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Reducing Mortality on the Fortymile Caribou Herd

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This is a progress report on continuing research. Information may be refined at a later date.

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SUMMARY

This is the second of 5 research reports to be written on reducing mortality of the Fortymile caribou (*Rangifer tarandus granti*) herd. This report also summarizes work completed during the prior 5 years on factors limiting the Fortymile Herd. The research proposal for reducing mortality on the Fortymile Herd was inspired by a diverse, international Fortymile Planning Team through their 21-page Fortymile Caribou Herd Management Plan (Boertje and Gardner 1996:Appendix A; http://aurora.ak.blm.gov/fmcaribou/). The Board of Game endorsed the Team's novel management plan in October 1995, and 10 independent scientists reviewed the draft research proposal for this project in winter 1995–1996.

The primary goal of the Team's plan is to begin restoring the Fortymile Herd to its former range; 77% of this former range was abandoned as herd size declined. Specific objectives call for increasing the herd at least 5–10% annually for the 5 years following winter 1996–1997, the first winter of reduced wolf (*Canis lupus*) predation. Currently, the herd's performance has exceeded our expectations. The herd has averaged 14% annual growth during the first 2 years of this study. We counted 25,910 caribou in late June 1997 and 33,110 during early July 1999.

Since 1994, intensive monitoring of radio collars on newborn and older caribou allowed investigations of caribou productivity and mortality. These data enabled us to complete 5 annual models illustrating how predation and other demographic factors affected herd size from mid May 1994 through early May 1999.

We identified wolf predation as a major limiting factor in all 5 annual models. Reducing wolf predation was deemed by the Team to be the most manageable way to help hasten or stimulate herd growth. The Team envisioned 2 strategies for reducing wolf predation: first, state-sponsored wolf translocations and fertility control in 15 key packs and, second, shifting

private wolf trappers to specific areas. The number of wolf packs preying on Fortymile caribou ranged from 26 to 37 in recent years, but most of the wolf predation occurred within the range of 15 packs. To help estimate wolf numbers in the herd's range, we have regularly radiotracked wolves in 16–23 packs since 1992.

Management actions began in autumn 1996 with a reduction in the harvest from ≤2% of the herd to <1% of the herd (150 bulls) for 5 years. This action was taken to increase the social acceptance of the plan. A privately sponsored incentive program for trappers during 2 winters helped significantly increase the wolf harvest rate above recent levels in winter 1995–1996 but not in winter 1996–1997. In spring 1997 the Board of Game approved a detailed agency plan for reducing wolf predation. We began actions to reduce wolf predation on Fortymile caribou in late November 1997. We treated 7 packs during each of the first 2 winters, 1997–1998 and 1998–1999. Wolves numbered 116 in these 14 packs before treatment and 25 after the first 2 winters of treatment; this constitutes a 78% reduction. Sterilized wolves (n = 27) suffered no mortality from surgery, failed to give birth, and at least 1 wolf in each pair retained its original territory through 1999. Untreated adjacent packs continued to raise litters as expected.

The following points will assist with continuing efforts to evaluate management objectives proposed by the Fortymile Planning Team:

1 Herd numbers remained relatively stable during spring 1990–1995 (about 22,000 to 23,000 caribou) before and during formulation of the Fortymile Caribou Herd Management Plan. Relatively stable herd size resulted from high adult mortality during 1989–1992 (17–40%), unusually poor pregnancy rate in 1993 (68%), and low to moderate calf:100 cow ratios in autumn 1989–1994 (16–30). Reduced nutritional status during this period was indicated by the low 1993 pregnancy rate, low newborn weights in 1994 (only 1994 and 1995 data available), and delayed calving in 1992 and 1993 (only 1992–1995 data available).

In contrast, we counted 4% more caribou in 1996, 10% in 1997, 20% in 1998, and ≥7% in 1999. Our latest count of the herd on 2 July 1999 totaled 33,110, and we suspect this count underestimated herd size. Annual increases in the herd since 1995 resulted from several factors, including elevated pregnancy rates in 1996 and 1998, improved adult survival rates compared to those of the early 1990s, and improved calf survival rates, particularly in 1997–1998 and 1998–1999. Improved nutritional status during this period was indicated by elevated pregnancy rates in 1996 and 1998, improved newborn weights compared with 1994, elevated 1997 autumn calf weights, and earlier calving compared with 1992 and 1993. We conclude that both optimal environmental conditions and reduced predation contributed to the herd's increase. The Team deemed it opportune to initiate and continue management actions during a period of optimal weather and natural increase.

2 Wolf and grizzly bear (*Ursus arctos*) predation have been the major sources of mortality, despite over a decade of the most liberal regulations in the state for harvesting wolves and grizzly bears. Wolves continue to be the most important predator. Wolves killed between 2000 and 3000 caribou calves annually from May

1994 to May 1998 and between 1000 and 2300 older caribou. No significant differences in annual wolf predation rates on radiocollared calves or adults were observed between May 1994 and May 1998, but annual wolf predation on radiocollared calves declined beginning in the 1998 cohort following our initial treatment of 7 packs in winter 1997–1998.

We have ceased plans to translocate grizzly bears during this study. The Fortymile Management Plan proposed translocating grizzly bears from the calving grounds during May 2001 *if* increased May grizzly predation compensated for expected decreased May wolf predation. However, May grizzly predation did not increase in 1997 or 1998, when May wolf predation declined compared to wolf predation in 1994–1996.

3 To increase social acceptance of the management plan, the Fortymile Team chose to reduce the annual caribou harvest to 150 bulls for 5 years beginning in 1996. We illustrated the minor role that harvest has played in herd dynamics in recent years. Harvests have been intentionally held low since 1973 to encourage herd growth (Valkenburg et al. 1994). Reducing harvests from 200–500 bulls (≤2% of the herd, 1990–1995) to 150 bulls (<1% bulls, 1996–2000) will not result in the ≥5–10% annual rates of herd increase desired by the Fortymile Team. Bull:cow ratios in the Fortymile Herd ($\bar{x}$ = 43 bulls:100 cows, range = 36–50, 1985–1997) are not reduced by harvest compared to ratios from the only Interior Alaska herd with no harvest in recent decades ($\bar{x}$ = 43 bulls:100 cows, range = 29–56 in the Denali Herd, 1985–1997).

4 We found consistent evidence for moderate to high nutritional status in the Fortymile Herd since 1994 when indices were compared with other Alaskan herds of similar or higher density. Antibody screening of blood samples (n = 159) analyzed since 1980 indicate there are no significant infectious diseases affecting the population dynamics of the Fortymile Herd.

5 Winter range can support elevated caribou numbers both in regard to lichen availability on currently used winter range and the availability of vast expanses of winter range formerly used by the herd. The herd currently uses <30% of its historic range, and winter fecal analyses indicate the herd consumes a high proportion of lichens compared to several other herds (80% lichen fragments in winter feces). Lichens are often the first forage to show signs of overgrazing because lichens grow slowly and are highly desired by caribou.

6 Despite private efforts that significantly increased wolf harvest during winter 1995–1996, autumn wolf densities on the respective annual ranges of the Fortymile Herd remained at densities (6–8 wolves/1000 km^2) often observed in Alaska–Yukon study areas with similar low prey densities and low wolf harvest rates. Only strong reductions in autumn wolf densities (≥69% reduction of precontrol wolf numbers for several years) have been followed by rapid increases in caribou numbers (Boertje et al. 1996). In contrast, the Team chose to selectively reduce 15 packs on the herd's range, <50% of the packs that usually feed on Fortymile caribou during a year. If private

harvests remain low, we expect autumn wolf densities to remain at about 5–8 wolves/1000km^2 on the respective annual ranges of the Fortymile Herd during this project.

We plan to continue studies of Fortymile calf mortality during 2000–2003 by deploying radio collars on newborns. These studies will allow us to evaluate whether treating wolves can continue to influence wolf predation on calves. We expect to reduce up to 15 packs to sterile pairs by April 2000 and to maintain these packs as pairs through April 2001. Treatment may have influences into 2002 if sterilized wolves continue to dominate territories. We will test whether wolf predation on calves is significantly reduced compared to the 3 pretreatment years (May 1994 through May 1997) when wolves killed 25–30% of radiocollared calves. In contrast, wolves killed only 14% of the radiocollared calves in the 1998 cohort following the treatment of 7 wolf packs in winter 1997–1998. Data from the 1999 calf cohort are incomplete, but deep snowfall in early winter 1999–2000 and caribou movements outside the treatment area apparently led to increased wolf predation.

Key words: Alaska, caribou, condition, fertility control, Fortymile caribou herd, management objectives, mortality, nutrition, predation, pregnancy rate, translocation, sterilization, wolf.

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BACKGROUND

The Fortymile caribou herd has the potential to be the most economically important wildlife population in Interior Alaska and the southern Yukon, both for consumptive and nonconsumptive uses. Potential for growth is indicated by Murie's (1935) extrapolated estimate of 568,000 caribou during a 20-day herd migration across the Steese Highway in 1920, compared to an aerial photocensus of 33,110 caribou on 2 July 1999. The herd's low point was in summer 1973 with about 7000 caribou (Valkenburg et al. 1994).

Caribou herds typically restrict range use as herd size declines. For example, the Fortymile Herd has not migrated across the Steese Highway since 1963 and rarely enters the Yukon because of its reduced size. The herd's historical range encompassed 220,000 km^2 (Murie 1935) compared with 50,000 km^2 total for all years since 1968 (Valkenburg et al. 1994; Fig 1) and 23,000–35,000 km^2 annually in recent years. Today, the historical range of the herd is largely devoid of caribou.

Population objectives for increasing the Fortymile caribou herd have wide public support in Alaska and the Yukon for consumptive and nonconsumptive reasons. This public support has developed because most of the herd's former range was abandoned as herd size declined and because current low numbers are, in part, a result of past management decisions.

We have learned much from past management of the Fortymile Herd. Valkenburg et al. (1994) detailed a case history of the herd from 1920 to 1990. The decline in the herd from >50,000 in 1960 to only 7000 in summer 1973 was partly a result of errors in the prevailing management beliefs. Overharvest was allowed in the early 1970s, and, simultaneously, high numbers of wolves and unfavorable weather contributed to the herd's decline to critically low levels (Davis et al. 1978; Valkenburg and Davis 1989; Valkenburg et al. 1994). Had this overharvest been prevented, the herd probably would have declined to only 10,000–20,000 caribou during the early 1970s and may have increased to 30,000–50,000 during favorable conditions in the 1980s.

Overharvest was allowed in the early 1970s in part because of the belief that poor range condition was the major factor causing low yearling recruitment. Thus, biologists allowed high harvests and largely ignored wolf predation while awaiting a compensatory rebound in yearling recruitment from improved range. However, it was a futile vigil; calf caribou became increasingly scarce through 1973. It was mistakenly believed hunters and predators usually killed animals that were about to die anyway (before successfully reproducing). It was also mistakenly believed that wolf and grizzly bear predation were minor influences on the herd. Also, the size of the Fortymile Herd was grossly overestimated during the decline to 7000 caribou, and the trend in herd size was inadequately monitored (Davis et al. 1978; Valkenburg and Davis 1989).

Today harvest programs for caribou are managed much more conservatively than in the early 1970s. During natural declines of caribou to low levels, harvests are eliminated or restricted to small percentages of bulls and carefully monitored using permit systems. Since 1973, substantial reductions in the human harvest of Fortymile caribou have made harvest an insignificant factor affecting herd growth compared to predation by wolves and bears (Valkenburg et al. 1994; Appendices A through E). Since 1984 radiocollaring of Fortymile caribou has given biologists the ability to efficiently estimate herd distribution to predict hunter success, particularly along roads. Other benefits from radiocollaring include efficient estimates of herd size, proportions of calves and bulls, mortality rates, causes of mortality, and relative nutritional status (Valkenburg and Davis 1989; Valkenburg et al. 1994; Valkenburg et al. 1999).

Today managers know adverse weather can initiate declines in caribou herds (Valkenburg et al. 1994; Adams et al. 1995*a*; Boertje et al. 1996). Adverse weather in Interior Alaska in the early 1990s and the simultaneous decline of several Interior caribou herds were, in part, the stimuli for this renewed study of the Fortymile Herd. During periods of adverse weather, herd condition can decline and predation can increase (Mech et al. 1995; Boertje et al. 1996). After weather improves, prolonged declines in caribou herds can occur from continued high wolf predation probably because of wolves switching to caribou as primary prey and because declines in wolf numbers are not tied strictly to caribou numbers and can lag behind declines in total caribou numbers (predator lag). We know of examples in which the proportion of a herd killed by wolves increased during adverse weather because caribou were more vulnerable and because wolf numbers increased as caribou declined (Adams et al. 1995*a*; Mech et al. 1995; Boertje et al. 1996).

Today it is a well-accepted belief that wolf and bear predation are often the major factors limiting caribou and moose (*Alces alces*) at low densities (Davis et al. 1978, 1983; Gasaway et al. 1983, 1992; Boertje et al. 1987, 1988; Larsen et al. 1989; Valkenburg and Davis 1989; Adams et al. 1995*b*; Boertje et al. 1996). Several studies summarized historical and recent predator-prey relationships in the Fortymile areas and documented the fact that predation was a major factor limiting recovery of caribou and moose populations (Davis et al. 1978; Boertje et al. 1987, 1988; Valkenburg and Davis 1989; Gasaway et al. 1992).

From 1981 through 1987, management actions were implemented to reduce grizzly bear and wolf predation in a portion of the Fortymile Herd's range (Valkenburg and Davis 1989; Gasaway et al. 1992). Control of wolf numbers by department personnel was terminated before desired reductions were achieved, and grizzly bear numbers were only moderately reduced in a small portion of the range. The subsequent 7–10% annual increases in caribou numbers could not be definitively linked to predator control because pretreatment studies were lacking and only small reductions in predator abundance occurred in the annual range of the Fortymile Herd (Valkenburg et al. 1994). Increased harvests of wolves and grizzly bears in the 1980s were insufficient to allow for herd growth during 1990–1995, presumably because of adverse weather and insufficient reduction of predators.

To definitively test the effectiveness of predator control, large reductions in predator abundance are necessary for several years (Crete and Jolicoeur 1987; Larsen and Ward 1995; Boertje et al. 1996; Farnell and Hayes, unpublished data). Large reductions in wolf numbers for several years resulted in dramatic increases in caribou numbers in central Alaska (16% per year; Gasaway et al. 1983; Boertje et al. 1996) and eastcentral Yukon (18% per year; Farnell and MacDonald 1988; Larsen and Ward 1995; Farnell and Hayes, unpublished data). In both studies, late winter wolf numbers were 69–85% lower than precontrol autumn wolf numbers during the 4–6 winters of effective control efforts. These are the only well-documented studies in which large reductions of wolves were maintained for more than 2 winters and wolves were subsequently allowed to recover.

MANAGEMENT PLANNING, OBJECTIVES, RATIONALE, AND PRESENTATIONS

International draft management objectives from the mid-1980s through 1995 called for increasing the herd to 50,000 adults or 60,000 caribou by the year 2000. These management objectives were written when the herd was growing at 7–10% per year and when population objectives were expected to be reached without further management actions. Instead, herd numbers were nearly stable between 1990 and 1995 at about 22,500 caribou.

Conflicting interagency management objectives by 1994 stimulated an interagency and international meeting focusing on Fortymile Herd management in Tok on 9 February 1994. Following this meeting, a diverse Fortymile Planning Team was created to write a new Fortymile Caribou Herd Management Plan (Boertje and Gardner 1996:56–77). This novel plan was completed and endorsed by the Board of Game in October 1995. The Team met 8 times between autumn 1994 and autumn 1995 to develop the plan and continues to meet to address issues of importance. Ten public meetings were held in various places to gather public opinion on the plan. The Board of Game approved a detailed implementation plan for the Fortymile Caribou Herd Management Plan in spring 1997, and we began implementation (wolf fertility control and translocations) in November 1997. We drafted the current 5-year research plan in 1995 for the years 1997–2002 (Boertje and Gardner 1996:Appendix A:28–56). This research plan was edited in winter 1995–1996 by 10 independent, international scientists. All were familiar with wolf biology and/or predator-prey relationships.

The Team described reasons for developing a recovery plan for the Fortymile Herd as follows (Boertje and Gardner 1996:Appendix A:31, 33):

- For the long-term benefit of the Fortymile ecosystem and, specifically, the biodiversity of this ecosystem.
- Help recover the Fortymile caribou herd to its traditional range and to benefit the people who value the herd and its ecosystem.
- Promote viewing opportunities of the Fortymile Herd during its spring and fall migrations, particularly along the Steese, Taylor, Top of the World, and Klondike highways where people once witnessed thousands of migrating caribou.
- Promote similar goals among the agencies involved in management of the Fortymile caribou herd.
- Resolve conflicts among interest groups.
- Encourage sound wildlife management decisions that consider diverse values.

The primary goal of the new Fortymile Caribou Herd Management Plan is to restore the Fortymile Herd to its former range, which entails initiating management actions to increase herd size. Specific objectives include increasing caribou numbers by at least 5–10% per year through the year 2002 using primarily nonlethal techniques to control wolf predation. The Wolf Conservation Management Policy for Alaska (see 5 AAC 92.110) directs the Alaska Department of Fish and Game to investigate nonlethal means of reducing predation.

In the following paragraphs, we describe the various management actions proposed by the Fortymile Team and the rationale.

- The nonlethal program recommended by the Team includes translocating (i.e., moving) wolves other than dominant pairs and controlling fertility among dominant pairs in up to 15 key packs during 4 winters (1997–1998, 1998–1999, 1999–2000, and 2000–2001). We will initially treat up to 7 new packs per winter. A site-based approach will be taken with the highest priority going to packs that are expected to be near young caribou, but wolves will have to be treated in the winter because of logistical problems in handling wolves without fresh snow. A further complication is that calving distribution changes annually in the Fortymile Herd. Also, we will treat only a portion of the packs that prey on caribou calves. For instance, 26–37 wolf packs fed on Fortymile caribou during recent years and at least 3 important packs live primarily in the Yukon-Charley Rivers National Preserve.

Mech et al. (1995) suggested fertility control in wolves may be preferable to lethal agency control for several reasons. Ethical and political objections to lethal wolf control by government agencies are significant (Boertje et al. 1995*b*; Mech 1995; Stephenson et al. 1995). With winter wolf harvest rates of <60%, a wolf territory is often filled in spring by a pregnant female with high spring and summer food requirements (Hayes 1995). In contrast, the absence of a litter of pups can reduce a pair's need for food by 40–60% in summer (Mech 1970, 1977). Also, vasectomizing males in 4 wolf packs in Minnesota and 1 in the Yukon resulted in stable or decreased pack size and retention of territories (n = 18 pack-years of data; Mech et al. 1996; RD Hayes, personal communication).

- Harvest quotas for caribou will be reduced from 450 bulls in 1995 to 150 bulls during autumn 1996–2000. Biological ramifications of this action are predicted to be small, but representatives of hunting groups on the Team sanctioned reduced caribou harvest to increase the social acceptance of the plan. Social acceptance of the management plan is vital to its implementation.

- The Team stated in the plan that local trappers could assist by shifting their efforts to wolves whose territories include the summer range of the Fortymile Herd, where few wolves were being trapped.

Herd response to these management actions will depend largely on changes in wolf and bear predation, weather, and caribou distribution and productivity. Thus, response to the proposed management actions could vary considerably among years.

For several reasons, the Team chose multiple, simultaneous actions to increase Fortymile herd size. First, the Team desired a consistent moderate to high annual growth rate (≥5–10%); this growth rate will be required to convince a broad scientific audience that proposed actions were indeed effective. For example, biologists have occasionally observed natural annual growth rates of 7% in the Fortymile Herd (Valkenburg et al. 1994) and the Denali Herd (Adams et al. 1995*a*), so a higher rate will be needed for several years to convince a broad scientific audience that a particular treatment was indeed effective. Second, based on previous research and modeling (Boertje et al. 1995*a,b*), the chances of significantly increasing herd size are small if only single nonlethal actions are used to reduce predation. Third, in the case of the Fortymile Herd, single actions are unlikely to be effective because no nonlethal treatment will occur on the central portion of the summer range, the Yukon-Charley Rivers National Preserve, or on much of the surrounding winter range. Relating cause and effect is a difficult proposition in natural systems and requires gathering support for a particular hypothesis over many years and study areas. No simple procedure exists for "proving" the proposed actions will reliably and significantly increase caribou numbers.

After the summer 2002 photocensus of the herd, results will be evaluated to determine public acceptance and the costs and effectiveness of the management actions. We presented our findings to date in 7 editions of *The Comeback Trail*, a newsletter written to inform the public and agencies of Fortymile Herd planning, management, and research. This newsletter is published by the Alaska Department of Fish and Game and mailed to 4000 interested parties to solicit their opinions. We also assisted Northern Native Broadcasting of Whitehorse in the production of a 52-minute documentary video on Fortymile Herd history, planning, and biology. This video was released in January 1998.

GOAL

Our goal is to evaluate effects of the above proposed management actions on both caribou and wolves, and, secondarily, to evaluate these actions' effects on moose and Dall sheep (*Ovis dalli*).

JOB OBJECTIVES

Literature Review

We will continue a literature review of wolf translocations; canid fertility control; responses of caribou and moose to reduced predation; ecology and interactions of these predators and prey; nonlethal techniques for reducing predation; and effects of harvest on wolves, bears, and caribou.

Caribou

As wolf numbers are reduced, we will continue to study Fortymile caribou herd production and causes and rates of mortality to evaluate annually the effects of wolf-caused mortality on herd trend. Data will be compared with data from pretreatment years (1994–1996).

Wolves

Wolf fertility control and translocations are scheduled for 4 consecutive winters (1997–1998, 1998–1999, 1999–2000, and 2000–2001) and will involve sterilizing adult pairs and translocating the remaining wolves in up to 15 packs.

We will monitor distribution and numbers of wolves in treated and several adjacent untreated packs during the course of this study using radiotelemetry. Our hypothesis is that sterilization will not reduce the chance of maintaining a territory or increase the probability of dispersal, as previously observed in smaller study samples by Mech et al. (1996) in Minnesota and RD Hayes (personal communication) in the Yukon. To ensure that sterilization does not interfere with gonadal cycling, males will be vasectomized using surgical techniques (Pineda and Hepler 1981). A qualified veterinary surgeon will conduct surgical sterilization; females will undergo tubal ligation.

We will monitor survival rates and homing abilities of translocated wolves to determine if young, translocated wolves regularly succumb near release sites, return to or attempt to return to capture sites, or disperse widely from release sites (Fritts et al. 1985). Fritts et al. (1985) concluded that survival of translocated wolves was comparable to that of other wolves and that pup wolves remained at release sites longer and had poorly developed homing abilities compared to adults. We will test these hypotheses using similar techniques. Wolf translocation/moving procedures will follow those of Fritts et al. (1984) in Minnesota with the following exceptions: 1) most wolves will be moved from October through June, but no wolves <5 months old will be moved, and 2) all wolves will be moved at least 100 miles (160 km) because of homing tendencies. Release sites will have prey densities greater than or equal to prey densities in the Fortymile range.

We will estimate wolf harvest rates in the respective annual ranges of the Fortymile caribou herd to monitor effects of harvests, translocations, and sterilizations on wolf numbers.

Grizzly Bears

Objectives for grizzly bears have been deleted from this study because conditions for their study, as described in the research proposal, have not been met. The Fortymile Team proposed translocating grizzly bears from the caribou calving grounds during May 2001 *if* grizzly bears increased their predation rates on May calves in response to expected decreased wolf predation on May calves. However, May grizzly bear predation did not increase to ≥15% in 1998 following decreased May wolf predation. Also, May grizzly bear predation did not increase in 1997 following significantly reduced May wolf predation relative to 1994–1996.

Moose

We will document whether a significant increase in moose density occurs in the treatment area between October 1998 and October 2002 compared to adjacent untreated areas.

In keeping with the Team’s goal of benefiting the biodiversity of the Fortymile ecosystem, we will survey moose before and after treatment to evaluate effects of the treatment on moose. Our 10-year objective will be to document whether moose increase to above the low-density dynamic equilibrium (40–400 moose/1000 km^2) described for this wolf-bear-moose-caribou-human system when predators are lightly harvested (Gasaway et al. 1992).

Dall Sheep

We will document whether significant increases in sheep numbers occur in the treatment area between 1997 and 2002 compared with nearby untreated areas.

We will survey sheep before (1997) and after (2002) treatment to document whether sheep increase during the period of wolf reductions in the treatment area. Data in the treatment area will be compared with data collected in adjacent untreated populations within the Yukon-Charley Rivers National Preserve. We will test the hypothesis that significant increases in sheep will occur if wolf numbers are reduced.

Public Involvement and Awareness

We will write progress reports, publish a final report, and incorporate results in future plans. The final report for the previous 5-year study was presented at the Eighth North American Caribou Workshop in Whitehorse in April 1998 and will be published as part of these proceedings. We will continue to publish *The Comeback Trail* newsletter, which both solicits and presents information on the Fortymile Herd. We will continue to present findings at pertinent public meetings. Additional guidelines are presented on page 39 of the Fortymile Caribou Herd Management Plan (Boertje and Gardner 1996).

PROCEDURES

CARIBOU CAPTURE

We have radiocollared 50 adults and 144 autumn calves since September 1990. Each autumn we collared 14 or 15 calves. Adults were collared in 1991, 1992, 1996, 1997, and 1998 to provide a sample of productive, older caribou. Blood samples and body measurements were routinely collected. Radio collars usually transmitted for 6 or 7 years (Telonics, Mesa, Arizona, USA and Advanced Telemetry Systems, Isanti, Minnesota, USA).

To immobilize adult caribou, we used 3 mg carfentanil citrate (3 mg/ml, Wildnil®, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA) and 100 mg xylazine hydrochloride (100 mg/ml, Anased®, Lloyd Laboratories, Shenandoah, Iowa, USA) administered in a 2-cc dart with a 1.9-cm barbed needle using a short-range Cap-Chur pistol fired from a Robinson R-22 helicopter. To reverse the immobilization, we injected 275 mg naltrexone hydrochloride (50 mg/ml, Trexonil®, Wildlife Pharmaceuticals) and 27.5 mg yohimbine hydrochloride (5 mg/ml, Antagonil®, Wildlife Pharmaceuticals) intramuscularly. We immobilized autumn calves with 1 mg carfentanil citrate and 67 mg xylazine hydrochloride reversed with 125 mg naltrexone hydrochloride and 12.5 mg yohimbine hydrochloride intramuscularly.

We radiocollared 50 newborn calves in May 1994, 52 in May 1995, 60 in May 1996, 55 in May 1997, 72 in May 1998, and 78 in May 1999. We used a 2-person, Robinson R–22 helicopter. Usually a person was dropped off to capture the calf by hand, but occasionally the helicopter was used to slowly herd the cow and calf toward the hidden person. Most calves selected for collaring had a collared dam, and we distributed the remaining collars both geographically and temporally to mimic the calving of collared dams. Handling took <1.5 minutes/calf. Expandable, breakaway radio collars transmitted for about 17 months.

ESTIMATING HERD NUMBERS AND GROWTH RATE FROM PHOTOCENSUSES

We estimated minimum numbers of Fortymile caribou between 14 June and 2 July 1990, 1992, and 1994 through 1999 using radio-search, total search, and aerial photo techniques (Valkenburg et al. 1985), as in previous estimates of herd size during the 1970s and 1980s (Valkenburg and Davis 1989). The entire summer range was divided among observers in 4 or 5 light aircraft during a 1-day census. These aircraft and a separate radiotracking plane communicated locations of caribou groups to the pilot of a DeHavilland Beaver aircraft equipped with a 9” × 9” format camera. This camera was usually used to photograph all groups numbering over 100 caribou; 6–35 groups were photographed during a census. Smaller groups (<100 caribou) were often visually counted. The number of caribou visually counted from the spotter planes totaled about 500 caribou annually, except in 1999 when caribou groups were well aggregated yet scattered over a wide area. In 1999 crew in spotter planes observed and photographed about 5500 caribou. Photographed caribou were counted using 10X magnification under bright lights. Counts probably include a high proportion of the calves, but we are certain some calves were missed because of their small size and because of varying photo quality. We suspect that a fairly consistent proportion of the calves are counted among years, but counters cannot consistently separate calves from adults in the photos, so we have no way of testing this hypothesis.

To date we have used photocensus data to calculate growth rates of the herd (Boertje et al. 1996). We also used data on herd composition, pregnancy, and mortality to model population trends because photocensuses have, on occasion, substantially underestimated caribou numbers in the Delta Herd (Boertje et al. 1996).

EXPLAINING CAUSES FOR HERD FLUCTUATIONS AND ESTIMATING TREND FROM DATA ON HERD COMPOSITION, PREGNANCY, AND MORTALITY

We developed simple conceptual models to assess how productivity and various mortality factors affected herd size among years. Data on herd composition and total numbers allowed us to calculate the number of potentially productive cows in the herd, i.e., cows ≥36 months old (Appendices A through F). We then calculated the number of calves born (pregnancy rate × number of cows ≥36 months old). Finally, using proportions of mortalities among collared samples, we calculated the number of calves and adults dying from various causes. This allowed us to calculate net recruitment (number of calves surviving 12 months minus the number of adults dying during those 12 months).

To estimate herd composition, we classified caribou from a helicopter during late September or early October 1991–1999 using the distribution of radiocollared caribou to randomly select caribou for counting. Cows, calves, and small, medium, and large bulls were counted during the 1-day survey each year. Caribou bulls and cows are more randomly mixed during this period than during the remainder of the year. The helicopter crew relied on a Bellanca Scout pilot to relay locations of radiocollared caribou. After each count, we verified that the proportion of caribou counted in an area closely matched the proportion of radio collars in that area, and we corrected biases in the counts using ratios when necessary.

We estimated pregnancy rates of the herd during mid to late May by documenting the presence or absence of a calf, hard antlers, and/or a distended udder among radiocollared female caribou ≥24 months old (Whitten 1995). Pregnancy was easy to confirm using these techniques. To confirm nonpregnancy, we repeated observations at least twice during 11–31 May 1984–1999.

We estimated mortality rates among different age classes from October 1992 to October 1999 by radiolocating all collared caribou 1 or 2 times monthly. In addition, from 1994 through 1999, we flew daily between 11 May and 31 May, 10–13 times in June, and weekly during July through September. Radio collars contained a mortality sensor that doubled the pulse rate if the collar remained motionless for 1 or 2 hours (newborn calf collars) or 6–10 hours (other collars). Annual mortality rate (M) was calculated as $M = A/B \times 100$, where A = the number of caribou dying during the 12-month period and B = the total number of collared caribou at the beginning of the 12-month period. We used the chi-square test of proportions to test for statistical differences among proportions (Conover 1980:144–151).

Evaluating Causes of Natural Caribou Mortality

When mortality was detected during daily May flights, we investigated the site via helicopter, usually within 4 hours of detection. After May, we investigated mortality sites as soon as possible, usually within 1 day of detection. We necropsied carcass remains either on site or in the laboratory and noted wounding patterns. Hemorrhaging associated with puncture wounds, blood (noncoagulated) on collars, or blood on remnants of hide served as evidence of a violent death. In these cases scats, tracks, wounding patterns, other signs, and season of kill (bears hibernating in winter) served to identify the predator involved (Ballard et al. 1979; Adams et al. 1989). Bears often scraped up portions of the tundra mat and buried portions of the carcass or left crushed, cleaned bones in a small area with the collar. Wolves often left the carcass intact, cached whole or half carcasses in snow or muskeg without obvious digging, or carried the bloody collar some distance from the kill site of scattered crushed bones, hair, and pieces of hide. Golden eagles (*Aquila chrysaetos*) always left long bones intact, muscle and sinew were threaded, and talon wounds were evident when significant muscle tissue remained on the sides of the calf. A collar soaked in blood indicated lynx (*Lynx canadensis*) predation, based on evidence of lynx predation in the snow at several sites.

Estimating Caribou Harvest

Procedures for estimating total and female caribou harvest varied, depending on the type of harvest reporting system. We considered harvest reports collected from permit hunts accurate estimates of total harvest because 97–99% of permittees responded. In addition, we added estimates of illegal harvest from road and trail surveys each year. All harvest since 1993 and most harvest during 1990–1992 was conducted under permit hunts. During general season hunts, harvest was reported by mandatory mail-in report cards without the benefit of reminder letters. Correction factors for general season hunts were derived from road surveys and surveys of transporter services during 1973. To avoid biased reporting, hunters were not told the purpose of these surveys. The surveys and subsequent mail-in harvest reports were treated as a mark–recapture sample to estimate total harvest. Harvest numbers from general season hunts were multiplied by 1.59.

EVALUATING HERD NUTRITIONAL STATUS

We used 4 indices to evaluate relative condition/nutritional status of the herd. First, we estimated pregnancy rates and age of first reproduction during the 1992 through 1999 calving seasons, using a radiocollared sample of cows as described above. Sample sizes varied annually from 39–68 cows ≥36 months old and 5–13 cows 24 months old. Second, we annually weighed 14–17 female autumn calves and 44–76 newborn calves using a calibrated spring or electronic scale. Third, we estimated the median calving date during 1992–1999, which is the date by which 50% of the pregnant radiocollared cows had given birth.

Last, we estimated the percent mortality of calves during their first 2 days of life. High calf mortality (e.g., 15–25%) during the first 2 days of life has been linked to malnutrition, and we evaluated this factor as an index to herd nutritional status (Whitten et al. 1992). To detect calf mortality during the first 2 days of life, we observed a sample of 32–56 radiocollared, pregnant cows on consecutive days during calving seasons 1992 through 1999. These cows were observed each day until they gave birth and on the first 2 consecutive days after birth. During 1994–1999, we determined the cause of mortality among calves to test the hypothesis that early mortality was attributable to malnutrition.

EVALUATING THE LICHEN COMPONENT OF THE HERD'S WINTER DIET TO ASSESS RANGE CONDITION

We collected 24 fecal samples from the Fortymile Herd winter ranges during January through April 1992–1996. Each sample contained 25 pellets; 1 pellet was collected from each of 25 different piles found afield (Boertje et al. 1985). Samples were analyzed at the Composition Analysis Laboratory in Fort Collins, Colorado.

WOLF CAPTURE AND TREATMENT

We captured 28 wolves in winter 1991–1992, 8 during winter 1992–1993, 26 during 1996–1997, 72 during 1997–1998, and 78 during 1998–1999. Usually 2 wolves were collared per pack. Before November 1997, captured wolves were radiocollared and released to help us evaluate wolf movements and numbers. We routinely collected blood samples and body measurements. Radio collars transmitted for 2–4 years (Telonics).

To immobilize wolves, we used 620–660 mg Telazol® (tiletamine HCl and zolazepam HCl, Fort Dodge Lab, Fort Dodge , Iowa, USA) and 0–0.4 cc propylene glycol administered in a 3-cc dart with a 1.9-cm barbed needle using a long-range Cap-Chur rifle fired from a Robinson R-22 helicopter. Darts were kept heated before deployment.

ESTIMATING WOLF HARVEST RATES IN THE HERD'S ANNUAL RANGES

To estimate wolf harvest rates within the respective annual ranges of the Fortymile caribou herd for the years 1992–1993 through 1998–1999, we delineated annual ranges of the herd based on monthly telemetry flights beginning 1 October. We then digitized the size of the annual ranges used by the herd and estimated wolf numbers and harvest in the respective annual caribou ranges. We estimated wolf numbers using radio collars, standard aerial track counts, and information from local trappers and pilots (Boertje et al. 1996). Mandatory reporting forms provided information on wolf harvest locations. Regulations allowed wolf hunting from 10 August–30 April and wolf trapping from 15 October–30 April on most of the herd's annual ranges.

RESULTS AND DISCUSSION

HERD NUMBERS AND TREND

The first systematic estimate of herd numbers occurred in 1920 when several observers counted portions of the Fortymile caribou herd crossing the Steese Highway on a 20-day autumn migration that was 60 miles wide. Murie's (1935:6) extrapolated estimate in 1920 was a "conservative" 568,000.

The low point for the herd came during 1973–1975 when the first photocensuses were conducted and only 7000 caribou remained (Valkenburg et al. 1994). Herd numbers increased during the late 1970s and 1980s at annual rates of 7–10% reaching 23,000 caribou by 1989 (Valkenburg et al. 1994).

During this study, photocensuses indicated a fairly stable trend from 1990–1995, with approximately 22,000–23,000 caribou in the herd, followed by an increase to ≥33,110 by 2 July 1999 (Table 1). In addition to photocensuses, we used annual population modeling to estimate herd trend because photocensuses can substantially underestimate herd size (Boertje et al. 1996). The annual proportional changes in herd size using photocensus data and modeling data were similar during 1994–1998 (Table 2). However, in 1999 photocensus and modeling results differed significantly, and we suspect that the 1999 photocensus underestimated herd size. Caribou were in numerous groups during the 1999 census and scattered over a large proportion of the summer range. Also, fewer aircraft were available for the 1999 census compared to previous years.

POPULATION MODELING

We completed 5 annual models using data on herd size, herd composition, pregnancy, and mortality to illustrate the relative importance of factors affecting the size of the Fortymile caribou herd (Table 3; Appendices A–E). With certain qualifications, the models can help us understand why herd size changed or remained stable among years. For example, if the herd increased, was this increase caused by decreased mortality, increased productivity, or both? And did the causes of mortality change among years?

The first year's model (15 May 1994–14 May 1995) indicated a fairly stable trend; i.e., the number of births almost equaled the number of deaths (Table 3; Appendix A). Calves composed 29% of the postcalving population and mortality totaled 30%. This stable trend was consistent with independent late June photocensuses from 1990–1995 (Table 1). To summarize, of the 20,000 adults and yearlings and 8090 newborn calves present in May 1994, we estimate wolves killed 4170 (15%) caribou within 12 months. In contrast, grizzly bears killed 2080 (7%), other predators killed 840 (3%), hunters killed 330 (1%), and nonpredation accounted for 950 deaths (3%, Table 3).

Data from 3 of the 4 subsequent annual models indicate the herd increased largely from reduced mortality rather than increased productivity (Table 3). For example, mortality rates were lower (16–23%) than when the herd was stable (30%), and approximately the same proportion of calves was in the postcalving populations (29–31%) as when the population was stable (29%).

An exception occurred in the 1996–1997 model when the herd increased largely from increased productivity rather than decreased mortality. The proportion of calves peaked (33%) in this model year, and the population increased despite high mortality (29%, Table 3).

By incorporating causes of mortality into the annual models (Appendices A–E), we concluded that wolves have continued to be the major predator on the herd each year. Wolves killed 9–17% of the postcalving populations yearly. Grizzly bears were consistently the second major predator, killing 4–7% of the postcalving populations each year. In comparison, other predators killed 1–5%, hunters took up to 1%, and nonpredation accounted for up to 3% (Table 3).

TIMING, RATES, AND CAUSES OF NATURAL MORTALITY

During the combined calving seasons of 1994–1999, we observed newborn calves during 11–28 May. By the end of June 1994–1996, 40–50% of the calves were dead. Annual mortality totaled 58–68% (Figs 2–4; Table 4). No significant differences occurred during these 3 years (chi-square test of proportions, 2×3 table, P = 0.56). This pattern of births and deaths is similar to that in other Interior Alaska caribou studies (Adams et al. 1995*b*; Valkenburg 1997).

A major change occurred in 1997 when calf mortality rates declined 20–30% compared to the previous 3 years; this decline was statistically significant (Table 4, chi-square test of proportions, 2×2 table, P = 0.0008). By the end of June 1997 only 18% of the calves were dead, and the total annual mortality rate was only 36% (Fig 5; Table 4). Decreased mortality in the 1997 cohort was caused by declines in predation by bears and eagles. Wolf predation did not decline significantly (Table 5). Frequent snowstorms and cool weather during the 1997 calving season provided mottled snow cover, which may have allowed caribou cows to more easily hide their newborns and increased the search effort required for predators to find calves (Bergerud and Page 1987). Calving did not appear more concentrated in 1997 compared to previous years.

Wolf predation declined on the 1998 calf cohort coincidental to reductions in the numbers of wolves (Table 5). Annual wolf predation rates (25–30%) on radiocollared calves (n = 50–60) varied little among the 1994–1996 cohorts and will provide the pretreatment data needed to evaluate whether reducing wolf numbers in up to 15 packs can consistently reduce wolf predation. Wolf reductions of 84% in 7 key packs began in winter 1996–1997 and may have slightly influenced winter survival of the 1997 cohort; thus, we disregard these data (24% wolf predation) as pretreatment data. The 1998 calf cohort suffered 14% wolf predation after the initial 7 wolf packs were reduced 84%. No pups were produced among these packs in May 1998. The 1998 calf cohort remained primarily within the treatment area.

Treatment of 14–15 key wolf pack territories is expected from May 1999 through May 2001, which will provide ≥2 additional cohorts to test whether wolf predation on calves is significantly reduced (1-tailed test) compared to the 3 pretreatment cohorts (1994–1996). We will also test for decreasing trends in summer wolf predation. Interpretations of data will depend in part on the distribution of wolf predation among the various years. For example, in spring and summer 1999 most of the wolf predation occurred in the range of 1 untreated wolf pack in and adjacent to the Yukon-Charley Rivers National Preserve. Also, in early winter 1999–2000, snowfall increased and much of the herd exited the treatment area. Wolf predation occurred outside the treatment area.

Wolves were consistently the major predator of calves in the 1994–1997 cohorts, and grizzly bears were consistently the second major predator (Table 5). After we treated 7 wolf pack territories during winter 1997–1998, wolves and grizzly bears killed equal proportions of collared calves in the 1998 cohort. Data for the 1999 cohort are incomplete. Golden eagles, black bears (*Ursus americanus*), and wolverines (*Gulo gulo*) were common minor predators during these studies. Black bears were significant predators in 1995, 1998, and 1999 when snow lingered above treeline and caribou subsequently calved among lower elevation spruce forests. Relatively few calves died from causes other than predation (Table 5).

We have ceased plans to translocate grizzly bears during this study. The Fortymile Management Plan proposed translocating grizzly bears from the calving grounds during May 2001 *if* increased May grizzly bear predation on calves compensated for expected decreased May wolf predation. However, May grizzly bear predation on calves did not increase in 1997 or 1998 when May wolf predation on calves declined compared to May 1994–1996 (Figs 2–6). In May 1999, grizzly bear predation did increase, but we do not know if this increase was a functional response to reduced wolf numbers or if bears were more dependent on calves in 1999 (Table 5).

Since 1991, wolf predation was the major cause of death among caribou calves 4–12 months old and caribou >12 months old. Of the 42 calves 4–12 months old for which cause of death was determined (1 Oct 1991–1 Oct 1999), wolves killed 36 (90%), lynx killed 2 (5%), a wolverine killed 1 (2%), and 1 (2%) died from nonpredation. Of the 42 caribou >12 months old for which cause of death was determined (Oct 1991–1 Oct 1999), wolves killed 36 (86%), grizzly bears killed 4 (10%), and 2 (5%) died from nonpredation deaths.

We found significantly higher mortality among caribou 4–16 months old compared to older caribou for the years 1993–1997 (Table 1, chi-square test of proportions, 2×2 table, $P =$

0.007). These data conflict with those of Davis et al. (1988) who reported similar mortality rates among >5-month-old calves, yearlings, and adults in the Delta Herd.

Elevated mortality from age 4–16 months in the 1991 cohort (57%, n = 14, Table 1) may have been associated with inadvertent separation of calves from their dams at collaring (27 Sep–22 Oct). We darted calves and their dams simultaneously in 1991, and only 2 of 14 cow-calf pairs reunited after recovery from drugging. In 1990 and 1992 through 1999, we radiocollared calves, but not their dams, and cow-calf pairs consistently reunited. Implications of these data are that human hunting of cows with calves during autumn or early winter may reduce the survival of orphaned calves where wolves are major predators. Seven (88%) of the 8 dead calves were killed by wolves.

CARIBOU HARVEST

To increase social acceptance of the management plan, the Fortymile Team chose to reduce the annual harvest to 150 bulls for 5 years beginning in 1996. We illustrated the relatively minor role that harvest has recently had on herd dynamics in Table 3. Harvests have been intentionally held low since 1973 to encourage herd growth (Valkenburg et al. 1994). Reducing harvests from 200–500 bulls (≤2% of the herd, 1990–1995) to 150 bulls (<1% bulls, 1996–2000) will not result in the 5–10% annual rates of herd increase desired by the Fortymile Team. Estimated annual harvest averaged 2.8% of the midsummer herd size during the 6 years before 1990. In 1990, harvest was intentionally reduced because natural mortality increased and calf:cow ratios declined (Table 1).

Following 4 hunting seasons (1996–1999) with a quota of 150 bulls, we have observed no significant increase in the bull:cow ratio (Table 1). We predicted in recent progress reports that no significant increases in bull:cow ratios would occur during the 5 years of restricted harvest quotas. We based our prediction on previous bull:cow ratios in the Fortymile Herd ($\bar{x}$ = 43 bulls:100 cows, range = 36–50, 1985–1997, Table 1), which do not differ significantly from ratios in the Denali Herd, the only Interior Alaska herd with no harvest in recent decades ($\bar{x}$ = 43 bulls:100 cows, range = 29–56 , 1985–1997).

HERD NUTRITIONAL INDICES, WEATHER, AND RELATED HERD PERFORMANCE

We studied indices to nutritional status, weather data, and herd productivity and survival for several reasons. First, we wanted to identify which nutritional indices were related to past Fortymile Herd performance to help predict herd performance 1 or more months before a photocensus and to evaluate herd nutritional status independent of the effects of predation. Predation is a driving force in the Fortymile Herd dynamics (Table 3) and is probably influenced to some degree by the nutritional status of the caribou (Adams et al. 1995*b*). An independent measure of nutritional status is needed to help clarify the significance of nutrition in herd performance. Second, we wanted to compare nutritional indices among other Alaska caribou herds to evaluate the relative nutritional status of the Fortymile Herd. Third, nutritional data provide us insights regarding which weather factors could be important to herd performance.

We have found several nutritional indices related to herd performance since 1992, but for most indices only extreme values appeared useful in predicting population trend. The significantly reduced pregnancy rate in 1993 was the single best evidence of malnutrition during this study, and herd numbers remained approximately stable during 1993 (Table 1). In contrast, major declines occurred in the Delta and Denali herds during 1993 (Boertje et al. 1996). Many adult cows (≥3 years old) apparently did not gain sufficient fat to breed in autumn 1992. The pregnancy rate in 1993 was low in the Fortymile Herd (68%; Table 1), the Delta Herd (30%), the Nelchina Herd (66%), and the Chisana Herd (50%, Valkenburg 1993). Pregnancy rates for caribou are commonly ≥82% (Table 1; Bergerud 1980). Only 5 (42%) of 12 3-year-olds produced calves in the Fortymile Herd in 1993, compared with 5 (83%) of 6 in 1994, 5 (71%) of 7 in 1995, 9 (100%) of 9 in 1996, 6 (100%) of 6 in 1997, 9 (100%) of 9 in 1998, and 9 (82%) of 11 in 1999. Only 126 snow-free days occurred in Fairbanks in 1992 compared with 160–199 days during the previous 19 years (Boertje et al. 1996). Snowmelt was several weeks late in spring 1992, and snowfall was several weeks early in autumn 1992.

Because we saw no strong decline in the Fortymile Herd during 1992 when nutritional status was poor, we conclude that poor nutritional status was not as strong a factor affecting caribou numbers in the Fortymile Herd as in the Delta and Denali herds (Boertje et al. 1996). A contributing factor may be that weather patterns are more continental in the Fortymile Herd's range.

We detected significantly elevated pregnancy rates in 1996 (97%) and 1998 (98%) when the herd was increasing (Tables 1 and 2). Also pregnant 2-year-old caribou were detected in 1998 (1 of 13 radiocollared 2-year-olds) and 1999 (1 of 9) when the herd was increasing. Pregnant 2-year-old caribou are rarely found in Alaska, and their calves rarely survive, but pregnancy in 2-year-olds signifies extremely good nutritional status (Davis et al. 1991; Valkenburg 1997).

We conclude that extremes in pregnancy rates of the various adult cohorts appear useful in predicting herd trend. However, in most years since 1991, pregnancy rates of adults varied from 82–87%, and a stable (1990–1995) versus increasing (1996–1999) population trend could not be predicted from these values (Table 1 and 2).

Autumn calf weights, like pregnancy rates, provide indices to the previous spring/summer/autumn condition. Elevated autumn calf weights appeared useful in predicting significantly elevated pregnancy rates. For instance, autumn calf weights were highest in 1995 and 1997 before the elevated pregnancy rates of 1996 and 1998 (Tables 1 and 6). However, autumn calf weights were not otherwise useful in predicting pregnancy rates or herd trend. For example, autumn calves reached relatively high weights in 1992 despite the short growing season of 1992; there was a low pregnancy rate in 1993. Only during 1997 were autumn calf weights significantly higher than all other years (P = 0.02 in comparing cumulative years, ANOVA, and P = 0.001–0.056 when comparing individual years, Student's *t*-test; Table 6). It is interesting that in 1997 the herd grew 20% based on modeling and photocensus data, and this was by far the best year of herd growth (Table 2).

Newborn weights and calving dates presumably provide indices to winter and spring conditions. Low newborn weights and delayed calving are thought to indicate malnutrition

(Espmark 1980; Reimers et al. 1983; Skogland 1985; Adams et al. 1995*b*). Based on limited data, newborn weights appeared to be a fair indicator of herd trend. For example, newborn weights indicated that spring nutritional status improved during 1996–1999 (when the herd was increasing) compared to 1994 (when the herd was stable, Tables 2 and 7). Unlike data from the Denali Herd, an increase in newborn weights did not occur when calf mortality declined naturally in 1997 (Tables 4 and 7; Adams et al. 1995*b*).

Median calving dates also appeared to be good indicators of herd trend. These dates indicate spring nutritional status improved beginning 1994. Median calving dates were 23 May in 1992 (n = 25) and 22 May in 1993 (n = 24), compared to 18 May in 1994 (n = 32), 1996 (n = 37), and 1997 (n = 39), 19 May in 1998 (n = 47), and 20 May in 1995 (n = 28) and 1999 (n = 58).

We found consistent evidence for moderate to high nutritional status in the Fortymile Herd during this study when indices were compared with other Alaska herds of similar or higher density (Table 6). For example, Fortymile autumn calf weights were significantly higher most years than the Nelchina Herd and similar to those in the Delta Herd, yet newborn calf weights were similar in all 3 herds (Table 7). Also, pregnancy rates in the Fortymile Herd have been similar to or higher than those in the Nelchina and Delta herds in recent years (Valkenburg et al. 1999).

We also examined the rates (1992–1999) and causes (1994–1999) of mortality among calves during their first 2 days of life to test whether perinatal mortality in the Fortymile Herd is caused primarily by nutrition-related factors, as concluded by studies of the Porcupine Herd (Whitten et al. 1992). We found no convincing support for this hypothesis in the Fortymile Herd. Instead, predation was the major cause of death among calves ≤2 days old, e.g., in 25 (78%) of 32 cases of observing radiocollared cows or calves. Also, rates of perinatal mortality were highly variable among years and not highest in 1993 when nutritional status was low or lowest in 1996 and 1998 when pregnancy rates were high. Perinatal mortality rates observed among offspring of collared cows were 3% (n = 30) in 1992, 14% (n = 28) in 1993, 22% (n = 32) in 1994, 7% (n = 28) in 1995, 21% (n = 38) in 1996, 3% (n = 35) in 1997, 11% (n = 45) in 1998, and 9% (n = 57) in 1999. In conclusion, perinatal mortality is not prevalent in the Fortymile Herd compared with the Porcupine Herd and does not appear to be correlated with nutritional status or herd trend. We also question its usefulness for the Fortymile Herd because it is the most expensive potential index to nutritional status that we studied.

We summarize here the approximate causes of herd performance and the nutritional indices that appeared most related to herd trend. Relatively stable herd size during 1990–1995 resulted from high adult mortality during 1989–1992 (17–40%), unusually poor pregnancy rate in 1993 (68%), and low to moderate calf:cow ratios in autumn 1989–1994 (16–30, Table 1). Poor nutritional status during this period was indicated by the low 1993 pregnancy rate, low newborn weights in 1994 (only 1994 and 1995 data available), and delayed calving in 1992 and 1993 (only 1992–1995 data available). Annual increases in the herd beginning in 1996 resulted from several factors including elevated pregnancy rates in 1996 and 1998, improved adult survival rates compared with the early 1990s, and improved calf survival rates, particularly in 1997–1998 and 1998–1999 (Tables 1 and 4). Improved nutritional status during this period was indicated by elevated pregnancy rates in 1996 and 1998, improved newborn weights compared with 1994, elevated 1997 autumn calf weights, and earlier calving compared with 1992 and 1993.

We conclude that both improved environmental conditions and reduced predation contributed to the herd's increase. The Team deemed it opportune to initiate and continue management actions to improve caribou survival during a period of optimal weather and natural increase.

To date, newborn weights and calving dates appear to be the best nutritional indices to predict herd performance, although both these indices can only be obtained about a month before the census. Calf:cow ratios were highly correlated to herd performance; this index is obtained about 9 months prior to the census but is influenced by predation. Therefore this index is not solely a nutritional index.

HERD DISEASES

Potential exposure of the Fortymile Herd to 10 ungulate diseases has been monitored since 1980 using blood sera collected from immobilized caribou ≥4 months old. Similar data have been collected from other herds in Alaska and the Yukon (Zarnke 1996). Few documented cases exist in which infectious diseases have had a detectable effect on caribou herds in Alaska. Brucellosis in arctic caribou herds is a notable exception (Valkenburg et al. 1996*b*, Zarnke 1996). From 1980–1995, 159 sera samples were analyzed from Fortymile Herd caribou. There was no evidence of exposure to *Brucella suis IV* in these samples.

RANGE CONDITION

Range condition was excellent during winters 1991–1992 through 1995–1996, as evidenced by high proportions ($\bar{x}$ = 80%) of lichen fragments in caribou fecal samples (Table 8). Samples were collected from several different wintering areas (Fig 7). Boertje (1981) and Boertje et al. (1985) provided data showing the usefulness of fecal samples in evaluating use of lichens on winter ranges. Lichens are slower growing than vascular plants and are a highly preferred and highly digestible winter forage, in contrast to mosses and evergreen shrubs (Boertje 1990). Fecal samples from overgrazed winter ranges contained reduced proportions of lichens (30–40%) and higher proportions of mosses (30–60%) or evergreen shrubs (30%) compared to values observed in this study (Table 8; Boertje et al. 1985; Valkenburg 1994).

WOLF TREATMENT AND HARVEST

The Board of Game approved nonlethal treatment of up to 7 wolf packs during the winters of 1997–1998 and 1998–1999. The first winter's treatment was completed in early April 1998 and resulted in an 84% reduction in 7 packs from 61 wolves to 10 (9 sterile and 1 fertile) wolves (Table 9). Methods included private harvest, sterilizing dominant pairs, and translocating the remaining wolves in these 7 packs. Twelve sterilizations were conducted on fertile adult wolves by qualified veterinary surgeons and included vasectomies in males and tubal ligations in females to retain gonadal cycling. Nine of these sterilized wolves remained in the study area through 1999, 1 was trapped, 1 was killed by another pack, and 1 resides mostly on the perimeter of the study area. We translocated 13 subordinate adult wolves (≥2 years old) in November 1998. These wolves were moved slightly more than 100 miles southeast to the winter range of the Nelchina Herd; 3 of these wolves returned to the treatment area during February–May 1998. In April 1998 we moved 18 wolves to the Kenai Peninsula; 15 were 11 months old and 3 were subordinate adult wolves. None of these 18 wolves returned to the treatment area.

During the second winter of treatment, we again treated 7 wolf packs and worked to maintain the original 7 packs as sterile pairs (Table 9). Qualified veterinary surgeons conducted 15 sterilizations and all treated wolves remained alive and in the study area through 1999. We moved 39 wolves and 0 returned to the study area. We moved wolves to Units 12 (7 wolves), 21C (5), 21D (2), 24(10), 26A (5), and 26B (10).

The Fortymile Caribou Calf Protection Program, a group of private citizens, paid $400 per wolf from a large area (33,200 km^2) including most of the Fortymile Herd's range beginning winter 1995–1996 and continuing through winter 1996–1997. This $400 approximately doubled the average market value of pelts and was contributed to stimulate increased wolf harvest with the goal of increasing the Fortymile Herd and associated moose and sheep populations.

To help evaluate the effect of the Caribou Calf Protection Program on wolves and caribou, we compiled estimates of wolf harvest rates from within the herd's respective annual ranges for 3 years before the program and during the 2 years of the program (Table 10). We analyzed wolf harvest rates over the herd's respective annual ranges because caribou used different wintering areas each year. Most of the wolf harvest has consistently occurred on caribou wintering areas rather than the summer range. We detected a slight reduction in the autumn wolf density following the initial winter harvest of 57% (Table 10). Wolf density declined from about 7.1 to 6.8 wolves/1000km^2. However, caribou winter ranges shifted annually. We may have seen a greater reduction in the wolf density if caribou had shifted to the area where wolves were most heavily harvested. We did not specifically survey wolf numbers in the area delineated by the Fortymile Caribou Calf Protection Program because Fortymile caribou did not use a significant portion of this area. Without substantial reductions in autumn wolf densities, annual wolf predation on caribou is not expected to decline significantly. We did not detect a decline in wolf predation on calves in the 1996 cohort (Table 5) or on older caribou (Table 1), following the only winter of high wolf harvests (1995–1996, Table 10).

Sustained wolf harvest rates exceeding about 28% of the autumn wolf population are expected to result in wolf population declines (Fuller 1989; Gasaway et al. 1992). However, significant increases in moose and caribou numbers have been reported only after maintaining spring wolf densities 69–85% below initial autumn wolf numbers for several years (Larsen and Ward 1995; Boertje et al. 1996). In contrast, wolf densities in the respective annual ranges of the Fortymile Herd were reduced only 22–31% by harvest during winters 1992–1993 through 1996–1997, except in winter 1995–1996 (57%, Table 10).

The objectives of the Fortymile Caribou Herd Management Plan did not prescribe a 69–85% reduction of wolves. Instead, the novel plan prescribed a focused reduction of 15 packs on the summer range to increase spring and summer calf survival. This reduction combined with intense private trapping on wintering areas might provide the high level of wolf reduction proven to increase caribou numbers. However, private wolf trapping declined strongly in winter 1998–1999 because of an overall decline in the fur market, including the market for wolves. Private trapping began declining in winter 1997–1998, when the initial season price for marten (*Martes americana*) fell considerably and private aircraft-assisted (land and shoot) wolf harvest was outlawed statewide.

With continued low harvest rates on wolves, we expect autumn densities in the herd's annual range to vary between about 5 and 8 wolves/1000 km^2 during this project because we are treating only 15 packs, <50% of the packs that usually feed on Fortymile caribou during a year (Table 10). Autumn densities of 6–8 wolves/1000 km^2 have been reported in most of this area since 1985 (Table 10, Gasaway et al. 1983:58). Likewise, in Denali National Park and Preserve, where little wolf harvest has occurred and prey densities were similar to those in the Fortymile Herd's range, Meier et al. (1995) reported autumn densities of 5–10 wolves/1000 km^2 during 1986–1992. Average autumn densities of 8 wolves/1000 km^2 were reported in 13 Alaska and Yukon study areas where wolves were lightly harvested and prey densities were similar to those in the Fortymile Herd's range (Gasaway et al. 1992:36–38). Sustained high harvest rates or fertility control are required to keep wolf populations below levels in systems with little or no harvest because wolves have high reproductive and immigration rates (Larsen and Ward 1995; Boertje et al. 1996).

CONCLUSIONS

The Fortymile Herd clearly has the potential to grow. The herd currently uses <30% of its historic range and nutrition is not a strong limiting factor. Predicting trends in caribou numbers is problematic. We know that a variety of factors can cause a surge or drop in numbers, that stability is seldom long term, and that rapid declines can occur from the synergistic effects of adverse weather and increased predation (Boertje et al. 1996). Also, we know that continental Alaskan caribou herds have commonly remained at multiyear densities of ≤500 caribou/1000 km^2 during the last 2 decades largely because of predation (Bergerud 1980; Valkenburg et al. 1996*a*). We found exceptions where strong predator control and favorable weather occurred and where wolf predation is naturally lessened. For example, coastal caribou herds have benefited by naturally low wolf predation because of a lack of alternative prey, particularly on coastal calving areas, and because rabies periodically reduces wolf numbers in most of coastal Alaska (Ballard and Krausman 1997). The Fortymile Herd multiyear density first exceeded 500 caribou /1000 km^2 in 1998.

Assuring achievement of time-specific objectives for increased Fortymile caribou numbers will depend on actions that substantially reduce predation, presumably combined with favorable weather, caribou movements, and nutrition. Novel experimental approaches to reducing predation have begun, and we are well prepared to test the effectiveness of these approaches. Numbers of wolves in 14 key wolf packs were reduced 78% by May 1999; 13 of these packs were fertility controlled to prevent reproduction in 1999. We expect to treat up to 15 total packs by April 2000 and to maintain these 15 packs as pairs through May 2001.

Reducing predation is a value-based socioeconomic and political decision beyond the scope of this paper. Ecological and biological issues are more easily addressed. For example, sustainable harvest of a caribou herd is ecologically sound compared to dependency on alternative livestock and agricultural industries. Past studies have shown wolf reductions can be biologically effective and sound, i.e., 1) caribou herds can grow rapidly following large reductions in wolf numbers and 2) wolf numbers can recover within a few years (Larsen and Ward 1995; Boertje et al. 1996). Often only with an abundance of wildlife are managers able to achieve land management policies that prioritize wildlife values over competing land uses.

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Figures

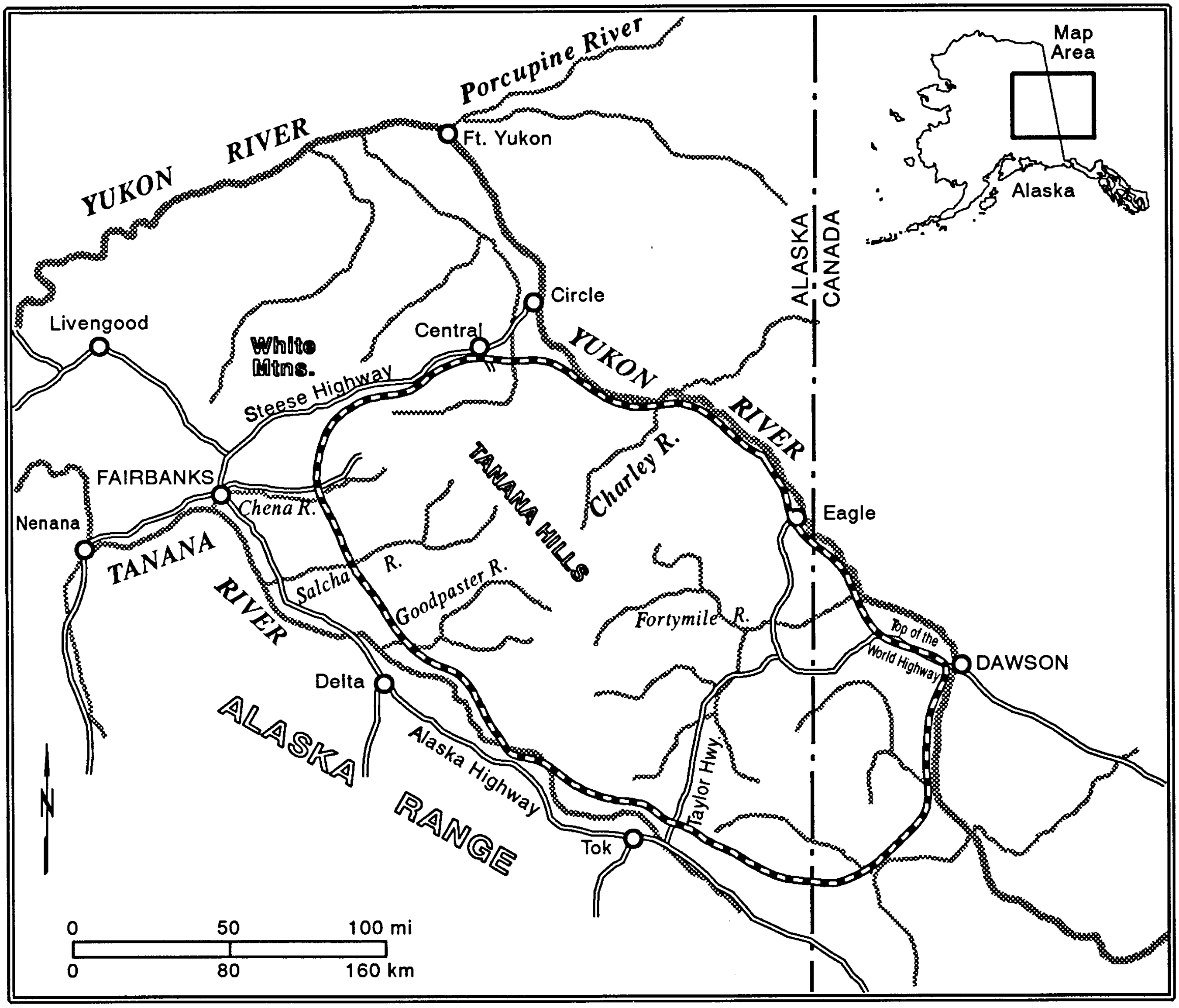

Figure 1 Range of the Fortymile caribou herd, 1984–1999

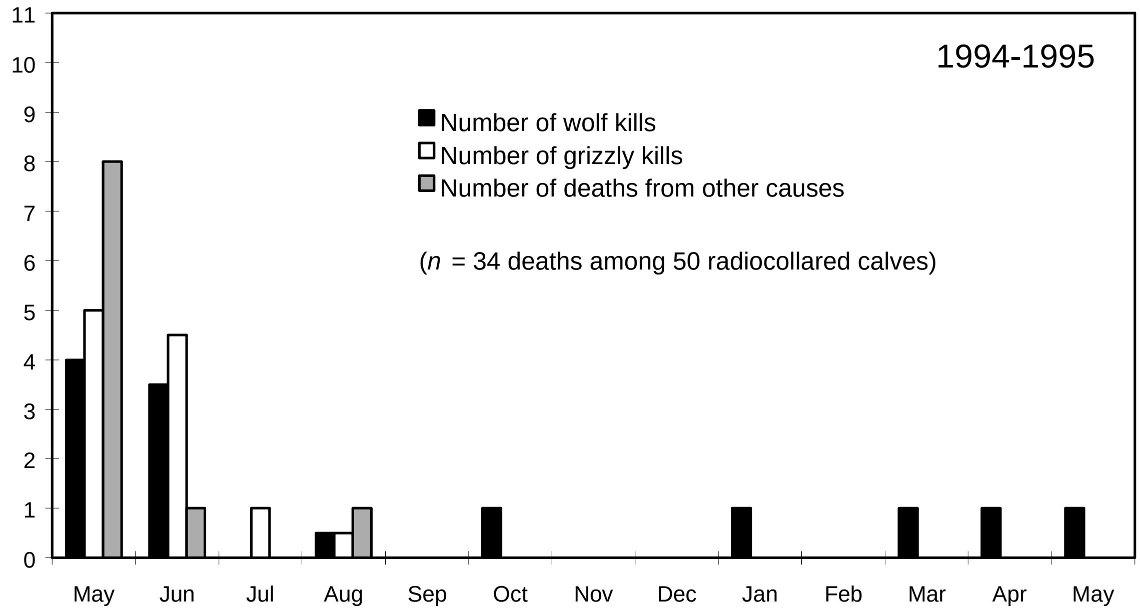

Figure 2 Frequency distribution of causes of death among 34 radiocollared caribou calves that died from May 1994 through early May 1995, Fortymile caribou herd, eastcentral Alaska

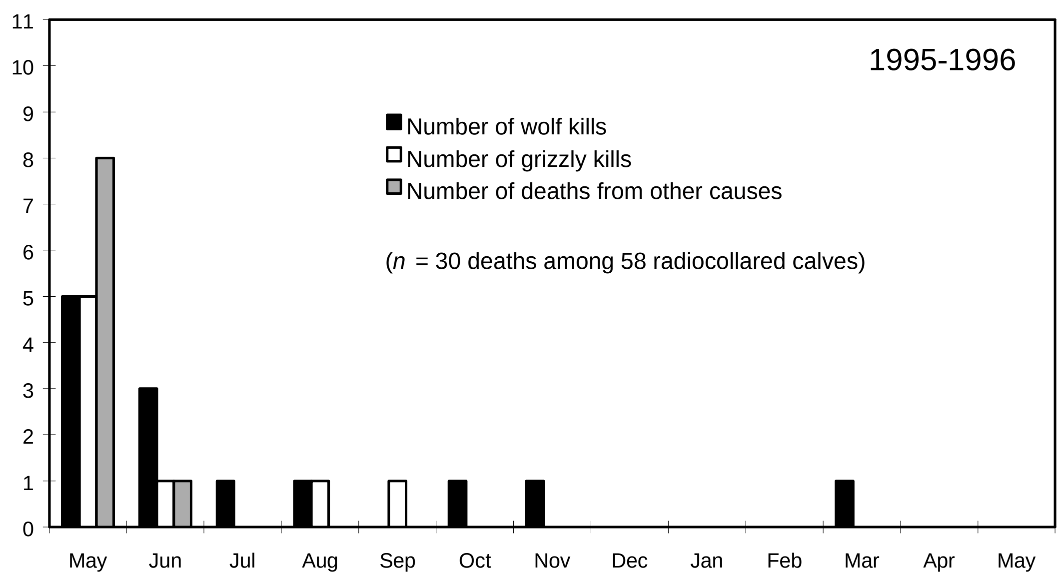

Figure 3 Frequency distribution of causes of death among 30 radiocollared caribou calves that died from May 1995 through early May 1996, Fortymile caribou herd, eastcentral Alaska

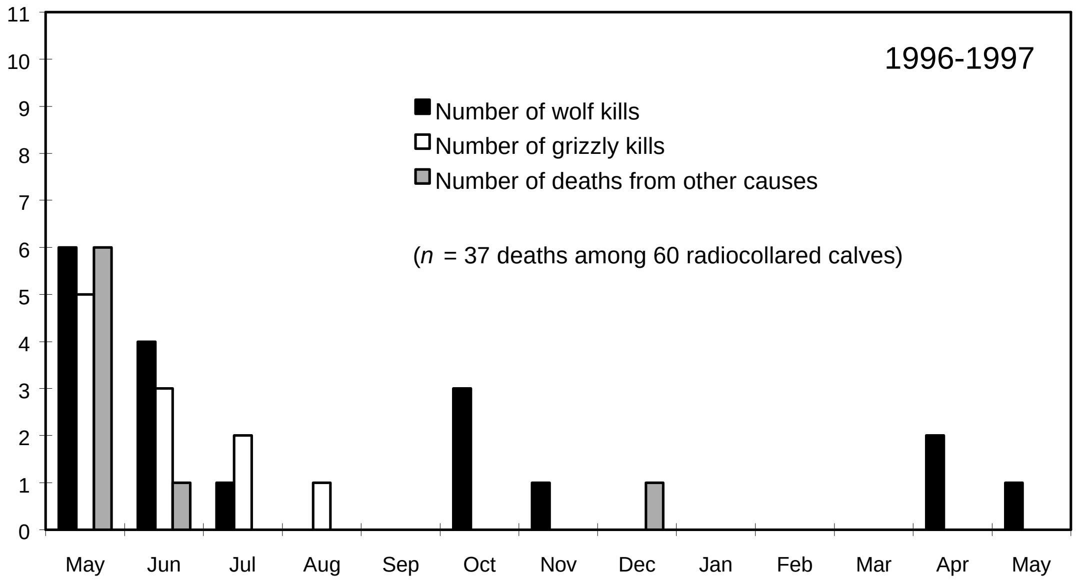

Figure 4 Frequency distribution of causes of death among 37 radiocollared caribou calves that died from May 1996 through early May 1997, Fortymile caribou herd, eastcentral Alaska

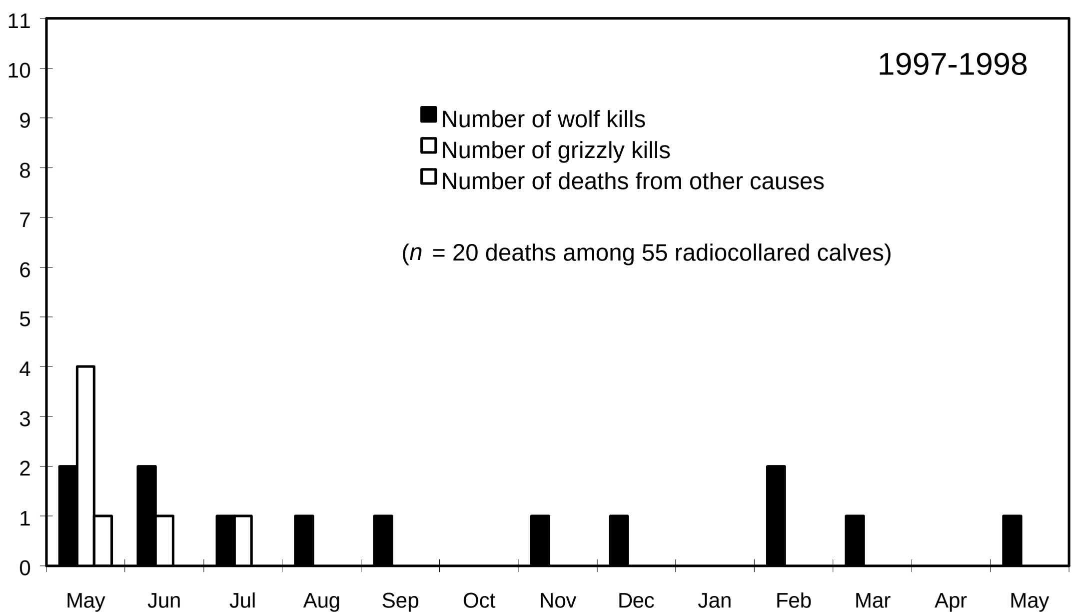

Figure 5 Frequency distribution of causes of death among 20 radiocollared caribou calves that died from May 1997 through early May 1998, Fortymile caribou herd, eastcentral Alaska

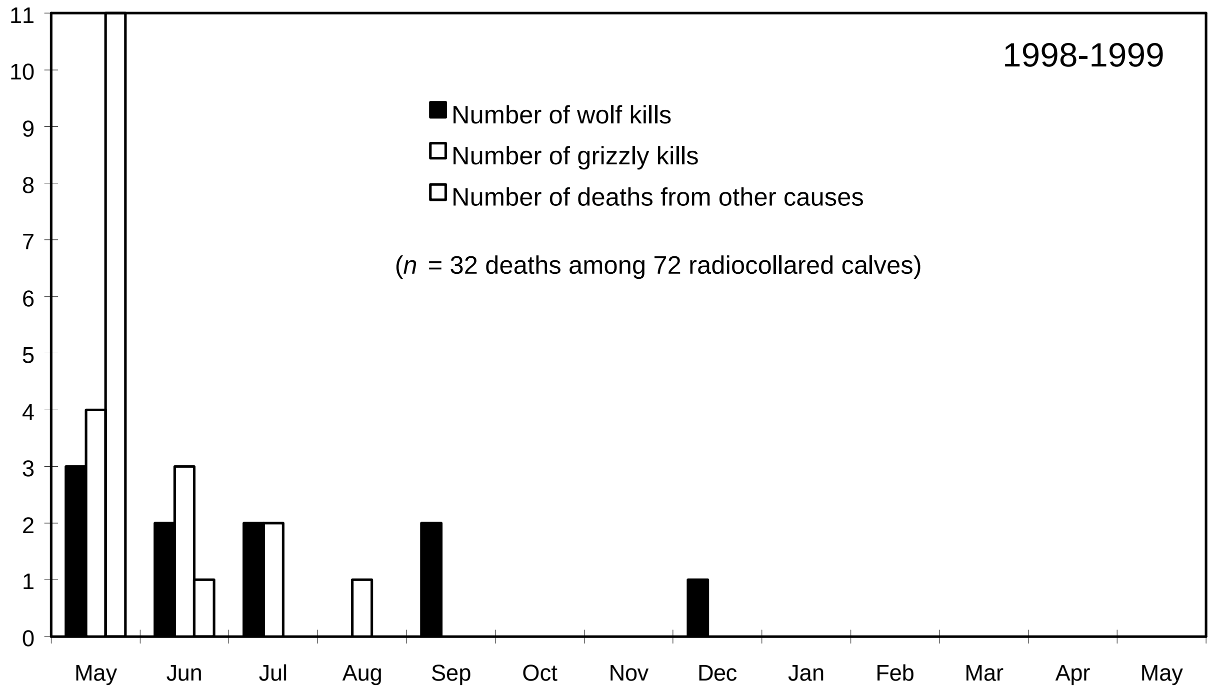

Figure 6 Frequency distribution of causes of death among 32 radiocollared caribou calves that died from May 1998 through early May 1999, Fortymile caribou herd, eastcentral Alaska

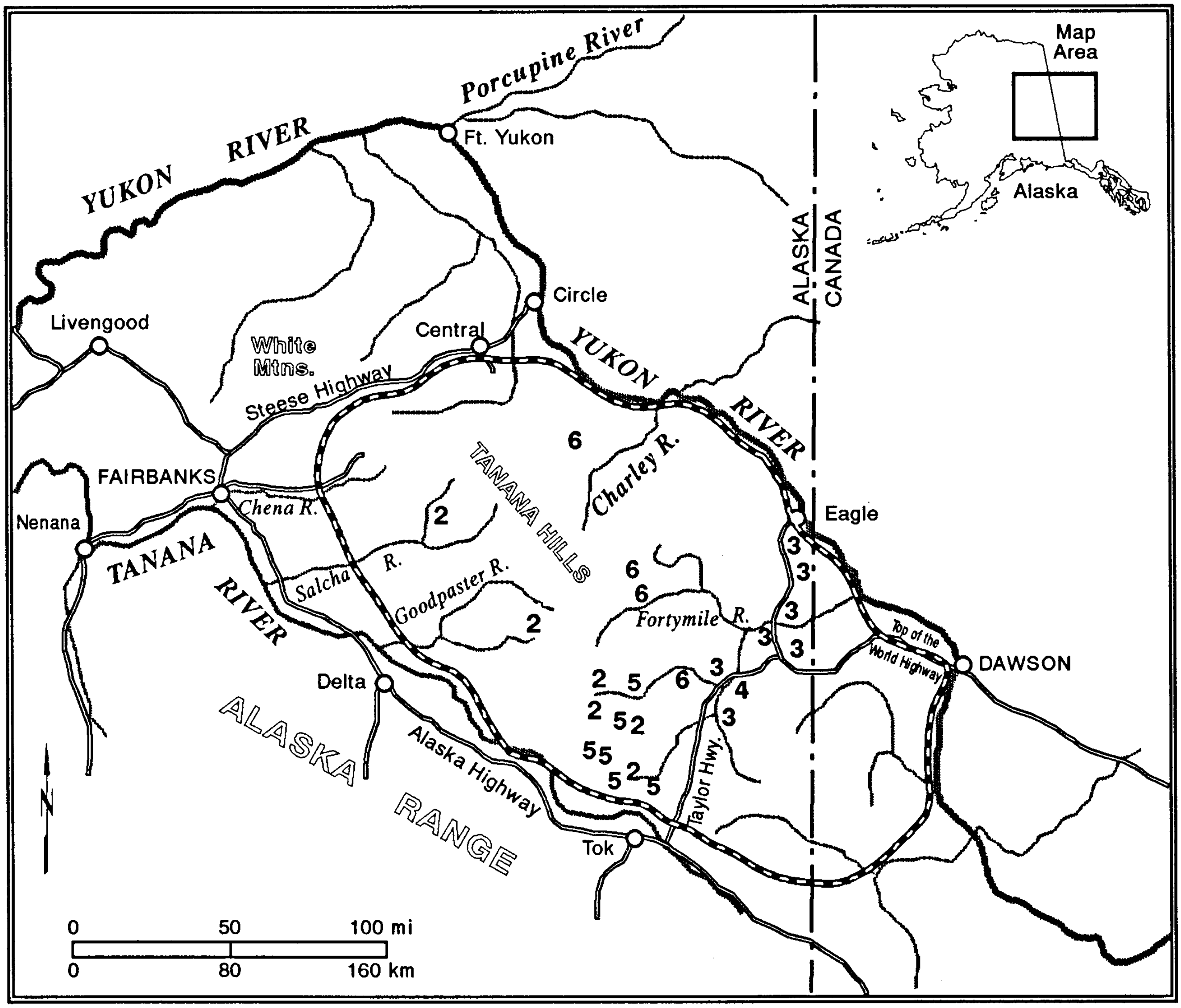

Figure 7 Locations where caribou fecal samples were collected during January–April 1992 (2), 1993 (3), 1994 (4), 1995 (5), and 1996 (6)

Tables

Table 1 Estimated numbers, harvest, natural mortality, pregnancy rates, and composition in the Fortymile Herd, 1984–1999

Year	Estimate of herd size		Estimated harvest[a] M	Estimated harvest[a] F	% Mortality of collared caribou 4–16 months old for year ending 1 Oct (*n*)		% Mortality of collared females 17–28 months old for year ending 1 Oct (*n*)		% Mortality of collared females >28 months old for year ending 1 Oct (*n*)		Pregnancy rate of collared females ≥36 months old (*n*)		Bulls or Calves:100 females Sep–Oct: Bulls	Calves	(*n*)[b]
1984	13,402	(19)[c]	430	20					10	(21)	87	(23)	--	--	--
1985	--	--	421	20					9	(22)	100	(19)	50	36	(574)
1986	15,307	(19)	360	20					17	(24)	95	(21)	36	28	(842)
1987	--	--	229	20					5	(19)	95	(19)	40	37	(1274)
1988	19,975	(39)	645	150					9	(33)	95	(20)	38	30	(770)
1989	--	--	401	100					19	(27)	--	--	27	24	(1182)
1990	22,766	(16)	321	22					40	(20)	88	(16)	44	29	(1002)
1991	--	--	495	10	21	(14)			17	(12)	91	(11)	39	16	(931)
1992	21,884	(64)	432	35	57	(14)	8	(12)	17	(35)	87	(39)	48	30	(1416)
1993	--	--	335	11	8	(12)	10	(10)	10	(51)	68[d]	(47)	46	29	(2095)
1994	22,104	(91)	313	15	17	(12)	10	(10)	11	(37)	82	(45)	44	27	(1710)
1995	22,558	(85)	203	22	20	(30)	10	(10)	8	(40)	85	(41)	43	32	(1879)
1996	23,458	(97)	145	5	18	(39)	14	(7)	7	(41)	97[e]	(39)	41	36	(2601)
1997	25,910	(113)	143	8	20	(44)	9	(11)	10	(51)	85	(46)	46	41	(3313)
1998	31,029	(146)	151	4	16	(51)	13	(15)	6	(52)	98[e]	(48)	40	38	(2433)
1999	33,110	(130)	143	8	7	(54)	18	(11)	4	(71)	87	(68)	48	37	(2347)

[a] From 1 Jul–30 Jun of the next year.

[b] *n* = number of females ≥1 year old classified.

[c] Number of caribou with independent radio collars during census.

[d] In 1993, 5 of 12 (42%) females 3 years old were pregnant, and 27 of 36 (75%) females ≥4 years old were pregnant. Pregnancy rate in 1993 was significantly lower than rates for each of the other years on this table (chi-square test of proportions, 2×2 tables, $P \leq 0.12$).

[e] Pregnancy rate in 1996 and 1998 was significantly greater than other rates during 1994–1997 (chi-square test of proportions, 2×2 tables, $P \leq 0.02$).

Table 2 Annual proportional change in the Fortymile caribou herd using data from photocensuses and modeling data, 1994–1999

Photocensus data		Modeling data	
Time periods	Annual change	Time periods	Annual change
1 Jul 1994–14 Jun 1995	2%	15 May 1994–14 May 1995	-1.5%
14 Jun 1995–21 Jun 1996	4%	15 May 1995–14 May 1996	10%
21 Jun 1996–26 Jun 1997	10%	15 May 1996–14 May 1997	5%
26 Jun 1997–28 Jun 1998	20%	15 May 1997–14 May 1998	20%
28 Jun 1998–2 Jul 1999	7%	15 May 1998–14 May 1999	16%

Table 3 Population modeling outputs for the Fortymile caribou herd, 1994–1995 through 1999–2000. Values are from Appendices A through F.

	Approximate number of adults and yearlings				Total calves and older caribou killed by: (% of postcalving population)					
Year	Precalving estimate	End of the year	Population trend	Calves born	Wolves	Grizzly bears	Other predators	Hunters	Nonpredation	All factors
15 May 1994–14 May 1995	20,000[a]	17,370 + 2360[b] = 19,730	Approximately stable	8090 (29%)[c]	4170 (15)	2080 (7)	840 (3)	330 (1)	950 (3)	8370 (30)
15 May 1995–14 May 1996	20,000[a]	18,550 + 3420[b] = 21,970	Increasing	8390 (30%)[c]	3200 (11)	1450 (5)	1330 (5)	225 (1)	220 (1)	6425 (23)
15 May 1996–14 May 1997	22,000[a]	19,100 + 4060[b] = 23,160	Increasing	10,770 (33%)[c]	5620 (17)	2250 (7)	1090 (3)	150 (<1)	490 (1)	9600 (29)
15 May 1997–14 May 1998	23,000[a]	21,500 + 6020[b] = 27,520	Increasing	9630 (30%)[c]	3510 (11)	1210 (4)	180 (1)	151 (<1)	60 (<1)	5110 (16)
15 May 1998–14 May 1999	27,500[a]	25,100 + 6720[b] = 31,820	Increasing	12,260 (31%)[c]	3650 (9)	1940 (5)	1910 (5)	155 (<1)	110 (<1)	7765 (20)
15 May 1999–14 May 2000	32,000[a]			13,220 (29%)[c]						

[a] The precalving population in 1994 was estimated from the 1 July 1994 photocensus minus 2000 calves that were possibly counted in the photos (Table 1). The 1995–1999 precalving estimates came from the model outputs of the previous year rounded to the nearest 500 caribou. These estimates agreed closely to those predicted from the photocensus minus 1100–3500 calves possibly counted in the photos each year.

[b] Yearlings recruited into population at 12 months of age calculated as number of calves born minus number of calves dying.

[c] Proportion of calves in the postcalving population.

Table 4 Timing of mortality of radiocollared calves in the Fortymile caribou herd, 1994–1999

	Radiocollared calves dying by period/Calves radiocollared in May (proportion dying, %)															
Year	May		Jun		Jul		Aug		Sep		Oct		Nov–May		Total	
1994	17/50	(34)	9/50	(18)	1/50	(2)	2/50	(4)	0/50	(0)	1/50	(2)	4/50	(8)	34/50	(68)
1995	18/52	(35)	5/52	(10)	1/52	(2)	2/52	(4)	1/52	(2)	1/52	(0)	2/52	(6)	30/52	(58)
1996	17/60	(28)	8/60	(13)	3/60	(5)	1/60	(2)	0/60	(0)	3/60	(5)	5/60	(8)	37/60	(62)
1997	7/55	(13)	3/55	(5)	2/55	(4)	1/55	(2)	1/55	(2)	0/55	(0)	6/55	(11)	20/55	(36)
1998	18/72	(25)	6/72	(8)	4/72	(6)	1/72	(1)	2/72	(3)	0/72	(0)	1/72	(1)	32/72	(44)
1999	22/78	(28)	13/78	(17)	6/78	(8)	2/78	(3)	1/78	(1)	4/78	(5)	--	--		

Table 5 Percent annual mortality by cause among radiocollared calves in the Fortymile caribou herd, May 1994–November 1999

	Year (birth to 12 mo except in 1999)					
	Pretreatment years			Winter only treatment[a]	Treatment of 7 wolf packs[b]	Treatment of 13 wolf packs[c]
	1994 (*n* = 50)	1995 (*n* = 52)	1996 (*n* = 60)	1997 (*n* = 55)	1998 (*n* = 72)	1999 (*n* = 78)
Annual percent mortality	66	58	62	36	44	63
Percent mortality by cause:						
Wolf	26	25	30	24	14[c]	24[c]
Grizzly bear	22	15	18	11	14	27
Eagle	6	6	8	0[d]	6	1
Black bear	2	8[e]	0	0	8[e]	6[e]
Wolverine	2	2	2	2	1	3
Nonpredation[f]	8	2	3	0	1	1

[a] Partial treatment included translocating 13 subdominant, adult wolves in November 1997 from 4 key packs. By early April, 7 key wolf packs were reduced 84% to 10 wolves.

[b] Treatment included reducing 7 key wolf packs 84% by early April 1998 and fertility control of 5 of these packs to prevent reproduction in 1998.

[c] Treatment included reducing 13 key wolf packs 78% by early April 1999 and fertility control of these packs to prevent reproduction in 1999 (Table 9). Data are only though October 1999. Wolf predation occurred largely from untreated wolf packs.

[d] Eagle predation in 1997 was apparently disrupted by frequent snowstorms during calving.

[e] Elevated black bear predation occurs when caribou calve below treeline. This occurs during springs with latent deep snow at higher elevations.

[f] In 1994, 3 calves broke their legs, 1 died from abandonment when its dam had no distended udder and 1 was suffocated at birth due to its large size (10.5 kg). In 1995, 1 died from a broken leg when trapped in a natural rock pit. In 1996, 1 died from abandonment when its dam had no distended udder, and 1 probably died from an unknown birth defect 48 hours after birth (no milk in stomach but dam present with distended udder). In 1998, 1 died from a bacterial infection. In 1999, 1 starved when its dam had no udder.

Table 6 Ranked mean weights (kg) of autumn calf caribou in 15 Alaskan herds of various sizes and densities, 1990–1999

Herd	Year	Mean weight (kg)	$s_{\bar{x}}$	*n*	Herd size in 1993[a]	Herd multiyear density per km^2 [a]	Herd size in 1995[b]	Herd multiyear density per km^2 [b]
Western Arctic	1994	32.4	1.3	15	450,000	1.5	450,000	1.5
	1995	36.8	1.2	9				
	1992	40.4	1.8	13				
Northern AK Peninsula	1995	44.7	1.6	10	18,000	0.5	12,000	0.4
	1996	46.0	2.4	10				
	1997	48.3	2.1	10				
	1998	49.4	1.3	29				
	1999	51.9	1.3	11				
Mulchatna	1998	48.5	2.2	14	110,000	1.1	200,000	1.9
Southern AK Peninsula	1998	52.2	1.2	13	2500	0.5	1550	0.3
Nelchina	1996	48.3	2.1	10	40,361	0.5	50,281	0.7
	1998	50.6	0.9	25				
	1999	52.0	0.8	38				
	1995	53.5	1.5	15				
	1997	55.5	1.8	10				
Nushagak Peninsula	1998	55.8	1.6	5	750	0.4	1519	0.8
Fortymile	1990	52.8	1.2	14	22,000	0.4	22,558	0.5
	1998	53.0	1.3	17				
	1991	53.9	1.4	14				
	1994	54.5	1.2	14				
	1996	54.7	1.4	14				
	1999	54.7	1.0	15				
	1992	55.1	1.7	14				
	1993	56.1	0.9	15				
	1995	56.7	1.2	15				
	1997	59.3	1.3	15				
Delta	1992	54.6	1.4	14	3661	0.3	4700	0.4
	1993	55.6	1.4	14				
	1996	55.7	1.4	14				

Herd	Year	Mean weight (kg)	$s_{\bar{x}}$	*n*	Herd size in 1993[a]	Herd multiyear density per km^{2}[a]	Herd size in 1995[b]	Herd multiyear density per km^{2}[b]
	1998	56.4	1.2	16				
	1999	57.1	1.3	14				
	1991	57.9	1.2	14				
	1997	58.2	1.0	20				
	1995	59.5	1.3	13				
	1994	59.6	1.3	15				
Chisana	1990	51.7	1.8	13	850	0.1	775	0.1
	1999	63.5	1.5	8				
	1998	66.7	1.2	3				
Macomb	1999	58.1	4.4	4	500	0.1	500	0.1
	1996	58.4	2.6	8				
	1998	60.2	1.4	12				
Wolf Mtn	1995	59.6	2.1	8	650	0.1	625	0.1
White Mtn	1991	58.5	2.1	9	1000	0.1	1200	0.2
	1995	60.6	2.1	6				
	1997	61.6	1.1	6				
Ray Mtn	1994	60.9	1.3	20	700	<0.1	1750	0.1
Rainy Pass	1999	63.6	2.5	5	750	0.1	500	0.1
Galena Mtn	1994	65.6	1.3	9	275	<0.1	400	<0.1
	1993	66.5	3.2	4				

[a] Herd sizes and multiyear densities from Valkenburg et al. (1996*a*) for 1993.

[b] Herd sizes from Valkenburg (1998) for 1995. Densities calculated based on multiyear herd ranges from Valkenburg et al. (1996*a*).

Table 7 Average newborn caribou weights from 8 Alaskan herds (Valkenburg et al. 1999)

Herd and year	Males			Females		
	Weight (kg)	$s_{\bar{x}}$ [a]	*N*	Weight (kg)	$s_{\bar{x}}$ [a]	*N*
S Alaska Peninsula 1989	6.70	0.67	9	5.4	0.57	9
S Alaska Peninsula 1999	7.70	0.28	25	7.14	0.16	29
Porcupine 1993	--	--	--	6.2	0.7	68
Porcupine 1984	7.30	0.22	33	6.70	0.18	23
Porcupine 1983	7.40	0.19	24	6.60	0.16	28
Porcupine 1985	7.70	0.23	27	7.30	0.20	26
Fortymile 1994[b]	7.71	0.20	22	7.55	0.27	22
Fortymile 1998	8.41	0.13	32	8.02	0.14	39
Fortymile 1997	8.52	0.25	24	7.97	0.21	32
Fortymile 1999	8.54	0.18	35	7.89	0.14	39
Fortymile 1996	8.54	0.24	26	8.09	0.17	32
Fortymile 1995	8.65	0.16	24	7.94	0.19	25
Nelchina 1996	8.26	0.24	23	7.19	0.19	17
Nelchina 1997	8.43	0.18	30	7.89	0.23	30
Nelchina 1998	8.97	0.20	30	8.57	0.18	30
Nelchina 1999	9.17	0.23	26	8.14	0.21	27
Delta 1997	8.35	0.18	40	7.98	0.21	35
Delta 1996	8.39	0.23	22	7.40	0.19	28
Delta 1998	8.41	0.22	15	7.70	0.29	15
Delta 1995	8.72	0.29	26	8.31	0.24	19
Delta 1999	8.86	0.32	26	7.89	0.19	35
N AK Peninsula 1999	8.35	0.25	22	7.41	0.24	22
N AK Peninsula 1998	8.44	0.24	19	7.17	0.30	20
Mentasta 1998[c]	8.66	0.27	15	7.98	0.32	12
Mentasta 1994[d]	8.83	0.21	18	8.09	0.19	23
Mentasta 1993[d]	8.90	0.23	15	7.91	0.20	23
Denali 1986–1987[e]	9.00	0.11	67	7.80	0.11	60
Denali 1998[c]	9.4	0.30	15	8.4	0.32	14

[a] With standard errors of about 0.2 kg, a difference in means of 0.6 kg would be significant at the $P = 0.05$ level (Student's 2-tailed *t*-test).
[b] Fortymile birthweights of males ($P = 0.0006$, $t = 3.51$) and females ($P = 0.053$, $t = 1.95$) increased significantly during 1995–1998 compared with 1994.
[c] Unpublished data from L Adams.
[d] Unpublished data from K Jenkins 1996.
[e] Denali data is corrected for calf age; uncorrected weights would be 0.3–0.5 kg higher (Adams et al. 1995*a*).

Table 8 Proportions of discerned plant fragments in 24 fecal samples collected from Fortymile caribou during January–April 1992 through 1996. Collection sites are depicted in Figure 7.

Plant genus or group	Mean % (± $s_{\bar{x}}$) of discerned plant fragments					
	1992 n = 6	1993 n = 7	1994 n = 1	1995 n = 6	1996 n = 4	All years n = 24
Lichens	72 ± 9	81 ± 4	80	84 ± 3	86 ± 4	80 ± 3
Equisetum	7 ± 6	3 ± 1	6	8 ± 3	6 ± 2	6 ± 2
Mosses	9 ± 3	7 ± 2	4	1 ± <1	1 ± 1	5 ± 1
Ledum	7 ± 2	5 ± 1	5	3 ± 1	4 ± 1	5 ± 1
Graminoids	1 ± <1	1 ± <1	4	2 ± 1	2 ± 1	2 ± 1
Forbs	3 ± 2					1 ± 1
Picea	2 ± <1	2 ± <1	<1	1 ± <1	1 ± <1	1 ± <1
Dryas	1 ± 1					<1
Salix		1 ± <1		<1	<1	<1

Table 9 Wolf numbers and composition in the 14 key territories treated during winters 1997–1998 and 1998–1999

Pack territory	Autumn 1997 numbers and composition	Translocations, mortalities, and dispersal	April 1998 numbers	Autumn 1998 numbers and composition	Translocations, mortalities, and dispersal	April 1999 numbers
Granite	16 (9 adults)	14 moved	2 sterile adults	3 adults (1 sterile)	1 moved	2 sterile adults
Butte	4 adults	1 moved, 1 killed by wolves, 1 dart mortality, 1 harvested	0	2 adults (1 sterile)	0	2 sterile adults
Middle Fork	9 (5 adults)	6 moved, 1 harvested, 1 dispersed	1 sterile adult, 1 fertile adult returned from Harper pack	3 adults (1 sterile)	1 moved	2 sterile adults
Harper	11 (6 adults)	3 moved, 6 harvested	2 sterile adults	2 sterile adults +1 single adult	1 moved	2 sterile adults
Wolf	8 (2 adults)	4 moved, 2 natural mortality	2 sterile adults	2 sterile adults	0	2 sterile adults
Eisen	3 adults	3 harvested	0	0	0	0
Tibbs	10 (5 adults)	3 moved, 5 harvested	2 sterile adults	2 sterile adults	0	2 sterile adults
Subtotal for initial 7 areas	61	52	10	15	3	12
Bullion				12 (6 adults)	10 moved, 1 dispersed	1 sterile adult
Gold				11 (7 adults)	7 moved, 2 harvested	2 sterile adults
Happy				8+1 single (3 adults)	7 moved	2 sterile adults
Sarah				7 (3 adults)	5 moved	2 sterile adults
Ricks				12 (7 adults)	7 moved, 1 harvested, 2 dispersed	2 sterile adults
Dan				2 adults	0	2 adults (1 sterile)
Porc				2 adults	0	2 sterile adults
Subtotal for second 7 areas				55	42	13

Table 10 Estimated autumn wolf numbers and harvest in the respective annual ranges of the Fortymile caribou herd, 1992–1997

	Column				
	A	B	C	D	E
Winter	Area of annual caribou range (1000 km^2)	Number of wolf packs preying on the herd (number of border packs)[a]	Estimated autumn wolf numbers (density) in annual caribou range[b]	Wolf harvest in and adjacent to respective range	Estimated percent wolf harvest (Columns D/C $\times$ 100)
1992–1993	29.1	32 (7)	187 (6.4)	54	29
1993–1994	23.1	26 (6)	156 (6.8)	49	31
1994–1995	30.4	35 (7)	186 (6.1)	40	22
1995–1996	27.7	33 (7)	220[b] (7.1)	126[c]	57[c]
1996–1997	35.0	37 (5)	239 (6.8)	68[c]	28[c]
1997–1998	30.7	37 (9)	233 (7.6)	59 + 31[d] = 90	39[d]
1998–1999	24.0	29 (6)	172 (7.2)	7 + 39[e] = 46	27[e]

[a] Border packs were packs that ranged only about 50% in the annual caribou range.
[b] Autumn wolf numbers are from the respective annual ranges of the Fortymile Herd for the years beginning 1 Oct. We included only 50% of the wolves in the border packs, except in 1995–1996 when large numbers of wolves were harvested along the border. Wolves in 1995–1996 ranged in about 31,000 km^2. To account for single wolves, we added 10% to the number of wolves estimated to be in the annual range.
[c] Caribou Calf Protection Program provided a private incentive to increase harvest.
[d] Harvest totaled 59 and we translocated 31 wolves to areas outside the herd's range.
[e] Harvest totaled 7 and we translocated 39 wolves to areas outside the herd's range.

Appendices

APPENDIX A Values and calculations used to model caribou population dynamics, Fortymile caribou herd, 15 May 1994–14 May 1995

Estimated parameters and calculations	Observed or calculated values
Number of cows ≥24 months old in May 1994 = percent cows in herd in October 1993 when randomly mixed (0.57) × estimated herd size in early May 1994 (20,000)	11,400
Number of 24-month-old cows in May 1994 = percent calves in herd in October 1992 (0.17) × estimated herd size in early May 1993 (20,000) × survival rate from 12 to 24 months old (0.90) × proportion of females (0.5)	1530
Number of cows ≥36 months old in May 1994 = (11,400–1530)	9870
Number of calves produced in May 1994 = (9870 × 0.82)	8090
Number of calves dying by 14 May 1995 = (8090 × 39/55)	5740
Number and cause of calf deaths, 15 May 1994–14 May 1995 (*n* = 34 deaths from known causes)	
Wolf (0.382 × 5740)	2190
Grizzly bear (0.324 × 5740)	1860
Other predators (0.147 × 5740)	840
Nonpredation (0.147 × 5740)	840
Number of nonhunting deaths among caribou ≥12 months old from 15 May 1994–14 May 1995 = (20,000) (6 ÷ 52)	2310
Number and cause of nonhunting deaths among these 2310 caribou (42 adult and yearling death sites were examined from 1 Oct 1991–1 Oct 1999)	
Wolf (0.857 × 2310)	1980
Grizzly bear (0.095 × 2310)	220
Nonpredation (0.048 × 2310)	110
Annual harvest of adults and yearlings May 1994–May 1995	330
Estimated herd size 15 May 1994 (counted 22,104 on 1 July 1994 with some calves included in photos)	20,000
Estimated herd size 14 May 1995 = (20,000 + 8090 - 5740 - 2310 - 330) rounded to nearest 100	19,700 a 1.5% decline
Conclusion: Herd trend approximately stable, consistent with photocensus results	

APPENDIX B Values and calculations used to model caribou population dynamics, Fortymile caribou herd, 15 May 1995–14 May 1996

Estimated parameters and calculations	Observed or calculated values
Number of cows ≥24 months old in May 1995 = percent cows in herd in October 1994 when randomly mixed (0.57) × estimated herd size in early May 1995 (20,000)	11,400
Number of 24-month-old cows in May 1995 = percent calves in herd in October 1993 (0.17) × estimated herd size in early May 1994 (20,000) × survival rate from 12 to 24 months old (0.90) × proportion of females (0.5)	1530
Number of cows ≥36 months old in May 1995 = (11,400-1530)	9870
Number of calves produced in May 1995 = (9870 × 0.85)	8390
Number of calves dying by 14 May 1996 = (8390 × 32/54)	4970
Number and cause of calf deaths, 15 May 1995–14 May 1996 (*n* = 30 deaths from known causes)	
Wolf (0.433 × 4970)	2150
Grizzly bear (0.267 × 4970)	1330
Other predators (0.267 × 4970)	1330
Nonpredation (0.033 × 4970)	160
Number of nonhunting deaths among caribou ≥12 months old from 15 May 1995–14 May 1996 = (20,000) (3 ÷ 49)	1220
Number and cause of nonhunting deaths among these 1220 caribou (42 adult and yearling death sites were examined from 1 Oct 1991–1 Oct 1999)	
Wolf (0.857 × 1220)	1050
Grizzly bear (0.095 × 1220)	120
Nonpredation (0.048 × 1220)	60
Annual harvest of adults and yearlings May 1995–May 1996	225
Estimated herd size 15 May 1995 (counted 22,558 on 14 June 1995 with some calves included in photos)	20,000
Estimated herd size 14 May 1996 (20,000 + 8390 - 4970 - 1220 - 225) rounded to nearest 100	22,000 a 10% increase
Conclusion: herd trend increasing, consistent with photocensus results	

APPENDIX C Values and calculations used to model caribou population dynamics, Fortymile caribou herd, 15 May 1996–14 May 1997

Estimated parameters and calculations	Observed or calculated values
Number of cows ≥24 months old in May 1996 = percent cows in herd in October 1995 when randomly mixed (0.57) × estimated herd size in early May 1996 (22,000)	12,540
Number of 24-month-old cows in May 1996 = percent calves in herd in October 1994 (0.16) × estimated herd size in early May 1995 (20,000) × survival rate from 12 to 24 months old (0.90) × proportion of females (0.5)	1440
Number of cows ≥36 months old in May 1996 = (12,540 - 1440)	11,100
Number of calves produced in May 1996 = (11,100 × 0.97)	10,770
Number of calves dying by 14 May 1997 = (10,770 × 38/61)	6710
Number and cause of calf deaths, 15 May 1996–14 May 1997 (*n* = 37 deaths from known causes)	
Wolf (0.486 × 6710)	3260
Grizzly bear (0.297 × 6710)	1990
Other predators (0.162 × 6710)	1090
Nonpredation (0.054 × 6710)	360
Number of nonhunting deaths among caribou ≥12 months old from 15 May 1996–14 May 1997 = (22,000) (8 ÷ 64)	2750
Number and cause of nonhunting deaths among these 2750 caribou (42 adult and yearling death sites were examined from 1 Oct 1991–1 Oct 1999)	
Wolf (0.857 × 2750)	2360
Grizzly bear (0.095 × 2750)	260
Nonpredation (0.048 × 2750)	130
Annual harvest of adults and yearlings May 1996–May 1997	150
Estimated herd size 15 May 1996 (counted 23,458 on 21 June 1996 with some calves included in photos)	22,000
Herd size 14 May 1997 (22,000 + 10,770 - 6710 - 2750 - 150) rounded to nearest 100	23,200 a 5.4% increase
Conclusion: Herd trend increasing, consistent with photocensus results	

APPENDIX D Values and calculations used to model caribou population dynamics, Fortymile caribou herd, 15 May 1997–14 May 1998

Estimated parameters and calculations	Observed or calculated values
Number of cows ≥24 months old in May 1997 = percent cows in herd in October 1996 when randomly mixed (0.57) × estimated herd size in early May 1997 (23,000)	13,110
Number of 24-month-old cows in May 1997 = percent calves in herd in October 1995 (0.18) × estimated herd size in early May 1996 (22,000) × survival rate from 12 to 24 months old (0.90) × proportion of females (0.5)	1780
Number of cows ≥36 months old in May 1997 = (13,110 - 1780)	11,330
Number of calves produced in May 1997 = (11,330 × 0.85)	9630
Number of calves dying by 14 May 1998 = (9630 × 21/56)	3610
Number and cause of calf deaths, 15 May 1997–14 May 1998 (*n* = 20 deaths from known causes)	
Wolf (0.65 × 3610)	2350
Grizzly bear (0.30 × 3610)	1080
Other predators (0.05 × 3610)	180
Nonpredation (0 × 3610)	0
Number of nonhunting deaths among caribou ≥12 months old from 15 May 1997–14 May 1998 = (23,000) (4 ÷ 68)	1350
Number and cause of nonhunting deaths among these 1350 caribou (42 adult and yearling death sites were examined from 1 Oct 1991–1 Oct 1999)	
Wolf (0.857 × 1350)	1160
Grizzly bear (0.095 × 1350)	130
Nonpredation (0.048 × 1350)	60
Annual harvest of adults and yearlings May 1997–May 1998	151
Estimated herd size 15 May 1998 (counted 25,910 on 26 June 1997 with some calves included in photos)	23,000
Herd size 14 May 1998 (23,000 + 9630 - 3610 - 1350 - 151) rounded to nearest 100	27,500 a 20% increase
Conclusion: Herd trend increasing, consistent with photocensus results	

APPENDIX E Values and calculations used to model caribou population dynamics, Fortymile caribou herd, 15 May 1998–14 May 1999

Estimated parameters and calculations	Observed or calculated values
Number of cows ≥24 months old in May 1998 = percent cows in herd in October 1997 when randomly mixed (0.53) × estimated herd size in early May 1998 (27,500)	14,580
Number of 24-month-old cows in May 1998 = percent calves in herd in October 1996 (0.20) × estimated herd size in early May 1997 (23,000) × survival rate from 12 to 24 months old (0.90) × proportion of females (0.5)	2070
Number of cows ≥36 months old in May 1998 = (14,580 - 2070)	12,510
Number of calves produced in May 1998 = (12,510 × 0.98)	12,260
Number of calves dying by 14 May 1999 = (12,260 × 33/73)	5540
Number and cause of calf deaths, 15 May 1998–14 May 1999 (*n* = 32 deaths from known causes)	
Wolf (0.313 × 5540)	1730
Grizzly bear (0.313 × 5540)	1730
Other predators (0.344 × 5540)	1910
Nonpredation (0.031 × 5540)	170
Number of nonhunting deaths among caribou ≥12 months old from 15 May 1998–14 May 1999 = (27,500) (7 ÷ 86)	2240
Number and cause of nonhunting deaths among these 1350 caribou (42 adult and yearling death sites were examined from 1 Oct 1991–1 Oct 1999)	
Wolf (0.857 × 2240)	1920
Grizzly bear (0.095 × 2240)	210
Nonpredation (0.048 × 2240)	110
Annual harvest of adults and yearlings May 1998–May 1999	155
Estimated herd size 15 May 1998 (counted 31,029 on 28 June 1998 with some calves included in photos)	27,500
Herd size 14 May 1999 (27,500 + 12,260 - 5540 - 2240 - 155) rounded to nearest 100	31,800 a 15.6% increase
Conclusion: Herd trend increasing, consistent with photocensus results	

APPENDIX F Values and calculations used to model caribou population dynamics, Fortymile caribou herd, 15 May 1999–14 May 2000

Estimated parameters and calculations	Observed or calculated values
Number of cows ≥24 months old in May 1999 = percent cows in herd in October 1998 when randomly mixed (0.56) × estimated herd size in early May 1999 (32,000)	17,920
Number of 24-month-old cows in May 1999 = percent calves in herd in October 1997 (0.22) × estimated herd size in early May 1998 (27,500) × survival rate from 12 to 24 months old (0.90) × proportion of females (0.5)	2720
Number of cows ≥36 months old in May 1999 = (17,920 - 2720)	15,200
Number of calves produced in May 1999 = (15,200 × 0.87)	13,220