in northwestern Alaska. Approximately 15,000-20,000 caribou representing 1.5-2 million pounds of meat are taken from the herd each year. The replacement value of the meat alone is approximately 3.5-4.5 million dollars annually. Many people within the herd's range cannot easily or economically obtain substitutes for the meat that caribou provide. Abrupt changes in regulations in response to a sudden population decline, such as the one that occurred in the mid-1970s, could cause economic hardship. This research project was initiated to better explain and perhaps predict future caribou population changes.

Causes of declines in caribou herds are still not well understood and several competing and/or complementary hypotheses explain previous decreases in various caribou herds (Leopold and Darling 1953; Klein 1968; Skoog 1968; Bergerud 1980; Skogland 1985; Van Ballenberghe 1985; Meldgaard 1986; Bergerud and Elliot 1986; Messier et al. 1988; Bergerud and Ballard 1989; Crete and Payette 1990; Davis and Valkenburg 1991; Eberhardt and Pitcher 1992; Seip 1992; Caughley and Gunn 1993; Messier 1995; Valkenburg et al., in press; Whitten, in press). The WACH reached a historic high level of about 450,000 between 1990 and 1993. Population density was about 1.9 caribou/km^2. The George River Herd in northern Quebec reached about 1.9 caribou/km^2 before density declined due to range expansion and a decline in the herd's growth rate due to poorer productivity (Couturier et al. 1990). In arctic caribou herds that typically escape wolf predation by migrating to areas where wolf density is low, most biologists agree that population declines will occur because caribou suffer malnutrition from exceeding either ecological or food carrying capacity and/or from severe weather patterns (Caughley and Gunn 1993; Messier 1995; Whitten, in press). We therefore placed the primary emphasis in this research project on assessing the nutritional condition of WAH caribou and developing a simple technique for objectively measuring condition over the long term. In any discussion of the causes of population changes and the development of an appropriate management program, objective data on body condition are critical. Gathering baseline data before a decline occurs is also critical.

When this research project was originally conceived in late 1990 and early 1991, the Division of Wildlife Conservation anticipated having a full-time caribou biologist based in Nome with an operating budget for research of about $40,000-$50,000. However, shrinking budgets and revised priorities resulted in having the biologist position based in Fairbanks and only spending about 2-3 months on the Western Arctic research project. The research project (Appendix A) was approved in early 1992 with a budget request of about $40,000. However, only $10,000 was allocated to the project. Some objectives were eliminated, and others were scaled down. Subsequently, the regional supervisor and area biologist in Kotzebue established a policy that aircraft, ADF&G personnel, and nonlocal hunters would not be used to aid in collecting caribou to assess body condition. This constraint made it infeasible to continue collecting data on body condition or to continue development of techniques, and the project was terminated 2 years ahead of schedule.

STUDY OBJECTIVES

- Develop, validate, and implement techniques for monitoring the nutritional status and predicting the productivity and population trend of the WACH.

JOB OBJECTIVES

The job objectives for this study were revised in 1994. Objectives which were deleted appear in parentheses.

- Annually estimate calf:cow ratio in October.

- (Annually collar a sample of female calves at the Kobuk River or other river crossings to estimate the age at first reproduction of females and to aid in finding nonreproductive segments of the population during censuses.)

- Annually determine the mean fall body weight of a sample of female calves (and adult cows), and the mean spring body weight of a sample of female calves from 1992 to 1997, and determine if weight and/or fat indices can be used as predictors of (pregnancy rate and) calf survival to fall.

- Annually determine the distribution of radiocollared caribou in September/October and in February/March.

- Place 10-20 radiocollars on bull caribou in years prior to censuses to facilitate finding bull groups during the census.

METHODS

ESTIMATING CALF:COW RATIO IN FALL

From 1992 to 1995 we used a Robinson (R-22) helicopter to classify caribou primarily to determine the fall calf:cow ratio and secondarily to determine the fall bull:cow ratio. Counts were done just prior to or during the rut to minimize problems with segregation of bulls and cows that could bias results. Based on a gestation period of 224-229 days (Bergerud 1975, Shuey et al. 1994) and an observed peak calving date of 8 June in 1992, we estimated the peak of rut to be about 20-25 October in the WACH. In all years except 1995, we scheduled composition counts for the 10 days prior to the peak of rut. In all years except 1994, we classified caribou as bulls, cows or calves, based on genitalia and body and antler size. In 1994 bulls were subjectively classified as small, medium, or large. Small bulls were those males that could not have been readily identified as males by antler characteristics alone. Large bulls were considered to be those that had reached maximum or near maximum antler size. Either a Bellanca Scout or Cessna 206 accompanied the helicopter, radiotracking collared caribou and carrying extra fuel. During 1992-1994 we used the radiocollared cows in the WACH to determine the distribution of caribou and tried to obtain sample counts from the largest area possible. Counts were later weighted according to the proportion of radiocollars in the count area. During 1992-1994 about two-thirds of the herd's distribution was sampled. In 1995 the approach was somewhat different. Individual collars were located and up to 200 caribou were classified in the vicinity of each radiocollar. With this approach, only about one-third of the herd's distribution was sampled.

From 1992 to 1994 the aircraft were based in Galena to be closer to the caribou concentrations and because weather is generally better away from the coast in fall. During those years, counts were done by T Osborne. In 1995, the aircraft were based in Kotzebue and counts were done by J Dau. No counts were conducted north of the Brooks Range due to the expense of taking the helicopter that far, although we did conduct counts as far north as Anaktuvuk Pass in 1992-1994. In all years at least 75% of all radiocollars were south of the Brooks Range.

To facilitate future reviews of WACH recruitment data, we compiled all known composition counts of WAH caribou (Appendix C).

ESTIMATING AGE AT FIRST REPRODUCTION

As originally outlined, we proposed to catch and collar female calf caribou at the Kobuk River crossing in September primarily to provide information on the age at first reproduction but also to estimate overwinter calf mortality, calf weights in fall, and to help find nonreproductive segments of the population (i.e., yearlings) during censuses. However, after determining the weight of WACH calves we realized they were much smaller than the calves of any other Alaskan herd and a standard size caribou collar (i.e., model 600, Telonics Inc., Mesa, Ariz) was thought to be too heavy for them to carry. The next smaller collar (model 500) had an expected life of only 2-3 years versus 5-6 years for the model 600. Although Telonics subsequently developed the model 505 collar with an expected life of about 4 years, range and pulse rate were compromised. These problems, along with reduced funding, caused us to abandon this objective.

DETERMINING CONDITION AND MEAN WEIGHTS OF CALVES AND ADULTS

Because we realized the importance of involving resource users in research and management programs, we tried to have local hunters involved as much as possible in assessing the weight and condition of calves and adults. We proposed to pay hunters $100 for adult females in October and $50 for female calves collected during October and April. However, because of reduced funding, we abandoned the idea of collecting adult females in October. Recent work in Interior Alaska in using female calves to monitor herd condition appeared promising (Valkenburg 1993, 1994*a*; Adams, unpubl data), and these animals were cheaper and easier to handle than adult cows.

We trained 5 cooperators to collect female caribou calves in 4 localities—Anaktuvuk Pass, Pah Flats, Kobuk Valley, and Unalakleet. These individuals were given calibrated scales, weighing poles, labels, and a set of instructions. In addition, if they were interested, a biologist was sent to work with them for a day or 2 of in-the-field training. Because this was a pilot project, ADF&G biologists collected 10 female calves in April 1992 in the Pah River Flats from a helicopter. G Bamford, a local trapper living in the Pah River Flats, requested and was issued a collecting permit so that he could hunt caribou from the ground after locating them from the air. On 2 occasions ADF&G biologists supplemented samples collected by local hunters by shooting female calves from the ground, and on 3 occasions cooperating nonlocal hunters shot samples of female calves under existing state hunting regulations, after flying to the range of the WACH.

The emphasis in this study was on developing a simple but objective field technique that could be used by many relatively unskilled cooperators in a long-term management program to monitor body condition. Whole body weight and gutted weight were the primary comparative measures of condition, with mandible marrow fat content (Davis et al. 1987) and a body fat index as supplemental measures for fatness. Because of the number of relatively unskilled people involved, we avoided even such standard measures as kidney fat index (Riney 1955), Kistner Score (Kistner 1980), collection of indicator muscles (Ringberg et al. 1981, Chan-McCleod et al. 1995), subjective condition scoring methods (Cameron et al. 1993), and body measurements. Cooperators were asked to weigh caribou calves; field dress them by removing the G-I tract, lungs, and heart; reweigh the carcass; collect the jaw; and record whether fat was present or absent in 4 fat depos—rump, brisket, mesenteries and heart. Subsequently, because percent mandible marrow fat was not a sufficiently accurate predictor of percent femur fat (Valkenburg 1994*b*), and because there is insufficient data on how mandibular fat is mobilized in relation to femur fat, we asked cooperators to also collect the femur. Weights, date, and the presence or absence of fat were then written on a plastic label and wired to the jaw and/or femur. Jaws and femurs were kept frozen and sent to Fairbanks where their fat content was determined (Neiland 1970), the age of the caribou confirmed by examining tooth eruption, and the length of the dried jaw and diastema measured.

We used simple linear regression to investigate whether mean whole weight, mean gutted weight, mean jaw length, mean condition index, and mean percent mandible fat in April had potential as predictors of fall calf:cow ratio (Tables 1 and 2). Mean condition index was calculated by assigning a value of 1 to each of the 4 fat depos that contained fat and dividing by the number of caribou calves in the sample.

DETERMINING THE DISTRIBUTION OF CARIBOU

Department biologists made a coordinated effort to determine the distribution of radiocollared WAH caribou in February-April and October each year from 1992 to 1995. During this period 2-10 satellite collars and 75-130 VHF collars (Telonics, Inc., Mesa, Ariz) were active on adult females. From 10 to 20 VHF collars were active on adult males. Tracking was done with C-185, Supercub, Bellanca Scout, and C-206 aircraft from Nome, Kotzebue, Barrow, and Fairbanks. The immediate purpose of individual tracking flights varied. Some were to document the distribution of caribou during composition counts, or determine the degree of mixing between caribou and reindeer on the Seward Peninsula, and others were to determine the distribution of caribou. A major goal was to document range expansion, dispersal of individuals, or emigration of groups of caribou to other ranges as the herd reached peak numbers. The adjacent Teshekpuk, Central Arctic, and Galena Mountain herds were also monitored, and unlocated WACH frequencies were listened for in the ranges of these herds.

RADIOCOLLARING BULL CARIBOU PRIOR TO CENSUS

Department biologists, with help from the National Park Service and local high school students, captured and collared caribou annually at the Kobuk River crossing in September. In 1992, 13 collars were placed on adult bull caribou in preparation for the 1993 census. As with females, the bulls were captured by driving up to them in a riverboat, holding them against the side of the boat by their antlers, and fastening the collar on. During the 1993 census 15 collared bulls were on the air. We evaluated whether these collars contributed to finding more caribou during the census.

ANALYSIS OF JAW COLLECTIONS

Jaws of WAH caribou were collected incidentally during research projects to investigate disease and radiation levels in WAH caribou during the 1960s and early 1970s, and to study population limiting factors during the late 1970s and early 1980s. Since then, jaws have been collected during fieldwork to collar caribou on the Kobuk River in fall.

In all collections, at least 3 measurements were taken on all jaws: mandible length (from the most anterior point on the ramus to the most posterior point on the curve of the ramus), diastema (from the most anterior point on the ramus to the most anterior point of the molar row), and toothrow (Langvatin 1977). We analyzed only mandible length and diastema because they have been found to be the most variable and consistently collected measurements and have been shown to be useful in tracking changes in body size in ungulates (Lowe 1972, Beninde 1973, Langvatin 1977, Valkenburg et al. 1991, Eberhardt and Pitcher 1992). Our primary interest in this study was determining whether body size of WAH caribou changed with population size and trend. We therefore compared the growth curves for mandible and diastema length from the late 1960s and early 1970s when the herd was high and declining to the growth curves for mandible and diastema length from the 1980s when the herd was growing rapidly. We used only jaws from males, because there were too few female jaws in the 1980's collection. The later collection came primarily from the Kobuk River in September where harvest is selective for males. We also analyzed data from 16 male calves collected incidentally during this study when the herd was high and appeared to be stabilizing.

To compare mandibular growth curves, we constructed a curvilinear model that increases rapidly at first, and then slows down, reaching some asymptote with time. Such a curve is given by

$$f_i(x_j|\beta_{0i},\beta_{1i},\beta_{2i}) \equiv \beta_{0i} + \beta_{1i}(1-\exp(-\beta_{2i}x_j)),$$

which has several names including the *monomolecular* growth model (Seber and Wild 1989:328). The intercept for this curve is β_{0i}. The growth rate is given by β_{2i}; the larger β_{2i}, the faster the curve reaches the asymptote. The amount of growth is given by β_{1i}, and the asymptote is $\beta_{0i} + \beta_{1i}$. Other parameterizations are possible. This is a nonlinear model and requires nonlinear statistical methods (Seber and Wild 1989). Because we wished to build a model of possibly 2 different curves, and to make decisions in parsimonious model-building, the full methodology is given here because it is not a standard method.

The class of statistical models we assumed for the data is given by

$$Y_{ij} = f_i(x_j) + \varepsilon_{ij},$$

where ε_{ij} are independent and identically distributed from a normal distribution for the *i*th group; $\varepsilon_{ij} \sim N(0,\sigma_i^2)$. Here, *i*=1 if year of birth (YOB) is between 1959 and 1967, and $i = 2$ if YOB is between 1976 and 1988. The data are uniquely indexed by *j*; *j*=1,...,*n*. For the *j*th animal, x_j is the age of that animal.

Fitting the Model

The likelihood for the data can be written as,

$$L(\theta|\mathrm{y}) = \prod_{j=1}^{n} \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{1}{2\sigma_i^2}(y_{ij} - f_i(x_j))^2\right),$$

where $\theta = (\beta_{01},\beta_{11},\beta_{21},\sigma_1,\beta_{02},\beta_{12},\beta_{22},\sigma_2)'$. The negative log-likelihood then is,

$$l(\theta|\mathrm{y}) = -\log[L(\theta|\mathrm{y}) \propto \sum_{j=1}^{n} \log(\sigma_i) + \frac{1}{2\sigma_i^2}(y_{ij} - f_i(x_j))^2.$$

We used the downhill simplex method by Nelder and Mead (1965) for a nonlinear minimization of $l(\theta|\mathrm{y})$. We attempted to make models more parsimonious by setting some elements in θ equal; for example, by assuming a constant growth rate among groups $\beta_{21} = \beta_{22}$. Following the idea of a likelihood ratio test, if setting such parameters equal did not increase $2l(\theta|\mathrm{y})$ by more than 3.84 (a Chi-square with 1 degree of freedom), then we allowed the parameters to be equal.

Diagnostics

The residuals from the fitted curve were examined. The residuals were plotted against x_j to look for any trend or inflation of variance in the residuals. Also, the residuals were tested to see if they were normally distributed.

DISEASE MONITORING PROGRAM

The Department of Fish and Game has been monitoring the prevalence of disease agents, in wildlife populations in Alaska, including the WACH, since the 1960s. Initially, in caribou, the emphasis was on *Brucella* spp. Since 1975 a more broad-based serologic survey has been conducted. Blood serum has been collected from the WACH opportunistically during collaring and collecting programs. Serum is periodically tested for a range of wildlife diseases, and serum samples are maintained in a whole blood and serum bank in Fairbanks for future testing as needed. Results of previous studies of disease in the WACH were published in 1985 (Davis and Valkenburg 1985). This report briefly summarizes data collected since 1985.

RESULTS

ESTIMATING CALF:COW RATIO IN FALL

To ensure a well distributed sample, we tried to determine the distribution of all radiocollared caribou during the composition counts. Low clouds and icing conditions in 1992-1994 prevented us from completely determining the distribution of radiocollared caribou. In 1995 the use of a chartered Cessna 206 rather than a less expensive state-owned aircraft also increased costs and precluded a more thorough search for radiocollars. Nevertheless, based on estimates of the number of active radiocollars in the herd, in all years except 1995, at least two-thirds of the herd was present in the areas where composition counts were done (Table 2). In 1995 the added expense of finding individual collars precluded sampling much of the distribution south of the Brooks Range.

Using the relatively inexpensive R-22 helicopter accompanied by a state-owned fixed-wing aircraft carrying extra fuel, we largely solved the logistical and cost problems of doing fall composition counts in the range of the WACH. The R-22 uses only 8 gal of fuel per hour versus 27 gal per hour for small turbine helicopters. Also, the $230 per hour charter cost of the R-22 was less than half that of a comparable turbine helicopter. One problem with the 2-place R-22 is that experienced observers are required because observers cannot be field-trained and cannot check each other's accuracy during the counts. Problems with classification accuracy surfaced in the 1994 counts of the Macomb Caribou Herd and in the WACH. In 1994 we corrected for classification errors that were discovered during the survey by recounting 1 area the next day and correcting other counts based on a replicate count of a small area done on the same day (Tables 2 and 3). In the worst case, corrected and uncorrected counts differed by about 5 calves:100 cows (Tables 3 and 4). To further address this problem, we videotaped caribou from the R-22 in late October 1994 and subsequently used the tape for training.

From 1992 to 1994 fall calf:cow ratios in the WACH declined. In fall 1995, however, the estimated calf:cow ratio was again high, possibly indicating increased survival of calves in summer 1995.

DETERMINING MEAN WEIGHTS OF CALVES

From April 1992 to September 1995 we obtained 6 samples of 9 to 16 female calves from the WACH (Table 1; Appendix B). About half of the collected caribou were taken by cooperating hunters and half by department biologists. Only 1 cooperator consistently provided samples, and shortly after the study began it became apparent that relying entirely on cooperating hunters to provide samples was unrealistic. Caribou movements were unpredictable. During the period of the study, few caribou moved through Anaktuvuk Pass in October or April, and some of those that did included radiocollars from the Central Arctic Herd. The 2 cooperators there had few opportunities to take animals. Likewise, in the Pah Flats caribou movements were not consistent, and the October period conflicted with the cooperator's preparations for the trapping season. The ice was also thin at that time of year, making aircraft landing hazardous. Because it appeared that WACH were beginning to consistently travel south to Unalakleet, in 1994 we enlisted the services of local residents in Unalakleet. However, in 1994-1995 caribou stayed further north, and the cooperator in Unalakleet left the village to live elsewhere.

Caribou crossed the Kobuk River consistently during 1992-1994, and most of the useful data obtained by local residents was collected there. However, traveling conditions were usually poor in October due to freeze-up, the timing of the spring migration was unpredictable, and mostly male calves were encountered during the latter part of the movement in late April and May during collection. To solve the problem with traveling conditions in fall, we agreed to have the fall collecting done after 15 September in 1994 while riverboat travel was still possible. However, for personal reasons, the cooperator could only do the collecting prior to 15 September, and we wondered whether calves collected in early September could be compared with those collected in October. In addition, calves collected by riverboat in the water were weighed wet.

Mean whole weights of female calves in fall 1994 were significantly different from mean whole weights of all other samples, except fall 1995 ($P < 0.1$, Fig 1). The 3 samples of weights from spring were not significantly different from each other ($P > 0.1$). We could not determine if there is a pattern of calf weight loss over winter in the WACH because of missing data in October 1993 and April 1995. However, even after the record snowfall year of 1992-1993 (Fig 2), mean whole weight of calves did not differ from 1992 and 1994 when snow was more normal. The extremely small calves in fall 1994 and low femur fat content suggested that WAH caribou were about to enter the winter in poor condition. This was supported by observations by biologists and hunters on the Kobuk that many cows and bulls were also in poor condition with little body fat.

Calf Weight as a Predictor of Pregnancy Rate and Subsequent Calf Survival

The early termination of the project and missing data precluded statistical analysis of potential relationships between calf weight and condition indices in April and pregnancy and survival (calf:cow ratio in fall). We tried to enhance the data set by using similar data from the Nelchina Herd after scaling for body size (body size data from Skoog 1968:25). However, there were no significant relationships found between calf:cow ratio and mean whole weight, mean gutted weight, mean jaw length, mean condition index, and percent jaw fat (Fig 3).

Distribution of Western Arctic Caribou in Spring and Fall

Despite increasing in size from 75,000 in 1977 to 450,000 in 1993, range size of the WACH has not increased significantly. During the previous population high in the 1960s, the herd ranged over about 140,000 mi^2 (Hemming 1970). During the population low in the late 1970s and early 1980s, range size was estimated at about 130,000 mi^2 although the upper drainages of the Koyukuk River from Allakaket north were used less frequently and by smaller numbers of caribou. Recently the herd has increased its range to about 150,000 mi^2. The primary area of range expansion since the herd began increasing in 1977 has been in the area south of the Shaktoolik River, west of the Yukon. In 1993-1994 tens of thousands of caribou crossed the Kaltag-Unalakleet winter trail for the first time in over a century, and a few continued as far south as the mouth of the Yukon River. In 1994-1995 wintering caribou remained north of Unalakleet, but a large movement again went south across the Kaltag-Unalakleet trail in October-November 1995. In late October and early November 1988, 1990, and 1992 approximately 3000-10,000 caribou moved east from the Nulato Hills onto the Koyukuk lowlands north of Galena (Osborne 1993). Also, in November 1992 about 50,000 caribou moved onto the Indian River Flats south of Hughes and remained there until mid April. A few thousand, including 2 with radiocollars, wintered on the Kanuti Flats southeast of Allakaket. Surprisingly, there has been little use of the John, Wild, Kanuti, and Upper Kobuk River drainages as the herd has expanded. These areas were all regularly used by thousands of caribou from the WACH during the 1960s and early 1970s. Also, there was probably less use of the arctic coastal plain during the late 1980s and early 1990s than there was during the 1970s and early 1980s (Davis and Valkenburg 1985), although radiotracking flights were sporadic from the early 1980s to about 1991.

ANALYSIS OF JAW COLLECTIONS

Growth curves for length and diastema of the ramus were significantly different between periods (Figs 4 and 5). During the late 1960s and early 1970s calves were smaller than during the 1980s, and they never caught up in size as they got older.

Ramus

The final model fitted had the growth rate and the amount of growth equal between the curves for both groups, with the intercepts and variances different. The fitted parameters are listed:

Parameter	Fitted Value
β_{01}	203.3
β_{11}	81.63
β_{21}	0.6330
σ_1	13.93
β_{02}	220.4
β_{12}	81.63
β_{22}	0.6330
σ_2	9.36

The residuals showed no pattern with age, and they also could not be rejected as coming from a normal distribution ($P = 0.6234$, $n = 438$ for the 1960 group; $P = 0.5393$, $n = 598$ for the 1980's group).

Diastema

The final model fitted had the growth rate and the amount of growth equal between the curves for both groups, with the intercepts and variances different. The fitted parameters are listed:

Parameter	Fitted Value
β_{01}	73.02
β_{11}	40.62
β_{21}	0.3623
σ_1	7.601
β_{02}	88.46
β_{12}	40.62
β_{22}	0.3623
σ_2	5.909

The residuals showed no pattern with age, and they also could not be rejected as coming from a normal distribution ($P = 0.9817$, $n = 438$ for the 1960 group; $P = 0.9288$, $n = 598$ for the 1980's group).

Male calves collected during this study had jaws intermediate in size compared with those from the previous collections. Analysis was made complex by the fact that most male calves in this study were collected in April-May rather than in fall, and some bone growth apparently continues over winter, at least in females (Table 1).

Disease Monitoring Program

The list of disease agents that have been monitored in the WACH has changed over the years. Similarly, sample sizes and sampling frequency have varied. Disease prevalence is summarized by year in Table 5.

DISCUSSION

Estimating Calf:Cow Ratio in Fall

During the previous research project on the WACH from 1977 to 1982, Davis and Valkenburg (1985) conducted annual fall composition counts to estimate recruitment. These counts are widely considered to be the most accurate measurement of recruitment in caribou herds. In fall the calf-cow bond is still strong, the period of high neonatal calf losses is over, and all age and sex classes of caribou are more uniformly mixed than at any other time of the year. In addition, in most years overwinter calf mortality is not significantly higher than adult mortality, and calf:cow ratios change little from fall to spring (Davis et al. 1991*b*, Adams et al. 1995). Annual fall composition counts provide particularly important data during population declines because they help biologists distinguish between summer and winter mortality (Eberhardt and Pitcher 1992). To be most useful, counts need to be done annually with the aid of a helicopter so that bulls can be distinguished from cows and a calf:100 cow ratio calculated, rather than a calf:adult ratio which is more subject to bias. Annual data is important because year-to-year variation can be significant and may become more annually variable as herd size increases or remains high. Because the range of the WACH is remote, no suitable helicopters have been based in the area during October. Weather in the area is typically poor for flying, and it has been expensive to conduct fall composition counts. For these reasons, no fall counts were conducted from 1983 to 1991. However, with the methods developed in this study, it is feasible to conduct these counts for about $5000-$10,000 annually, provided a state-owned aircraft is available for radiotracking.

Annual counts of adult caribou and calves (short yearlings) done from fixed-wing aircraft in April can provide a useful estimate of recruitment and may complement the fall calf:cow ratio data. Doing both these counts may allow biologists to determine the relative importance of summer versus winter mortality. In the smaller Interior caribou herds, high summer calf mortality preceded recent population declines (Valkenburg et al., in press), but in previous declines of the larger WACH and Nelchina herds, "winter" calf mortality was more important (Doerr 1980). However, April counts, especially when done with fixed-wing aircraft, are subject to strong biases, particularly because calves segregate from cows during winter and spring and typically are not uniformly distributed at the time of the counts. There are no radiocollars on calves in the WACH, and the distribution of calves relative to cows cannot be determined at present.

CALF WEIGHT AND MARROW FAT CONTENT AS INDICATORS OF HERD NUTRITION, PRODUCTIVITY, AND SURVIVAL

Body weight has long been a standard measurement of animal nutrition, and with some constraints, fall body weight is closely correlated with subsequent pregnancy in female ungulates (Park and Day 1942, Palsson and Verges 1952, Bandy et al. 1956, Severinghaus and Gottlieb 1959, McEwan and Wood 1966, Swenson 1973, Reimers 1983, Skogland 1985, Davis et al. 1991*a*, Cameron et al. 1993). Weight has also been shown to represent seasonal changes in body reserves in adult females and calves in the George River Herd and, more recently, in the Porcupine and Central Arctic herds (Huot and Goudreault 1985; Huot 1989; Allye-Chan 1991; Cameron et al. 1993; Chan-McLeod et al. 1995; Gerhart et al., in press). It is now generally accepted that prerut nutrition strongly influences conception rate and that overwinter nutrition influences calf size and survival in reindeer and caribou (McEwan and Whitehead 1972, Dauphine 1976, Roine et al. 1982, Thomas 1982, Reimers 1983, Reimers et al. 1983, Skogland 1985, Eloranta and Niemanen 1986, Allye-Chan 1991, Allye-Chan and White 1991). In *Rangifer* and other cervids, body weight of calves at birth has been shown to be related to maternal weight and nutrition during gestation and is highly correlated with subsequent calf survival (Haukioja and Salovaara 1978, Skogland 1985, Adams et al. 1995). In herds where nutrition is poor, peak calving is delayed, calves have a shorter period of rapid growth in summer and enter the rut and winter at lower body weights than in herds where nutrition is good (Skogland 1985). Calf nutrition is also affected by summer forage through milk production of the mother and forage consumption by the calf (McEwan 1968, Rognmo et al. 1983). The nutritional condition (i.e., weight and fatness) of calves in fall is likely, therefore, to primarily reflect nutrient availability over the preceding summer but is also influenced by nutrition of their mothers during the preceding winter. Nutritional condition of calves in late winter reflects nutrient availability over the preceding winter and summer and, perhaps, the winter before. Recent declines in the Denali and Delta caribou herds were coincident with decreased weights of newborn and 5- and 10-month old female calves (Adams et al. 1995; Valkenburg et al., in press). Furthermore, in the Delta and Denali herds, calf weight in April has been correlated with fall calf:cow ratio since 1979. This indicates that weight of female calves in April reflects nutrition in adult females and the subsequent vulnerability of their calves to mortality factors. In all wild caribou studied so far, point values for mean weight of calves have decreased over winter (McEwan 1968, Adamczewski et al. 1987, Huot 1989, Valkenburg 1994*b*) although in some cases the decrease was not significant, probably due to sample size. In at least 1 study of captive caribou where calves were on an unrestricted diet, body weight continued to increase over winter (McEwan 1968). Studies of wild caribou calves on excellent winter range are needed to determine if calves can gain weight and/or fat over winter.

Since 1978 biologists in Alaska have collected calf weight data from 50 samples of calves in 17 caribou herds (Table 6). When consistently collected over a period of time, mean calf weight data appear to be a simple, easily collected, objective, and quantitative measure of herd nutrition. Sample variance generally requires 9-15 weights to detect a statistically significant difference ($P < 0.05$) between point values that differ by 10 lb (4.5 kg) in mean weight. Point values of sample means within herds have differed by as much as 20 lb. Other studies have also shown that standard errors of samples of calf weights are low enough that even relatively small samples can be useful in assessing changes in condition (McEwan 1968, Adamczewski et al. 1987, Huot 1989). The present study of Western Arctic caribou was not conducted long enough to test whether samples of 15-30 female calves would be sufficient to predict recruitment in this large herd where predation is of minor importance.

Except for 1992, calving ground surveys were not conducted in a way that made it possible to estimate pregnancy rate, perinatal mortality, peak calving date, or peak calf numbers (Table 7). It was, therefore, not possible to relate calf weights in fall and spring to any of these parameters. However, low body weight of calves in fall 1994 corroborated qualitative data on herd condition based on reports from hunters and biologists who saw many thin caribou and small calves during the Kobuk River crossing in September 1994. Subsequently, in November-December at least 1100 caribou died of starvation in the Point Hope area during a period of severe weather (North Slope Borough Dep Wildl Manage, unpubl data). Unfortunately, no April 1995 data of calf weight and fatness were obtained, and it is not known whether caribou calves on the southern, lichen-rich winter ranges were able to regain condition over the winter. No major die-offs were reported from the southern winter range, indicating adequate winter nutrition. In addition, calf survival over summer was probably good (Table 2), which also suggests that cows received adequate winter nutrition.

Mean marrow fat content of mandibles and especially of femurs of caribou calves may be another simple and quantitative index of nutrition over a wide range of values (Table 1). Female calves from the Nushagak and Mulchatna caribou herds which have been moving into pristine range had the highest mean percent femur marrow fat values of any herd measured to date, and these values were significantly higher than values for stable or slowly increasing herds (Valkenburg et al., in press). In adults, percent femur marrow fat has been shown to be primarily useful in determining whether animals are near starvation (Ringberg et al. 1981, Mech and DelGiudice 1985, Chan-McLeod et al. 1995). However, femur marrow fat of calves is more variable (Ringberg et al. 1981) probably because calves need most of their resources for growth and only store excess energy as fat. The femur is also more useful than the mandible in assessing condition of calves because fat mobilization occurs more rapidly in the femur than in other long bones (Davis et al. 1987; Chan-McLeod et al. 1995). Chan-McLeod et al. (1995) determined that absolute weight of femur marrow fat and percent femur marrow water may be even better measures of body fat than percent femur fat over a wide range of values in adults. Body weight and marrow fat content are complementary indices of condition, but marrow fat may be more useful in comparing data between herds.

The primary reason for collecting body condition data from the WACH and other caribou herds is to improve our understanding of changes in caribou numbers. During the previous widespread caribou declines in Alaska in the early 1970s, there was considerable speculation about causes. In the WACH few data were collected between 1970 and 1975 when the herd declined rapidly, and biologists could not adequately explain the decline to local people who were being asked to refrain from harvesting caribou. People felt that ADF&G unfairly blamed them for the decline. In retrospect, although high harvests and high wolf numbers caused a rapidly accelerating decline in the early 1970s, it is likely that the WACH had been declining for many years, and nutrition could have been involved (Valkenburg et al. 1991; Figs 4 and 5). Although the current population monitoring program in the WACH will enable us to detect a similar decline in a more timely manner, without quantitative, objective information on body condition, explanation of causes will be difficult. Subjective, qualitative information may be useful, but such data must be collected and archived in an organized manner.

MOVEMENTS AND DISTRIBUTION OF WAH CARIBOU

In contrast to other large, rapidly growing caribou herds, the WACH did not extend its range significantly during its increase from 1977 to 1990, when population density reached about 3 caribou/mi^2 (1.2 caribou/km^2). The Taimyr Peninsula Herd in Russia more than doubled its range to over 1.5 million km^2 as population size approached 600,000 (Pavlov et al., in press). The George River Herd in Quebec and the Mulchatna Herd in southwestern Alaska have also greatly extended their ranges as herd size increased. Their peak densities reached 1.9 caribou/km^2 and about 1.5 caribou/km^2, respectively (Couturier et al. 1990, Van Daele 1993). One reason the WACH has not greatly extended its range may be that range size did not decline much after the population crash in the early 1970s. The population remained low for only a short period. After the previous population crash in the 1880s, the WACH restricted its movements to a relatively small area in northwestern Alaska north of the Baird and Endicott mountains and west of the Killik River until the 1930s (Gubser 1965, Skoog 1968).

After reviewing historical information of caribou movements and changes in abundance in Alaska, Skoog (1968) concluded that sudden shifts in distribution and large-scale interchanges of groups of caribou occurred. However, Davis et al. (1978) and Valkenburg et al. (in press) concluded that the historical evidence is ambiguous and that there is no evidence for interchanges after 1950 when aircraft began to be used for survey work. Despite radiocollaring over 2000 caribou in Alaska since 1975, permanent dispersal of caribou away from their natal herd and subsequent use of other herd's calving ranges have been documented in only 2 cases (Valkenburg et al., in press). In the central Alaska Range, however, progressively increased mixing between the Delta and adjacent, small Yanert Herd resulted in the amalgamation of the 2 herds around 1989 (Davis et al. 1986, Davis et al. 1991*b*). Recently, with increased mixing of Mulchatna and Kilbuck caribou, fidelity of Kilbuck females may also be decreasing (Kacyon, pers commun). There has been no documented dispersal of radiocollared caribou from the WAH or from other adjacent herds despite the fact that the WAH has routinely mixed with Central Arctic, Teshekpuk, and Galena Mountain caribou in fall and winter. Mechanisms for dispersal in caribou are still not well understood, and most data come from females. However, caribou dispersal rates appear to be very low.

Using Radiocollared Bulls to Find Nonreproductive Segments of the Population During Censuses

Few additional caribou were found by locating the 16 radiocollared bulls during the 1993 census. However, the presence of these caribou increased our confidence that most caribou were in the post-calving aggregations.

In most other Alaskan caribou herds, collars are routinely placed on 5- or 10-month old females. For their first summer or first 2 summers after collaring, these caribou are also nonreproductive and add confidence to census results. With advances in the technology of radiocollars, it may soon be possible to use this technique in the WACH. In addition to helping find nonreproductive segments of the population during censuses, there are many other advantages to collaring calves. One can estimate condition of caribou calves in fall during collaring, estimate winter calf mortality, and determine age at first breeding and age at death.

Analysis of Jaw Collections

Caribou in the WAH were smaller during the 1960s and early 1970s while the herd was high and declining and larger during the population increase in the 1980s. These results confirm patterns reported previously in the Nelchina and Western Arctic herds (Valkenburg et al. 1991, Eberhardt and Pitcher 1992). Because body size can vary among cohorts, hundreds of jaws collected over multiple years are required to establish growth patterns, and it will be several years before similar curves can be constructed for the WACH for the recent period of diminished population growth. Mean mandible length of

23 jaws of male calves collected incidentally in this study was 208 mm—intermediate to calf jaws from previous collections. Western Arctic caribou could be getting smaller again.

DISEASE MONITORING PROGRAM

Brucellosis is the most well-known disease of caribou. It is caused by the bacterium *Brucella suis* IV. Infection localizes in 1) joints, where it causes lameness; and/or 2) the reproductive tract, where it can cause abortion and sterility.

Serologic survey data indicate a distinct geographic pattern. Antibody prevalence ranges from 5%-25% in the 4 arctic herds (Western, Teshekpuk, Central, and Porcupine). Prevalence is essentially 0% in all other herds. Potential explanations for this phenomenon focus on interaction between the WACH and reindeer herds on the Seward Peninsula. Brucellosis is enzootic in the reindeer herds. They may serve as a continuing source of exposure for the arctic caribou herds.

The so-called "bovine respiratory group" consists of the following 4 viruses: 1) infectious bovine rhinotracheitis (IBR), 2) bovine viral diarrhea (BVD), 3) parainfluenza III (PI3), and 4) respiratory synctial (RSV). These viruses typically infect the upper respiratory tract. They cause flu-like illness. Morbidity rates may be high. Mortality rates are low.

Antibody prevalence of IBR, BVD, and PI3 in caribou exhibits a distinct pattern. Annual prevalence of IBR, BVD, and PI3 ranges from 5%-25% in the arctic caribou herds. Prevalence is essentially 0% for all other herds in Alaska. At present, there is no apparent explanation for this pattern. In recent years RSV has been added to the survey. Limited data indicate that antibody prevalence will not be high for RSV as for the other 3 viruses.

Epizootic hemorrhagic disease (EHD) and bluetongue (BLU) are 2 closely-related viruses. Epizootic hemorrhagic disease is primarily a wildlife pathogen. Bluetongue is primarily a livestock pathogen. They both cause a disruption of the 1) clotting mechanism of blood and 2) permeability of blood vessels. Infected animals can essentially bleed to death internally. These 2 viruses have been included in ADF&G's survey since its inception. There has been occasional evidence of exposure in a wide variety of species, including WAH caribou. However, there is no pattern regarding years, species or geographic location. In similar situations, we often consider the serologic test results invalid. However, in this case the testing lab has confirmed and reconfirmed the results. Lab personnel believe that a variant of either EHD or BLU is circulating in Alaska wildlife. There have been no reports of clinical cases of disease. The epizootiology of EHD and BLU remains a mystery.

Contagious ecthyma (CE) virus occurs worldwide in domestic sheep and goats. Infection localizes in unhaired portions of the body, where it causes large dark-colored masses of tissue to develop. When these lesions occur near the mouth, they interfere with eating. When they occur above the hoof, they interfere with walking. The disease occasionally erupts in Dall sheep (*Ovis dalli*) and mountain goat (*Oreamnos americanus*) populations in Alaska. Serological surveys indicate that WAH caribou are occasionally exposed to CE virus. From a population perspective, the effects of CE are imperceptible.

Leptospirosis is a bacterial disease. It can be caused by any of several so-called "serovars" of *Leptospira interrogans*. Infection causes chronic degradation of the kidney. Serologic surveys indicate that a variety of wildlife species in Alaska (including WAH caribou) have been exposed to *L interrogans*. Leptospirosis may be a minor mortality factor for the WAH.

During the 1960s and early 1970s and again during the late 1970s and early 1980s, calving ground surveys included flights to sample for the prevalence of retained placentas among parturient cows. The prevalence of retained placentas was higher during the 1960s when the WACH was high and declining than during the late 1970s and early 1980s when the herd was increasing (Davis and Valkenburg 1985). Retained placentas are thought to be indicative of the presence of brucellosis, but this has never been proven in the WACH, and it is possible they are related to other disease agents or to poor nutrition.

There is no evidence that disease prevalence has increased in the WACH in recent years as herd size has increased.

MANAGEMENT CONSIDERATIONS AND RECOMMENDATIONS

ESTIMATING CALF:COW RATIO IN FALL

Annual fall composition counts with a helicopter should be incorporated into the management program for the WACH. Spring estimates of calves/100 adults should also continue (Appendix D). Fall calf:cow ratio estimates have the potential to be more accurate than spring estimates of calves/100 adults and they are more timely. Caribou declines can occur suddenly and are not necessarily related to herd size or density (Valkenburg et al., in press; Whitten, in press). In all of the caribou herds studied in Interior Alaska, reduced calf numbers in fall have been among the first indicators of impending population declines (Eberhardt and Pitcher 1992; Valkenburg et al., in press). Calves can have either high or low survival during the summer, depending on their weights at birth and summer foraging conditions, so calving ground surveys may not provide reliable indices of recruitment. If only 1 measure of annual recruitment were to be obtained in the WACH, the fall counts should be first priority.

RANGE CONDITIONS

In contrast to most other ungulates, caribou are highly adapted to extreme cold and prolonged snow cover, and winter ranges are generally much larger than summer ranges. On mainland ranges significant winter die-offs have never been documented and summer nutrition is probably more important as a limiting factor than winter nutrition. In the George River Herd, reduced summer nutrition that resulted in lower recruitment was the primary mechanism for population stabilization (Huot and Goudreault 1985; Messier et al. 1988). Lichen abundance on summer ranges decreased and ground cover was replaced by mineral soil (Messier 1995; Huot, pers commun). In the present study of WAH caribou, the marked variation in size and weight of caribou calves in fall (Figs 3-5) indicated that summer nutrition was also more variable than winter nutrition, despite record snow in some years. Poor condition of caribou at the end of summer could be due in whole or in part to summer weather conditions and insect abundance, but interactions with population size or density could play a role. There is no useful historical data on the extent and quality of summer range for caribou in northwestern Alaska, and such data would be difficult to collect.

The WACH apparently still has a large reserve of winter range, and like the George River Herd, it has room to extend its winter range. The Nulato Hills from Unalakleet south have not had significant grazing by reindeer since before 1945 or by caribou since the 1880s (Skoog 1968, Pegau 1970). Other areas such as the Pah Flats and middle and lower Koyukuk River valleys are interspersed with rich lichen mats and sedge meadows which are excellent winter range but have received only light use so far. Even with deep snow on the southern winter range in 1990-1991 and 1992-1993, and deeper than normal snow in most years since 1989, WACH caribou calves were able to maintain body condition and fatness in April 1992-1994. In addition, the 3 fecal samples collected from the WACH winter range during this study in 1992 and 1993 were relatively low in mosses—an indication that caribou were able to obtain preferred foods without difficulty even when snow was deep (Valkenburg 1994*a*:17). Small die-offs occurred on the north slope in 1990-1991 and near Cape Thompson in November-December 1994, but relatively few caribou have been wintering in these areas and the overall effect on herd dynamics was small. Despite good winter range, a large winter die-off of WAH caribou could occur if caribou leave the summer range in poor condition and then encounter icing conditions on the southern winter range which can be influenced by wet, coastal weather systems.

MONITORING NUTRITION IN THE WACH

When biologists reviewed declines of caribou that occurred in Alaska in the early 1970s, there was a general consensus that better recruitment data and information on body condition, herd nutrition, and birth and death rates would have been extremely valuable (Klein and White 1978, Eberhardt and Pitcher 1992). Knowledge of the role of nutrition in a caribou decline can help biologists explain events to interested users and determine which management actions might be most appropriate. Several simple indices and measurements can provide inexpensive data on herd nutrition in *Rangifer*. These include surveys to determine peak calving date and pregnancy rate (Skogland 1985, Whitten 1995), and sampling to determine body weight and fatness (Chan-McLeod et al. 1995). Presently, little information on nutrition is coming from the WACH monitoring program. Periodic collections of mandibles are valuable and should be continued, but this information is only valuable from a historical perspective. Pregnancy rate and peak calving date cannot be determined from the present calving ground surveys, and only qualitative, anecdotal information from incidental observations of caribou crossing the Kobuk River has been collected in fall.

Weights of female calves should be measured annually in fall. Sampling could either be in conjunction with fall composition counts or at the Kobuk River crossing in conjunction with the annual collaring program. Adequate samples could be obtained inexpensively, and local people could be involved with supervision from biologists.

COLLARING PROGRAM

The primary reasons for the present collaring program are to 1) aid in finding caribou during the census every 3 years, 2) aid in determining herd distribution and whether dispersal occurs, 3) help survey caribou in fall and spring, and 4) estimate mortality rates. In all other caribou herds in Alaska, female calves are being collared in fall or spring. Additional information could be obtained in the WACH if calves could be collared there as well. When a lightweight collar with sufficient signal strength and life is available, collaring female calves in fall should become part of the annual management program.

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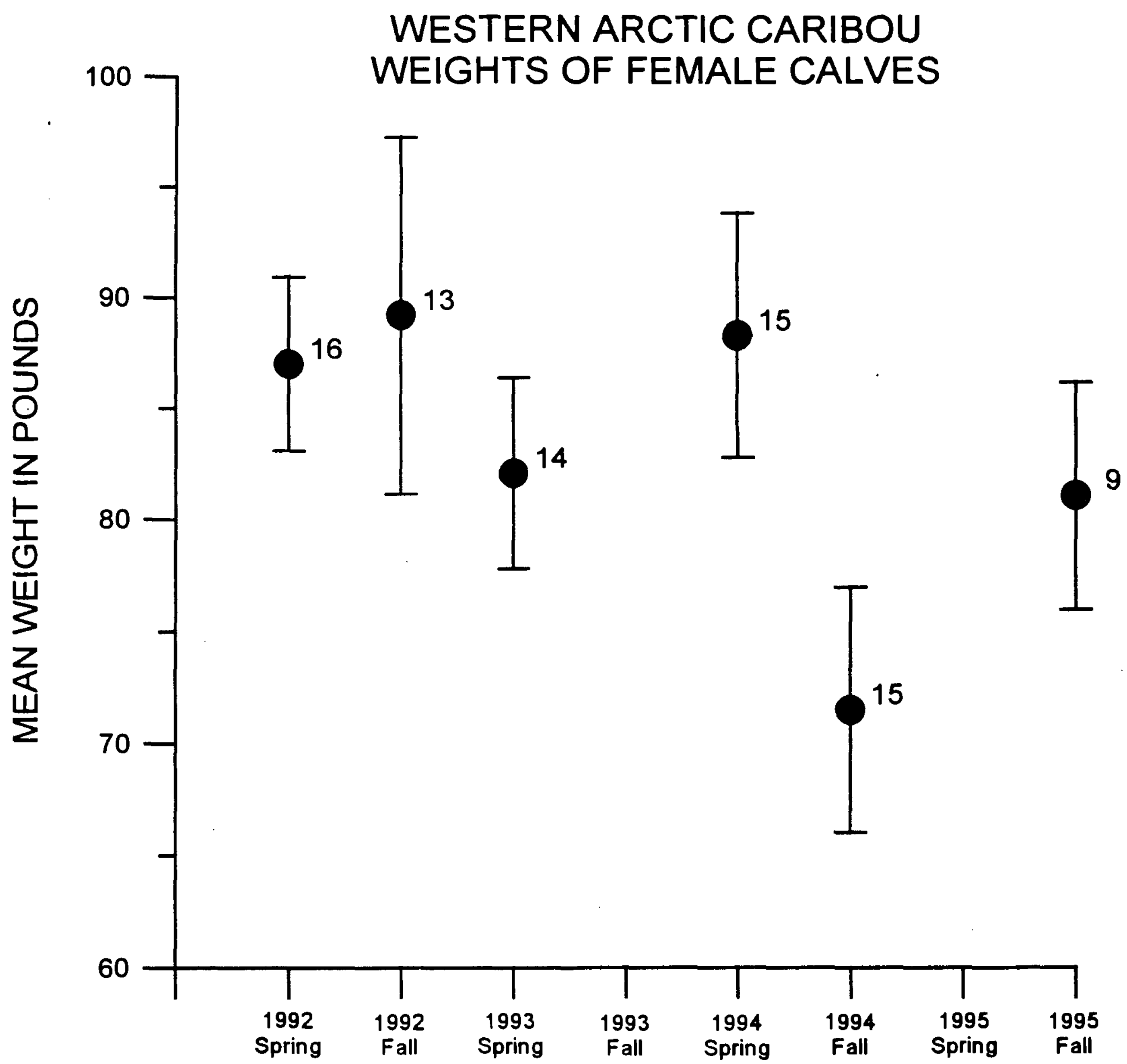

Fig 1 Mean weight, sample size, and confidence interval (95%) of samples of female caribou calves collected from the WACH, 1992-1995

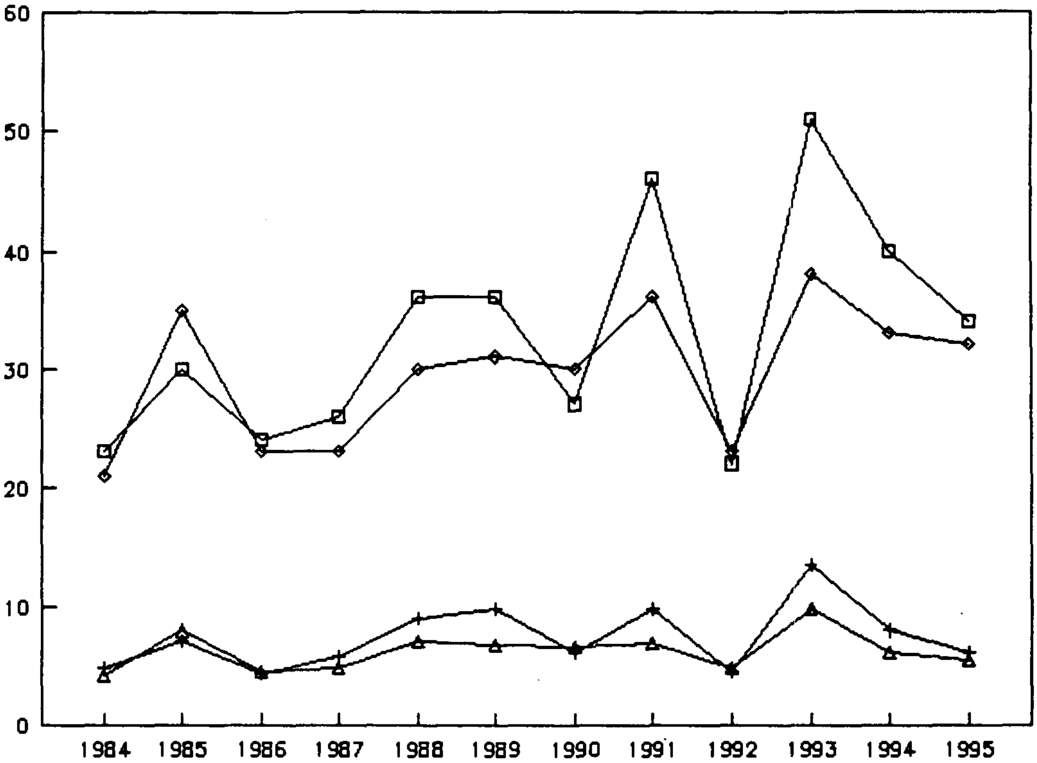

Fig 2 Scatter plots of 5 independent variables and fall calf:100 cow ratio in the WACH, 1992-1995

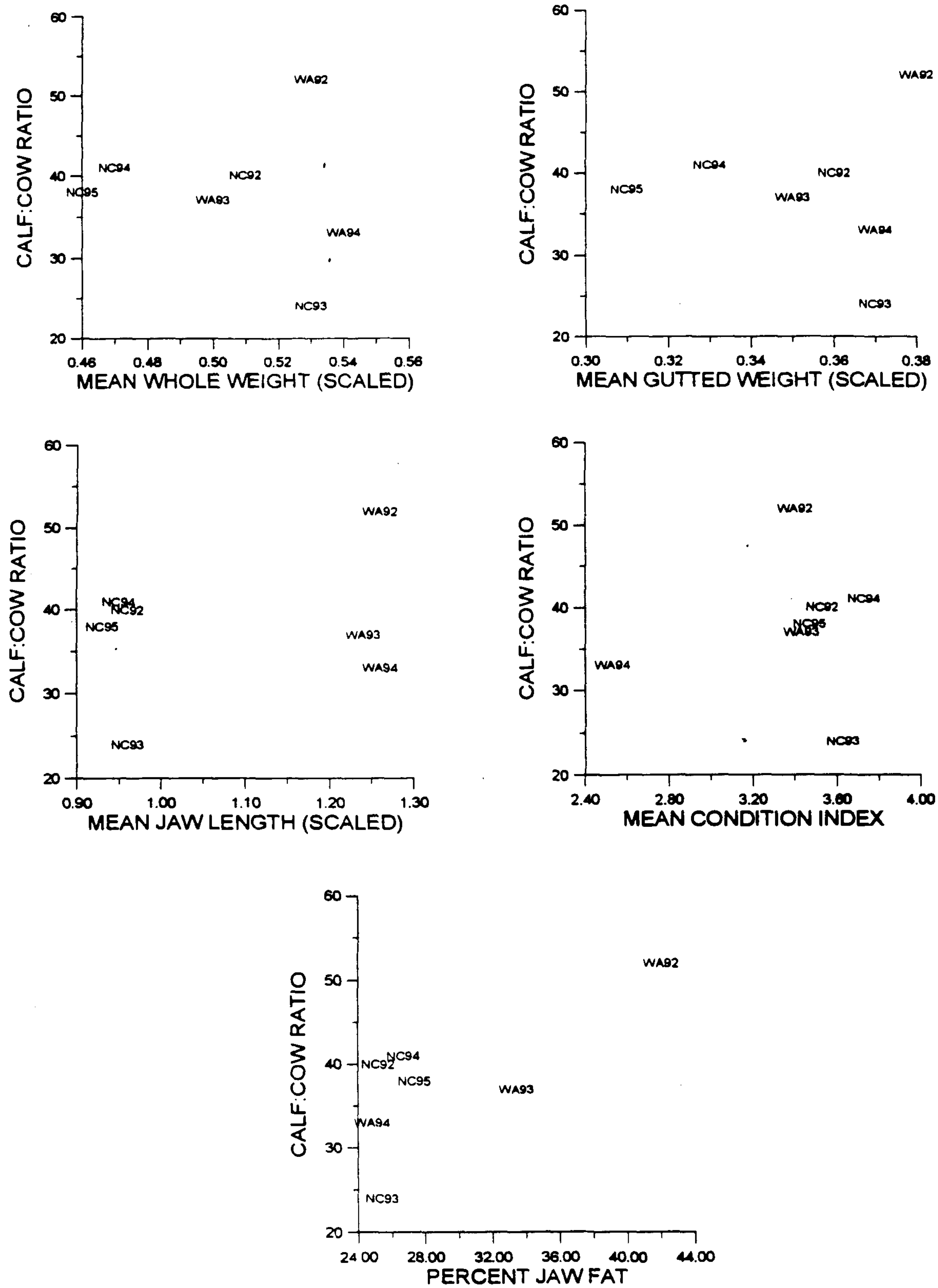

Fig 3 Snow depth (in) and water content (in) at Bettles (squares) and Todatonten Lake (diamonds) on 1 Apr, 1984-1995

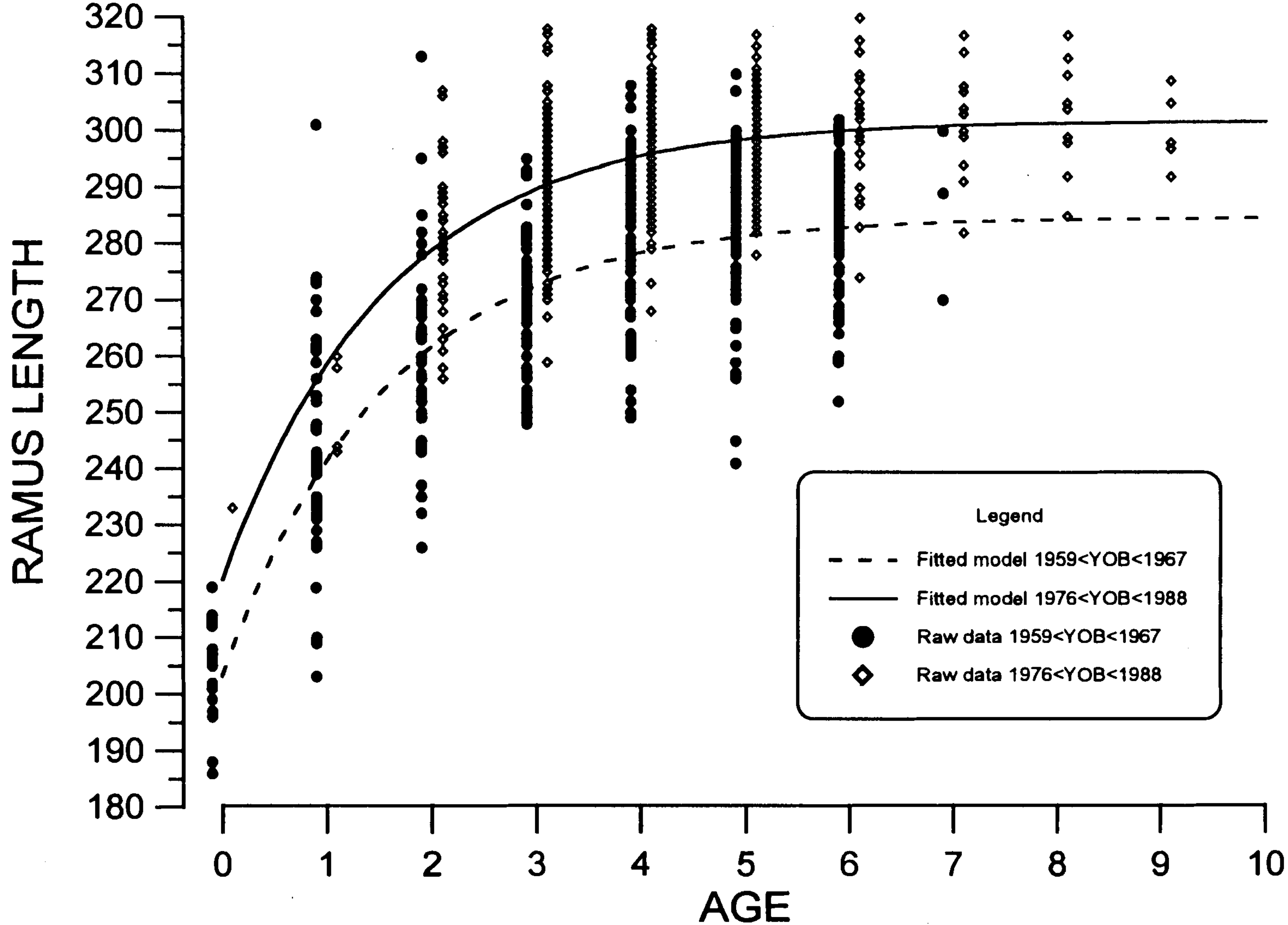

Fig 4 Growth curves for ramus (jaw) length in male WACH caribou born during 1959-1967 and 1976-1988

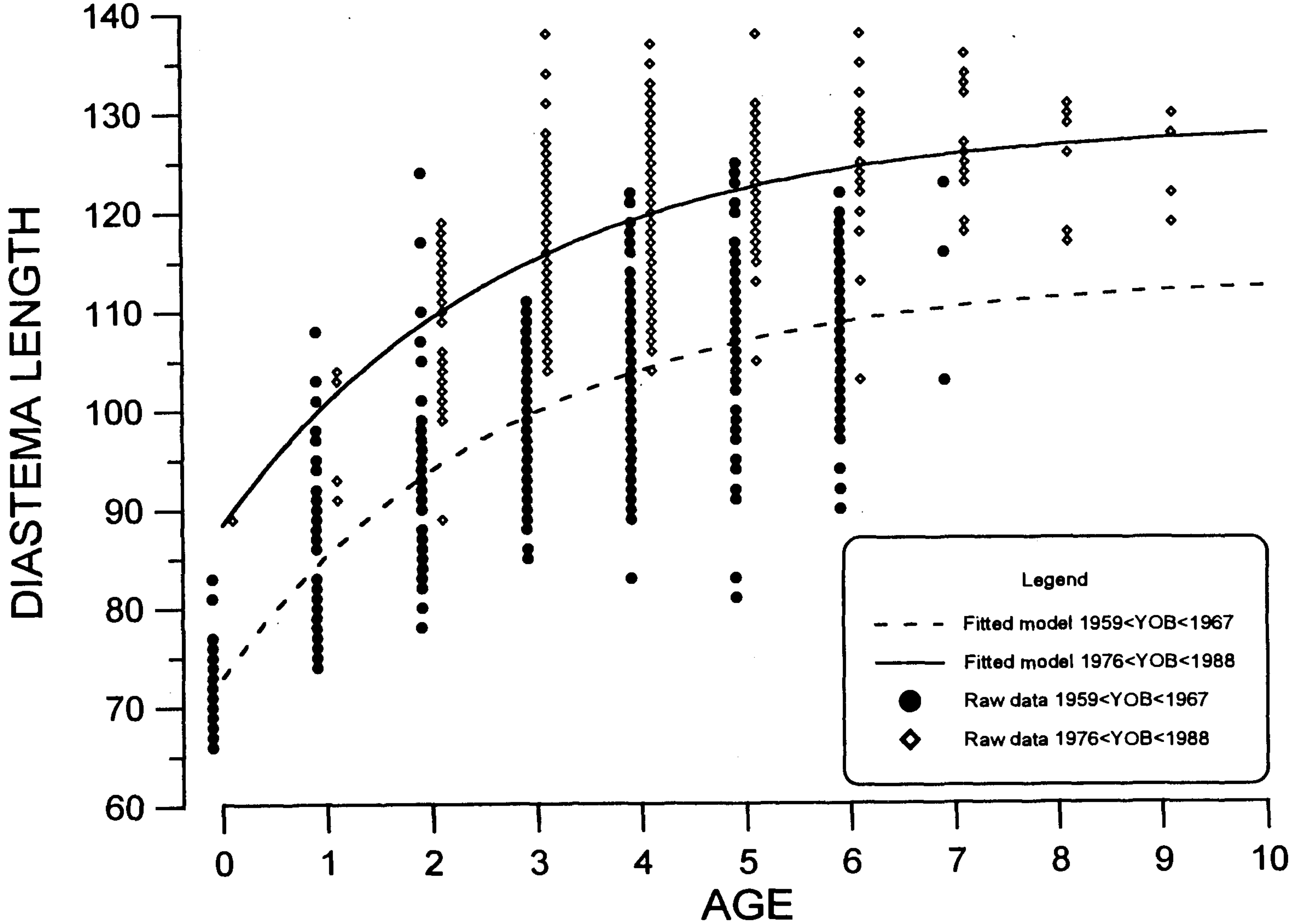

Fig 5 Growth curves for diastema length in male WACH caribou born during 1959-1967 and 1976-1988

Table 1 Whole weight, gutted weight, mandible length, diastema length, mandible fat, femur fat, warble numbers, and fat deposit index of female calves from the Western Arctic, Nelchina, and other selected caribou herds, 1992-1995

		Whole weight			Gutted weight			Mandible length			Diastema length			%[a] Mandible fat			%[a] Femur fat			Warbles			Fat deposit
Collection	Month	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	index[b] (*n*)
Mulchatna 1995	Apr	110.6	3.0	10	75.8	2.3	10	215.3	2.3	9	80.8	0.8	10	53.5	4.4	10	76.3	3.3	10	108.0	21.0	10	3.8 (9)
Nelchina 1992 (Unit 13)	Apr	109.4	7.2	8	76.0	4.9	8	216.7	4.9	7	83.1	2.2	8	15.5	2.8	8	--	--	--	--	--	--	3.0 (8)
Nelchina 1992 (Unit 12)	Apr	124.4	2.7	9	87.1	2.0	9	224.8	1.5	9	86.9	1.0	9	34.4	3.6	9	--	--	--	--	--	--	4.0 (9)
Nelchina 1993 (Unit 13)	Apr	118.0	3.3	11	82.5	2.2	11	221.3	1.9	12	84.6	0.9	12	23.7	2.4	12	50.0	4.0	11	46.7	7.8	12	3.5 (12)
Nelchina 1993 (Unit 12)	Apr	125.7	4.0	7	86.9	3.1	7	221.2	3.0	7	83.4	1.1	7	29.4	4.9	7	50.7	6.4	7	56.7	11.3	7	3.9 (7)
Nelchina 1994	Apr	107.8	4.2	11	75.0	3.1	11	219.2	2.6	9	84.4	1.3	9	26.7	5.1	9	48.0	7.1	10	111.1	18.0	11	3.7 (11)
Nelchina 1995	Apr	105.0	1.9	29	71.7	1.9	15	214.7	1.3	13	80.6	0.8	14	27.3	3.0	15	39.9	5.6	15	116.0	24.0	15	3.5 (15)
Nelchina 1995	Oct	118.0	3.4	15	80.0	2.5	11	202.5	2.5	11	79.6	1.3	11	--	--	--	65.3	4.2	11	--	--	--	3.4 (11)
Northern Alaska Peninsula 1995	Apr	112.6	3.0	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Northern Alaska Peninsula 1995	Oct	98.6	3.6	10	66.2	2.9	10	195.1	2.2	10	73.8	1.2	10	--	--	--	56.6	5.1	11	--	--	--	3.6 (9)
Nushagak Peninsula 1995	Apr	125.8	2.9	15	88.3	7.0	5	225.4	6.2	5	85.0	2.8	5	49.4	1.0	5	78.8	2.1	5	--	--	--	4.0 (5)
Western Arctic Pah Flats, Ambler 1992	Apr	87.0	2.0	16	62.1	1.8	16	207.8	1.7	16	79.1	0.7	16	42.3	4.2	10	--	--	--	--	--	--	3.2 (16)
Western Arctic Pah Flats, 1992	Oct	89.2	4.1	13	60.4	2.8	13	192.8	1.9	13	73.7	1.4	13	--	--	--	--	--	--	--	--	--	3.5 (11)

Table 1 Continued

Collection	Month	Whole weight			Gutted weight			Mandible length			Diastema length			%[a] Mandible fat			%[a] Femur fat			Warbles			Fat deposit
		Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	index[b] (*n*)
Western Arctic Hunt River, 1993	Apr	79.3	5.2	4	55.3	3.3	4	201.8	7.5	4	75.0	3.1	4	--	--	--	--	--	--	--	--	--	2.3 (4)
Western Arctic Indian River Flats, 1993	Apr	83.2	2.4	10	58.8	1.6	10	205.3	1.5	10	78.3	1.0	10	33.7	3.4	10	40.0	7.2	10	66.3	13.5	8	3.9 (10)
Western Arctic 1994	Apr	88.3	2.8	15	61.1	1.8	15	207.2	2.0	15	79.1	1.1	15	24.8	6.8	15	42.1	4.0	15	--	--	--	2.5 (15)
Western Arctic 1994	Sep	71.5	2.8	15	50.3	2.1	15	175.2	1.8	15	67.9	0.9	15	12.4	3.8	11	16.7	3.3	15	--	--	--	1.6 (15)
Western Arctic 1995	Apr	81.1	2.6	9	54.3	2.5	9	185.2	2.1	9	71.6	1.4	9	--	--	--	46.4	8.3	9	--	--	--	3.1 (9)

[a] After Neiland (1970). Percent marrow fat calculated from % dry weight as follows: % fat = (% dry weight*1.05)-6.95.

[b] Fat deposit index was calculated by assigning a value of 1 point for the presence of fat in each of 4 sites on the carcass (i.e., rump, brisket, mesenteries, heart), summing the values for all animals, and dividing by the number of animals in each collection. For example, if each calf in a collection of 10 all had fat in each of the 4 fat deposit sites, the Fat Deposit Index would be 40/10 = 4.0.

Table 2 Western Arctic caribou fall composition counts and estimated population size, 1952 to 1995

Approximate survey date	Bulls: 100 C	Calves: 100 C	Calves %	Cows %	Small bulls % of bulls	Medium bulls % of bulls	Large bulls % of bulls	Total bulls %	Composition sample size
10/52	--	--	26	--	--	--	--	--	320
10/53	--	--	24	--	--	--	--	--	164
9/54	--	--	28	--	--	--	--	--	393
10/61[a]	55	37	19	50	--	--	--	27	1006
10/68[a]	62	34	16	46	--	--	--	28	2217
10/70[a]	64	44	19	44	--	--	--	28	6219
10/75[a]	31	48	25	52	--	--	--	16	2243
10/76[a]	58	48	21	43	--	--	--	25	7140
10/77[a]	43	42	19	47	--	--	--	20	6888
10/78[a]	51	50	22	44	--	--	--	22	5097
11/80[a]	53	53	22	42	--	--	--	22	3187
10/81	--	--	22	--	--	--	--	--	5050
10/82	59	60	27	46	--	--	--	27	13,996
10/10/92	65	53	24	46	--	--	--	30	5397
15/10/93	38	39	21	57	--	--	--	21	4039
9/10/94	48	33	18	56	21	28	52	26	5756
23-26/10/95	58	52	25	48	--	--	--	28	4262

[a] Yearlings were classified in these counts.

Table 3 Results of 1994 Western Arctic Caribou Herd composition counts corrected for classification error

Count group	Date	Bulls: 100 C	Small bulls: 100 C	Calves: 100 C	Calves %	Cows %	Small bulls % of bulls	Medium bulls % of bulls	Large bulls % of bulls	Total bulls %	Total caribou	Group weighting factor
Purcell Mtn to Tag R	10/9/94	49	9	37	20	54	18	23	60	26	2582	18.00
Tag R to Granite Mtn	10/9/94	36	8	31	19	60	21	28	51	22	1532	49.00
Kobuk Delta-Ambler	10/10/94	34	9	39	23	58	28	25	48	20	813	1.00
Ambler-Shungnak	10/10/94	97	29	40	17	42	30	35	35	41	575	1.00
Shungnak-Bettles	10/10/94	101	22	32	14	43	22	33	45	43	254	10.00
Unweighted		64	15	36	18	51	24	29	48	30		
Weighted[a]		48	10	33	18	56	21	28	52	26		

[a] Weighted by distribution of radiocollared caribou.

Table 4 Results of 1994 Western Arctic Caribou Herd composition counts not corrected for classification error

Count group	Date	Bulls: 100 C	Small bulls: 100 C	Calves: 100 C	Calves %	Cows %	Small bulls % of bulls	Medium bulls % of bulls	Large bulls % of bulls	Total bulls %	Total caribou	Group weighting factor
Purcell Mtn to Tag R	10/9/94	42	3	35	20	56	8	26	67	24	2582	18.00
Tag R to Granite Mtn	10/9/94	29	2	30	19	63	8	33	59	18	1532	49.00
Kobuk Delta-Ambler	10/10/94	27	4	37	23	61	14	30	56	17	813	1.00
Ambler-Shungnak[a]	10/10/94	97	29	40	17	42	30	35	35	41	575	1.00
Ambler-Shungnak	10/10/94	75	3	35	17	48	4	35	61	36	229	1.00
Shungnak-Bettles	10/10/94	71	4	27	14	50	5	40	55	36	254	10.00
Unweighted		57	7	34	18	53	11	33	55	29		
Weighted[b]		39	3	31	18	59	8	32	60	22		

[a] Caribou classified by P Valkenburg.

[b] Weighted by distribution of radiocollared caribou.

Table 5 Prevalence of 10 diseases for which tests were done in the Western Arctic Caribou Herd, 1985-1994

Agent[a]	Test Method[b] (Titer)[c]	1986	1992	1993	1994
IBR	SN (8)	2/40[d]	29/60	5/63	3/64
BVD	SN (8)	1/40	35/60	34/63	31/64
PI3	HI (8)	10/41	36/59	38/63	36/64
RSV	IFA (20)	0/40	0/56	0/63	0/63
EHD	ID (+/-)	1/41	0/60	3/63	8/64
Bluetongue	ID (+/-)	0/41		0/63	0/64
CE	CF (10)	0/15			
Brucellosis	BATA (+/-)	7/37	2/53	6/51	5/50
Q fever	CF (20)	0/41			
Leptospirosis	MAT (100)	0/41	2/60	3/63	1/64

[a] IBR = Infectious Bovine Rhinotracheitis, BVD = Bovine Viral Diarrhea, PI3 = Parainfluenza 3 virus, RSV = Respiratory Syncytial Virus, EHD = Epizootic Hemorrhagic Disease, CE = Contagious Ecthyma.

[b] SN = Serum Neutralization Test, HI = Hemmagglutination Inhibition Test, IFA = Indirect Fluorescent Antibody Test, ID = Immunodiffusion Test, CF = Compliment Fixation Test, BAPA = Buffered Acidified Plate Antigen Test, MAT = Microscopic Agglutination Test.

[c] Number in parenthesis indicates minimum titer necessary to be considered evidence of exposure to the agent. A (+\-) indicates the test is either positive or negative.

[d] Number positive/number tested.

Table 6 Weights and standard errors of 50 samples of female calf caribou from 17 Alaskan caribou herds, ordered by weight

Herd	Year	Season	Mean weight (lb)	Standard error	Sample size
Western Arctic	1994	Fall	71.5	2.8	15
Western Arctic	1995	Fall	81.1	2.6	9
Western Arctic	1993	Spring	82.1	2.2	14
Western Arctic	1992	Spring	87.0	2.0	16
Western Arctic	1994	Spring	88.3	2.8	15
Western Arctic	1992	Fall	89.2	4.1	13
Northern Peninsula	1995	Fall	98.6	3.6	10
Nelchina	1995	Spring	105.0	1.9	29
Macomb	1990	Fall	107.3	2.6	12
Nelchina	1994	Spring	107.8	4.2	11
Nelchina Unit 13	1992	Spring	109.4	7.2	8
Mulchatna	1995	Spring	110.6	3.0	10
Chisana	1990	Fall	112.6	3.8	14
Delta	1991	Spring	113.1	2.9	10
Northern Peninsula	1995	Spring	112.6	3.0	18
Fortymile	1990	Fall	116.3	2.5	14
Nelchina Unit 13	1993	Spring	118.0	3.3	11
Nelchina	1995	Fall	118.0	3.4	15
Macomb	1994	Fall	118.8	3.1	10
Fortymile	1991	Fall	118.9	3.0	14
Delta	1992	Spring	119.1	2.6	17
Delta	1990	Spring	119.9	3.3	12
Fortymile	1994	Fall	120.0	2.7	14
Delta	1992	Fall	120.4	3.0	14
Delta	1987	Spring	120.8	2.8	9
Fortymile	1992	Fall	121.5	3.7	14
Delta	1993	Spring	122.3	2.9	12
Delta	1993	Fall	122.9	3.0	11
Delta	1995	Spring	123.1	2.7	15
Fortymile	1993	Fall	123.7	1.9	15
Nelchina Unit 12	1992	Spring	124.4	2.7	9
Fortymile	1995	Fall	125.0	2.6	15
Nelchina Unit 12	1993	Spring	125.7	4.0	7
Nushagak	1995	Spring	125.8	2.9	15
Delta	1984	Spring	126.9	1.9	14
Delta	1991	Fall	127.6	2.6	14
White Mountains	1995	Spring	130.1	3.0	8
White Mountains	1991	Fall	131.1	4.7	9
Delta	1995	Fall	131.1	2.7	13
Wolf Mountain	1995	Fall	131.1	4.7	8
Delta	1988	Spring	131.3	2.9	12

Table 6 Continued

Herd	Year	Season	Mean weight (lb)	Standard error	Sample size
Delta	1994	Fall	131.4	3.0	15
Delta	1979	Spring	132.3	2.4	11
White Mountains	1995	Fall	133.3	4.7	6
Delta	1989	Spring	133.6	2.7	9
Ray Mountains	1994	Fall	134.4	3.8	20
Delta	1982	Spring	135.1	3.9	11
Delta	1981	Spring	137.0	7.4	5
Delta	1983	Spring	137.2	3.3	13
Galena Mountain	1994	Fall	143.4	3.2	9

Table 7 Number of radiocollared cows visually observed with and without calves during calving ground surveys of the Western Arctic Caribou Herd, 1987-1995

Survey dates	Cows w/ calf	Cows w/o calf	Total cows	Calves:100 cows
6/17-19/87[a]	30	16	46	65
6/3-5/88	26	27	53	49
6/10-12/89	34	16	50	68
6/11-13/90	51	20	71	72
1991[b]				
6/8-14/92[c]	52	12	64	81
6/11-17/93	38	41	79	48
6/10-13/94	42	38	80	52
6/9-20/95	47	37	84	56

[a] During all surveys (except for the 8-9 Jun 1992 survey) cows were observed from a Cessna 185 for the presence of hard antlers and calves at heel. Cows were observed only once during the survey period.

[b] No counts.

[c] Two surveys were flown in 1992. One was flown in a Bellanca Scout on 8 and 9 Jun. During this survey cows were observed for the presence of distended udders, hard antlers, and calves at heel. During the second survey from 12 to 14 Jun, cows were checked for hard antlers and calves at heel.

APPENDIX A Wildlife Research Study Plan

Project No. W-24-1
Study No. 3.37 (Revised)
Study Duration
From: July 1, 1992
To: June 30, 1996

Project No. W-23-5
Study No. 3.37
Study Duration
From: July 1, 1991
To: December 31, 1996

WILDLIFE RESEARCH STUDY PLAN

Alaska Department of Fish and Game
Division of Wildlife Conservation

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

THE PROBLEM or NEED:

1. Statement

There is a great demand for caribou hunting in the relatively accessible areas of interior Alaska, but managers are unsure how to maximize the long-term sustainable harvest from caribou herds. This doubt exists because the natural regulation of caribou numbers is not well understood. If caribou populations are normally regulated by density-dependent food limitation and/or dispersal, maximum long-term harvests will be achieved by deliberately maintaining herds at moderate densities. If, on the other hand, weather and/or predation are most often the main regulating (or limiting) factors, maximum long-term sustainable harvests will be achieved by maintaining herds at relatively high levels and controlling predator numbers. The situation is made more complex because different limiting factors may be operational at low versus high densities. Managers need guidelines on approximate herd densities at which maximum harvests can be achieved.

2. Justification

Biologists have not yet had an opportunity to study a declining caribou herd using modern techniques, and the mechanisms involved in initiating declines have been the subject of an ongoing controversy (VanBallenberghe 1985, Ballard and Bergerud 1988). During the caribou decline that occurred in the late 1960's and early 1970's little data were collected and radiocollar technology was not sufficiently advanced for efficient use on caribou. The Delta Caribou Herd (DCH) (formerly 2 separate herds--Delta and Yanert) recently reached a historically high level and has declined during the past 2 years. It is not clear whether this decline is a temporary setback caused by the harsh winters or the beginning of a sustained downward trend. Because the population dynamics of the DCH have been studied intensively for 12 years and because the adjacent low-density Denali Herd is also being studied, we are in an ideal position to gain additional information on factors that regulate caribou herd size.

3. Background

In 1977 the leading caribou biologists in North America identified the need for a long-term population dynamics study of 1 or more caribou herds in Alaska (Klein and White 1978). In response to this recommendation, Davis and Valkenburg (1983) began a long-term investigation of the DCH because of its proximity to Fairbanks and a relatively large amount of recent background data available. Two consecutive 5-year research projects were completed (Davis and Valkenburg 1985, Davis et al. 1991). These 2 projects greatly increased our knowledge of caribou population dynamics, especially during a population recovery, and many publications resulted from this work (see Davis et al. 1991 for a list of publications).

During the early 1980's recruitment in the DCH was high and, despite heavy harvests, the herd increased at about 11% annually. In the mid-1980s, as population density increased, recruitment declined, and the wolf population within the herd's range stabilized at about 180; DCH harvest had to be reduced to maintain population growth. By 1989, the rate of population increase had slowed to less than 5% even though the number of females harvested was very small (<50). The pregnancy rate of yearling females was initially relatively high (10-50%) but declined to zero by 1984. The DCH probably began to decline in 1990 following the severe winter of 1989-90. The 1990-91 winter was also severe (the most severe winter on record in Fairbanks) and recruitment to April 1991 declined to 8 calves:100 cows (the second lowest calf:cow ratio ever measured in the DCH). Other herds in the Alaska Range also experienced poor recruitment following these 2 bad winters, including the Denali, Macomb, Tonzona, and Chisana Herds. The low-density Denali Herd is adjacent to the DCH and is also being intensively studied. Therefore, there is now an opportunity to compare the population dynamics of a high-density and a low-density herd in similar ecological circumstances. During the next phase of the Delta Herd study we intend to investigate the relative influences of weather, food limitation, predation, and hunting on the recent, and perhaps continuing, decline of the DCH.

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STUDY OBJECTIVES

To evaluate the influence of weather, density, food limitation, hunting, and predation on the population dynamics of the Delta Caribou Herd.

EXPECTED RESULTS AND BENEFITS

By understanding the influence of predation, weather, and food limitation on the DCH, biologists will be in a better position to recommend population management objectives and harvest levels for this and other accessible caribou herds in interior Alaska.

STUDY APPROACH

The initial approach will be to monitor population parameters and body condition through and immediately after the hard 1990-91 winter and into a period of more normal weather to determine if recruitment and condition improve in the Delta and Denali Herds when weather returns to normal. If recruitment does not improve after two normal winters, further work, including possible manipulation of the wolf and/or caribou population, will be initiated to separate the influence of wolf predation from other natural factors. A predation study, if warranted, will be initiated as a separate but complementary project.

JOB OBJECTIVES

1. To census the Delta Herd annually from 1991 to 1995. The modified APDCE technique (Davis et al. 1979) will be used.

2. To determine the natality rate of the DCH. Radio-collared caribou will be observed daily from 18 to 31 May each year to determine reproductive condition (Bergerud 1964, Davis et al. 1991). Natality rate of Delta Herd caribou will be compared with the natality rate of Denali, Macomb, Chisana, Fortymile, White Mountains, Ray Mountains, and Galena Mountains Herds to test the hypothesis that the natality rate of female caribou ($\geq$3 years old) is essentially constant and does not vary within or between herds.

3. To determine the timing of peak calf production in the Delta and other Interior herds. Radio-collared caribou in the Delta, Denali, Macomb, Chisana, Fortymile, White Mountains, and Galena Mountains Herds will be monitored to determine if the timing of calving is correlated with herd density, body size, relative abundance of lichens on winter ranges, and proportion of lichens in the winter diet (Bergerud 1964, Skogland 1985, Davis et al. 1991, Whitten 1991).

4. To determine recruitment in the DCH. Calf:100 cow ratios will be determined with helicopter composition counts in late September and in April. Survival of calves of radio-collared cows and radio-collared calves will also be determined (Pollock et al. 1989). To determine whether April composition counts are a valid method of measuring recruitment, 30 4-month-old calves will be collared in October and their distribution in relation to that of adult cows will be monitored in April.

5. To measure harvest by hunters. Harvest will be monitored through the ongoing management program with adjustments made for nonreporting (McNay 1990).

6. To determine when major mortality occurs to both calves and adults. Adult female mortality during all years will be determined by monitoring radio-collared adult female caribou (Pollock et al. 1989). During the first year of the study, calf mortality will be determined by monitoring the 30 collared calves during their first winter (Pollock et al. 1989). In other years, calf mortality will be monitored by conducting composition counts in late September and in April and observing calves of radio-collared cows during summer. Natural mortality rates and timing of mortality will be compared with other Interior herds.

7. To monitor movements and distribution to see how range use changes with population size, and to see if dispersal occurs. Radio-collared caribou will be monitored and surrounding areas will be searched for any missing radiocollars. We will test the hypothesis that dispersal is unimportant to the dynamics of the Delta and other Interior caribou herds.

8. To monitor body condition and changes in body size and weight in calves and adults. To determine the influence of summer vs. winter weather on body condition and test a model that predicts recruitment from April calf weight. In the Delta herd, a sample of 30 calves the first year and 20 in succeeding years will be caught, weighed, and measured during radio-collaring in fall, and a sample of 10-15 calves will be collected, weighed, and measured, and condition scored (Kistner 1980) in April. Condition, fat indices (Kistner 1980), and carcass weight of caribou killed during the late winter hunting season will be monitored by operating hunter checking stations during an annual February or March hunt. Radio-collared cows will be caught, weighed, and measured when collars need to be replaced (about 20 the first year and 10 the second year) to see if adult females are growing as large as they were when the herd was smaller. Up to 30 calves will be collected from the Nelchina herd annually and 10-20 will be immobilized or collected from the other Interior herds as necessary. Caribou may be collected, rather than immobilized, for logistical or cost reasons, or if it is determined that more extensive measures of body condition or chemistry are needed than can be collected from live immobilized animals. Caribou will not be collected until it is determined that the removal of collected animals will not have a significant impact on the population dynamics of the herd. Local advisory committees and other interested individuals will be informed of collections, and all meat from collected caribou will be returned in the best possible condition for human consumption.

9. To compare winter food habits of the Delta, Denali, White Mountains, and Macomb Herds. Fecal pellets will be collected annually from the winter ranges of these herds (Sparks and Malechek 1968, Boertje et al. 1985). The hypothesis that food habits of Delta Herd caribou are similar to adjacent herds and that Delta caribou eat only a small proportion of the annual production of lichens annually will be tested (Fleischman 1990).

10. To census the wolf population within the range of the DCH to determine if it has increased since the early to mid-1980s when the DCH was increasing (Ballard and Becker, in prep; McNay, in prep).

11. Prepare annual progress reports and final report including a manuscript for publication in refereed literature.

APPENDIX A Continued

Personnel

Patrick Valkenburg, PCN 2052; 9.5 months/year PFT FY92-96, 6.0 months FY97
Vacant, PCN 2149; 1 month/year PFT
Rodney D. Boertje, PCN 2130; 1 month/year PFT
Jay Ver Hoef, PCN 2206; 1 month/year PFT
Robin M. Eagan, PCN 2097; 1 month/year PFT
Mark E. McNay, PCN 2133; 1 month/year PFT

Cooperators

David R. Klein and Robert G. White, Cooperative Wildlife Research Unit and Institute of Arctic Biology, University of Alaska, Fairbanks
Layne G. Adams, Research Biologist, National Park Service, Anchorage
Winston Hobgood, Bureau of Land Management, Fairbanks

SCHEDULE

Years active	Job No.	Activity	Est. oper costs	Est. person days/year
1-5	1	Annual census	S&I	job 15
1-5	4,6	Fall and spring composition count	S&I	job 15
1-5	5	Monitoring harvest	S&I	job 20
1-5	8	Determining weight and size of calves in April in the Delta, Nelchina, Fortymile, and other Interior herds	1.5	30
1-5	9	Food habits of interior herds	1.0	30
1-5	2,3,6	Determining pregnancy rate of collared caribou and timing of calving	1.0	30
1-5	6,7	Monitoring movements and dispersal and mortality	1.0	30
2-5	4,8	Collaring 15 calves in fall	8.0	30
1	4,6	Determining when major mortality occurs and accuracy of April composition counts (collaring 15 male calves in fall 1992)	8.0	30
1	10	Censusing wolves	S&I	job 50
2-5	1-4,6-8	Recollaring adults	8.0	20
1-5	1-4,6-8	Refurbishing collars	5.0	0
1-5	1-4,6-8	Drugs and equipment for immobilizing caribou	2.0	10
2-3	8	Graduate student project analyzing weather data and determining influence of summer weather on caribou populations	5.0	10

APPENDIX A Continued

Years active	Job No.	Activity		Est. oper costs	Est. person days/year
1-5	11	Report preparation		0.5	30
5	11	Final report, publication cost		3.0	150
		Total cost	Year 2	41.0	290
			Year 3	33.0	260
			Year 4,5	28.0	250
			Year 6	3.0	150

* Cost assumes use of state aircraft for most fixed-wing flights.

GEOGRAPHIC LOCATION

Primarily south of the Tanana River, north of the Denali Highway, west of the Delta River, and east of the Parks Highway. Within the ranges of other caribou herds in Alaska as necessary to meet the project objective.

RELATED FEDERAL PROJECTS

1. A study of calf mortality and population dynamics of the Denali Caribou Herd by the National Park Service.

2. A cooperative study and management program to monitor population dynamics, harvest, and age at first reproduction in the Fortymile Caribou Herd. Cooperating agencies include the Alaska Department of Fish and Game, Yukon Department of Renewable Resources, and the National Park Service. ADF&G has the lead role in this project with financial assistance from other agencies.

3. A cooperative study and management program to monitor population dynamics, harvest, and age at first reproduction in the Chisana Caribou Herd. Cooperating agencies and individuals include the Yukon Department of Renewable Resources, the National Park Service, and Pioneer Outfitters of Chisana, Alaska. Biologists are cooperating in data collection and all agencies are contributing funds. Pioneer Outfitters has contributed flying time, logistical support, and local knowledge.

4. A cooperative study of the population dynamics and age at first reproduction in the White Mountains Herd and the effect of a recent large burn on the movements of the herd. ADF&G has the lead role in the population dynamics and reproduction portion of the study, and the BLM has the lead role in the fire effects study.

5. A proposed cooperative study of the population dynamics and age at first reproduction in the Galena Mountains Herd, and interaction with the Western Arctic herd (possibly including genetics). ADF&G will take the lead role in the population dynamics and reproduction study, and the U.S. Fish and Wildlife Service will take the lead role in habitat work and interactions with the Western Arctic Herd.

6. A proposed cooperative study of the identity, movements, size, and age at first reproduction in the Ray Mountains Caribou Herd. Cooperating agencies include ADF&G, Bureau of Land Management, and U.S. Fish and Wildlife Service.

APPENDIX A Continued

REPORTING SCHEDULE

Progress Report will be in Headquarters by September 1, 1992-96
Final Report will be in Headquarters by December 31, 1996

APPENDIX B Raw data for all known composition counts of Western Arctic Herd caribou, 1952-1995

Date	Yearlings	Calves	Cows	Bulls	Total adults	Total
10/52	–	83	–	–	237	320
10/53	–	39	–	–	125	164
9/54	–	110	–	–	283	393
6/60	–	1680	2300	–	2300	3980
7/60	197	568	797	323	1317	1885
7/61	440	495	2179	959	2578	3073
10/61	42	187	501	276	819	1006
7/62	630	–	2899	–	2899	3529
5/63	–	162	639	376	1015	1177
6/63	–	769	–	–	1582	2351
6/64	–	1577	1971	7	1978	3555
6/65	–	3431	4940	–	4940	8371
7/68	485	725	1767	1085	3337	4062
10/68	235	345	1010	627	1872	2217
6/69	–	2187	3798	–	3798	5985
7/70	4043	5171	10,789	6247	21,079	26,250
10/70	543	1198	2732	1746	5021	6219
6/71	–	4085	5185	–	5185	9270
7/75	396	1617	2673	383	3452	5069
10/75	154	558	1171	360	1685	2243
6/76	577	2884	3936	19	4532	7416
10/76	807	1471	3077	1785	5669	7140
4/77	–	3204	6947	2366	9313	12,517
6/77	174	1771	2586	–	2760	4531
7/77	1852	6071	11,647	1031	14,530	20,601
10/77	922	1342	3227	1397	5546	6888
4/78	–	1567	6557	1248	7805	9372
6/78	119	1731	2550	31	2700	4431
7/78	1635	6062	9538	3455	14,628	20,690
10/78	556	1137	2258	1146	3960	5097
4/79	–	1035	–	–	2992	4027
6/79	699	3922	5534	267	6500	10,422
3/80	–	2559	–	–	7823	10,382
6/80	225	875	1062	11	1298	2173
7/80	1467	5950	8982	1504	11,953	17,903
11/80	407	711	1354	715	2476	3187
3/81	–	414	735	669	1404	1818
6/81	–	256	–	–	2265	2521
6/81	258	885	1079	–	1337	2222
10/81	–	1129	–	–	3921	5050
4/82	–	1164	–	–	3988	5152
6/82	–	1250	–	–	1712	2692
6/82	151	1033	1368	–	1519	2552
10/82	–	1923	3189	1886	5075	6998
3/83	–	1648	–	–	5079	6727
6/83	–	215	–	–	746	961
4/84	–	503	–	–	1646	2149
4/85	–	600	–	–	2776	3376
6/85	–	1858	–	–	6207	8065
4/86	–	1227	–	–	5372	6599
6/86	–	871	–	–	4106	4977

APPENDIX B Continued

Date	Yearlings	Calves	Cows	Bulls	Total adults	Total
4/87	--	1858	--	--	6222	8080
4/88	--	1312	--	--	6047	7359
4/89	--	1718	--	--	5321	7039
4/90	--	1198	--	--	5231	6429
6/90	--	2650	--	--	4860	7510
4/91	--	1371	--	--	7111	8482
4/92	--	1678	--	--	7660	9338
6/92	--	4065	--	--	8505	12,570
10/10-12/92	--	1299	3498	1600	5098	5397
4/93	--	814	--	--	4396	5210
6/93	--	3848	--	--	12,866	16,714
10/15/93	--	859	2321	859	3180	4039
4/94	--	1587	--	--	8369	9956
6/94	--	4426	--	--	11,761	16,187
10/9-10/94	--	1118	2284	1354	4638	5756
4/95	--	2196	--	--	13,283	15,479
10/23-26/95	--	1057	2029	1176	3205	4262

APPENDIX C Raw data from 84 female caribou calves collected during 1992-1995

Access. number	Date of collection	Location	Whole weight (lb)	Gutted weight (lb)	Jaw length (cm)	Diast. length (cm)	Jaw % fat	Femur % fat	Back fat	Brisket fat	Mes. fat	Heart fat	Warbles (#)
104111	19920412	PAH FLATS	91	65	210	80	41	--	Y	Y	Y	Y	--
104112	19920412	PAH FLATS	101	75	216	83	51	--	Y	Y	Y	Y	--
104113	19920412	PAH FLATS	77	55	200	76	22	--	N	Y	Y	Y	--
104114	19920412	PAH FLATS	94	69	212	83	47	--	Y	Y	Y	Y	--
104115	19920412	PAH FLATS	95	64	213	82	47	--	Y	Y	Y	Y	--
104116	19920412	PAH FLATS	95	69	212	80	50	--	Y	Y	Y	Y	--
104117	19920412	PAH FLATS	94	71	215	82	58	--	Y	Y	Y	Y	--
104118	19920412	PAH FLATS	86	62	199	76	55	--	Y	Y	Y	Y	--
104119	19920412	PAH FLATS	90	66	215	82	22	--	N	Y	Y	Y	--
104120	19920412	PAH FLATS	83	57	197	73	27	--	N	Y	Y	Y	--
104068	19920427	HOLLY LAKES	75	54	204	77	--	--	N	Y	N	Y	M
104085	19920427	HOLLY LAKES	78	59	210	78	--	--	Y	Y	Y	Y	L
104086	19920427	HOLLY LAKES	92	64	217	80	--	--	N	Y	Y	Y	L
104069	19920428	HOLLY LAKES	82	59	202	78	--	--	N	Y	Y	Y	M
104083	19920527	AMBLER	84	55	203	78	--	--	N	Y	N	Y	H
104082	19920607	AMBLER	75	49	200	78	--	--	N	N	N	N	L
104092	19921020	BAMFORD	104	65	197	77	--	--	Y	Y	Y	Y	L
104093	19921020	BAMFORD	90	61	190	71	--	--	N	Y	Y	Y	L
104103	19921020	BAMFORD	118	78	206	82	--	--	Y	Y	Y	Y	N
104094	19921022	BAMFORD	94	65	199	77	--	--	N	Y	Y	Y	L
104095	19921022	BAMFORD	105	77	194	64	--	--	Y	Y	Y	Y	N
104098	19921022	BAMFORD	92	62	192	77	--	--	N	Y	Y	Y	L
104099	19921022	BAMFORD	99	66	198	77	--	--	Y	Y	Y	Y	L
104104	19921022	BAMFORD	76	49	183	69	--	--	N	Y	Y	Y	L
104100	19921023	BAMFORD	79	54	193	78	--	--	N	Y	Y	Y	L
104102	19921023	BAMFORD	74	52	189	72	--	--	N	Y	Y	Y	M
104091	19921024	BAMFORD	85	60	191	74	--	--	Y	Y	Y	Y	L
104105	19921111	GALENA	72	52	195	74	41	--	--	--	--	--	--
104106	19921111	GALENA	71	44	179	66	46	--	--	--	--	--	--
104085	19930112	ANAKTUVUK	105	75	200	75	--	--	Y	Y	Y	Y	--
104086	19930112	ANAKTUVUK	95	65	203	82	--	--	--	--	--	--	--
104121	19930310	INDIAN R. FLATS	79	52	204	74	46	40	Y	Y	Y	Y	L
104122	19930310	INDIAN R. FLATS	95	65	211	85	46	68	Y	Y	Y	Y	L
104169	19930402	INDIAN R. FLATS	78	57	201	77	14	7	N	Y	Y	Y	L (25)

APPENDIX C Continued

Access. number	Date of collection	Location	Whole weight (lb)	Gutted weight (lb)	Jaw length (cm)	Diast. length (cm)	Jaw % fat	Femur % fat	Back fat	Brisket fat	Mes. fat	Heart fat	Warbles (#)
104170	19930402	INDIAN R. FLATS	78	57	204	78	42	63	Y	Y	Y	Y	M (45)
104172	19930402	INDIAN R. FLATS	84	59	208	79	35	26	Y	Y	Y	Y	H (12) 5
104173	19930402	INDIAN R. FLATS	74	54	200	76	21	11	Y	Y	Y	Y	H (120)
104174	19930402	INDIAN R. FLATS	92	63	210	82	39	28	Y	Y	Y	Y	M (30)
104176	19930402	INDIAN R. FLATS	83	58	200	77	37	67	Y	Y	Y	Y	M (75)
104177	19930402	INDIAN R. FLATS	76	55	202	77	26	56	Y	Y	Y	Y	M (50)
104171	19930403	INDIAN R. FLATS	93	68	213	78	28	32	Y	Y	Y	Y	M (60)
104185	19930525	HUNT RIVER	91	64	220	83	--	--	N	Y	Y	Y	H
104188	19930526	HUNT RIVER	82	54	198	73	--	--	N	Y	N	Y	L
104192	19930528	HUNT RIVER	78	55	205	76	--	--	N	Y	N	Y	L
104180	19930529	HUNT RIVER	66	48	184	68	--	--	N	Y	N	Y	H
104293	19940504	HUNT R	87	62	204	77	14	18	N	Y	N	Y	M
104296	19940521	HUNT R	104	74	216	81	26	58	Y	Y	Y	Y	L
104297	19940521	HUNT R	97	70	213	78	46	74	N	Y	Y	Y	L
104298	19940521	HUNT R	89	62	205	75	10	34	N	Y	Y	Y	M
104299	19940521	HUNT R	106	69	218	88	14	52	N	Y	N	Y	--
104307	19940521	HUNT R	91	60	220	83	--	34	N	Y	N	Y	L
104306	19940523	HUNT R	84	61	200	78	12	30	N	Y	N	Y	L
104300	19940524	HUNT R	102	65	218	85	--	67	N	Y	N	Y	M
104301	19940524	HUNT R	77	53	197	75	9	46	N	Y	N	Y	M
104303	19940524	HUNT R	84	59	203	74	78	43	N	Y	N	Y	H
104302	19940525	HUNT R	83	60	205	76	29	47	N	Y	Y	Y	L
104304	19940525	HUNT R	78	54	197	75	--	30	N	Y	N	Y	M
104305	19940525	HUNT R	73	52	201	80	--	32	N	Y	Y	Y	M
104295	19940601	HUNT R	74	50	207	83	5	36	N	Y	N	Y	M
104294	19940604	HUNT R	96	65	204	79	30	31	Y	Y	Y	Y	M
104401	19940902	AMBLER	63	48	171	64	--	11	N	N	N	N	--
104397	19940904	AMBLER	67	44	177	70	1	6	N	N	N	N	--
104402	19940904	AMBLER	75	53	179	70	5	8	N	Y	N	N	--
104403	19940904	AMBLER	70	52	171	66	3	11	N	Y	N	Y	--
104406	19940904	AMBLER	81	56	177	69	33	31	N	Y	N	Y	--
104408	19940904	AMBLER	91	66	185	72	31	46	N	Y	N	Y	--
104399	19940905	AMBLER	69	54	174	67	21	20	N	Y	N	Y	--
104404	19940905	AMBLER	72	52	180	69	--	11	N	Y	N	Y	--
104405	19940905	AMBLER	80	56	182	74	--	11	N	Y	N	Y	--

APPENDIX C Continued

Access. number	Date of collection	Location	Whole weight (lb)	Gutted weight (lb)	Jaw length (cm)	Diast. length (cm)	Jaw % fat	Femur % fat	Back fat	Brisket fat	Mes. fat	Heart fat	Warbles (#)
104400	19940906	AMBLER	54	39	161	62	1	1	N	Y	N	N	--
104407	19940906	AMBLER	78	51	179	67	--	7	N	N	N	N	--
104398	19940907	AMBLER	52	32	169	64	3	14	N	Y	N	Y	--
104394	19940909	AMBLER	62	44	164	63	16	24	N	Y	N	Y	--
104395	19940909	AMBLER	75	55	182	73	16	38	N	Y	N	Y	--
104396	19940909	AMBLER	83	53	177	68	6	11	N	Y	Y	Y	--
104657	19950910	SELAWIK R	82	57	185	70	--	34	N	Y	Y	Y	--
104658	19950910	SELAWIK R	69	44	180	72	--	10	N	Y	Y	Y	--
104659	19950910	SELAWIK R	89	67	180	65	--	69	Y	Y	Y	Y	--
104660	19950910	SELAWIK R	82	55	189	76	--	59	N	Y	Y	Y	--
104661	19950910	SELAWIK R	85	55	190	73	--	30	N	Y	Y	Y	--
104662	19950910	SELAWIK R	82	55	191	74	--	15	N	Y	Y	Y	--
104663	19950910	SELAWIK R	89	58	193	76	--	74	Y	Y	Y	Y	--
104664	19950910	SELAWIK R	67	42	174	65	--	52	N	Y	Y	Y	--
104665	19950910	SELAWIK R	85	56	185	73	--	75	N	Y	Y	Y	--

APPENDIX D Western Arctic caribou late winter composition counts 1962-1995

Approximate survey date	Bulls: 100 C	Calves: 100 C	Calves %	Cows %	Total bulls %	Composition sample size
7/62[a]	–	22	18	82	–	3529
5/63	59	25	14	54	32	1177
4/77	34	46	26	56	19	12,517
4/78	19	24	17	70	13	9372
4/79	–	–	26	–	–	4027
3/80	–	–	25	–	–	10,382
3/81	91	56	23	40	37	1818
4/82	–	–	23	–	–	5152
3/83	–	–	24	–	–	6727
4/84	–	–	23	–	–	2149
4/85	–	–	18	–	–	3376
4/86	–	–	19	–	–	6599
4/87	–	–	23	–	–	8080
4/88	–	–	18	–	–	7359
4/89	–	–	24	–	–	7039
4/90	–	–	19	–	–	6429
4/91	–	–	16	–	–	8482
4/92	–	–	18	–	–	9338
4/93	–	–	16	–	–	5210
4/94	–	–	16	–	–	9956
4/95	–	–	14	–	–	15,479

[a] In this count "calves" actually refers to caribou 11-months old.

Alaska's Game Management Units