Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Final Report

A Decade Later: Interrelationships of Predators, Ungulates, and Humans Following Wolf Reductions in an Interior Alaska Study Site

by

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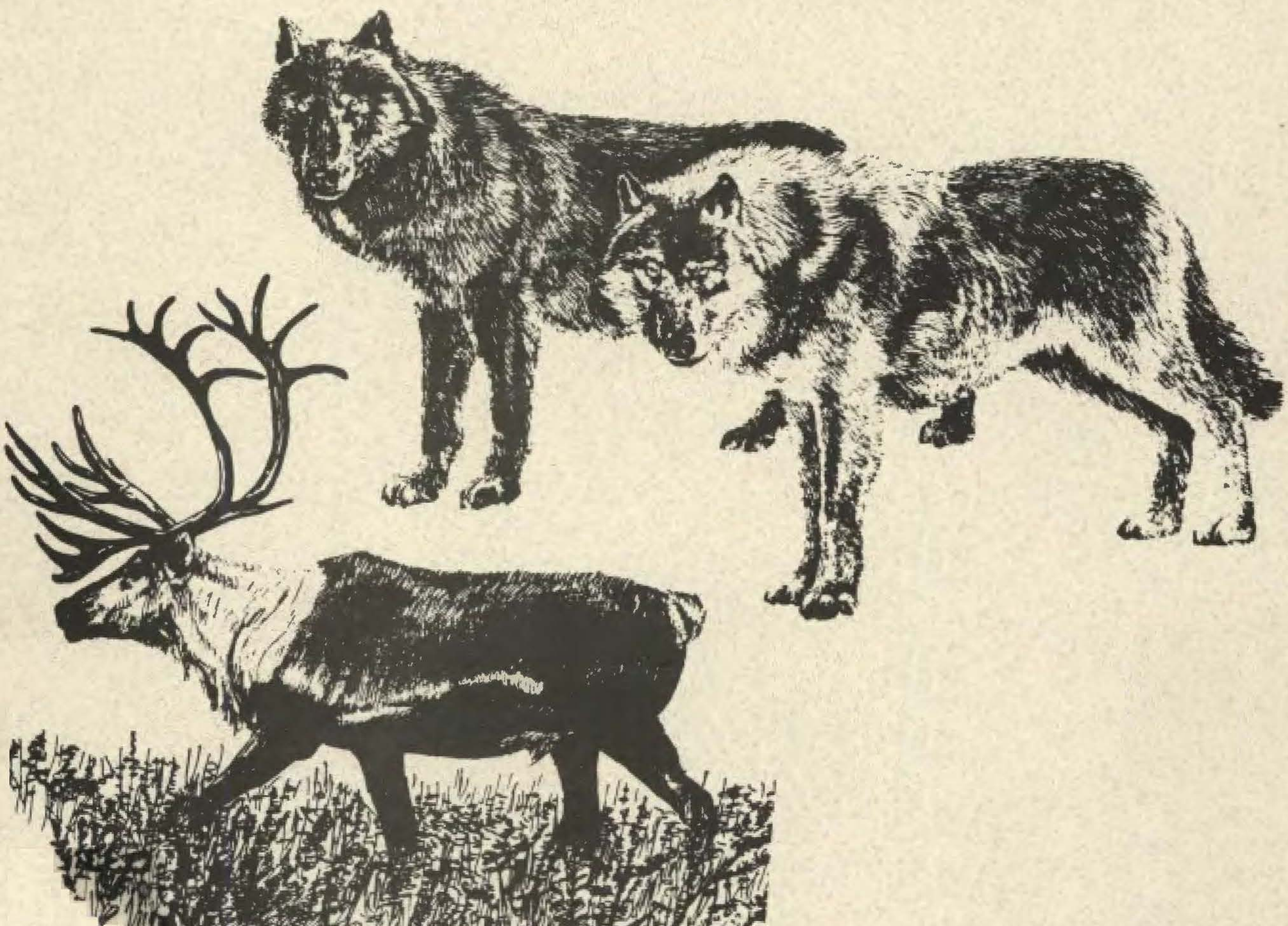

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SUMMARY

We present a case history of the long-term increases in moose (*Alces alces*), caribou (*Rangifer tarandus*), wolves (*Canis lupus*), and harvest of moose and caribou following five winters of agency wolf control. We also document that low- and moderate-density moose populations better cope with deep snow than high-density moose populations. In contrast, low- and high-density caribou populations declined synchronous to adverse weather. In last year's progress report we documented that wolf reproductive potential was dependent in part on ungulate availability (Can. J. Zool. 70:2441-2443).

Data from this wolf control area have not been summarized since spring 1979, when Gasaway *et al.* (1983) discussed the immediate response of moose and caribou to reductions in wolf numbers. Documentation of long-term responses to wolf control are a prerequisite to estimating the cost:benefit ratios of this wolf control program.

This case history begins during winter 1975-76 with the initiation of five winters of agency wolf control in an area of low and declining moose and caribou densities. During the 16 years of surveys, moose numbers increased continuously (λ = 1.09) to about 4.0 times the original density. When the study terminated, moose density was 6.7 times higher than the average moose density in 20 Alaska and Yukon sites where predators were not controlled. Moose density apparently remained below the level where habitat and/or deep snow could initiate a population decline, although the rate of increase slowed in later years simultaneous to three consecutive winters of deep snowfall. The moose population increased despite (1) the deepest snowfall on record during 1990-91, and (2) a 10-year average annual harvest of 418 male moose in 13,000-km^2 of moose habitat. This sustainable harvest (32 male moose/1,000 km^2) exceeded the approximate 3-year sustainable harvests in sites where predators were not controlled (0-18 male moose/1,000 km^2).

Caribou numbers increased 4.9-fold during the first 14 years of the study (λ = 1.13) and attained a high density relative to adjacent, untreated herds. The herd's decline during the last 3 years of the study was synchronous with declines in adjacent low-density caribou herds, suggesting that adverse weather played a major role in initiating the herd's decline. Annual caribou harvests ranged from 0 during the first 4 years after the initiation of wolf reductions to an average of 573 (7% of herd size) during the subsequent 12 years. High harvest rates and high densities apparently contributed little to the herd's decline, as evidenced by simultaneous declines in two adjacent low-density herds that were lightly harvested or unharvested. Data presented indicate these three declines were related to both significantly increased snowfall and reduced rainfall.

Wolf density rebounded to precontrol densities within at least 4 years of the termination of agency reductions, except along the northern portion of the treated area. By 1991, wolf densities had increased to high levels in the treated area relative to untreated areas.

Wolf control apparently resulted in long-term growth of moose and caribou populations to high densities, which subsequently allowed wolf densities to reach high levels. High densities of moose and caribou allowed for increased harvest of these species per unit area. Repeatability of this experiment will depend on favorable weather conditions for caribou, because caribou can at times be limited at low densities by adverse weather. However, caribou are often held at low densities by combined wolf and bear (*Ursus* sp.) predation, as evidenced by the increased caribou abundance in the treated versus untreated areas, historical data, and a prior review. Moose populations are regularly held at low densities by combined wolf and bear predation, and low- and moderate-density moose populations did not decline following deep snowfall winters.

Key words: Alaska, caribou, degree-days, harvest, moose, predator-prey relationships, rainfall, snow, weather, wolf, wolf control.

CONTENTS

BACKGROUND

The scientific literature lacks timely documentation of the long-term effects of agency wolf control on wolves (*Canis lupus*) and their prey using current survey techniques. Agency wolf control and poisoning in the 1950s in portions of Alaska were followed by elevated numbers of moose (*Alces alces*) and caribou (*Rangifer tarandus*) in the 1960s, but timely documentation and survey techniques were poor (Gasaway *et al.* 1983, 1992; Ballard *et al.* 1987). Declines in these enhanced moose and caribou populations were initiated in the 1960s and continued into the 1970s. High moose densities in combination with deep snow, reduced range condition, and/or declines in caribou (which served as alternate prey to wolves) were contributing initial factors in several documented declines in moose numbers (Bishop and Rausch 1974; Gasaway *et al.* 1983, 1992; Ballard *et al.* 1991). Initial causes for declines in caribou were less clear (Davis *et al.* 1978, Bergerud and Ballard 1989). It is clear that wolf and bear (*Ursus* sp.) predation and, in some cases, overharvest helped accelerate declines in both moose and caribou numbers. Wolves had reached high densities by the 1960s, and wolf numbers declined slowly relative to declines in prey (Peterson and Page 1983, Gasaway *et al.* 1992).

Since the 1950s, several agency wolf control programs were implemented in Alaska but all but two were prematurely terminated (<4 years of control). Programs were terminated primarily for political reasons (Harbo and Dean 1983, Stephenson *et al.* 1993). Those that were prematurely terminated failed to result in strong increases in moose or caribou. Failures occurred because of inadequate wolf reductions and high bear predation (Gasaway *et al.* 1983:44-45, 1992) or in one case because moose:wolf ratios were already high; in this case wolf predation was a minor factor limiting moose because of high public wolf harvests (Ballard *et al.* 1987, 1991).

In this paper we describe a 17-year case history of the effects of the only state-sponsored wolf control program that endured for 5 years. State-sponsored wolf control occurred in this area during five of the seven winters between 1975 and 1982, and moose and caribou populations increased. However, published data documented only the short-term effects of control through 1979 (Gasaway *et al.* 1983). Long-term case histories of the effects of wolf control are essential to help predict the effects of future wolf control programs on moose, caribou, and wolves and to evaluate cost:benefit ratios of wolf control.

Our current conceptual models of wolf-bear-moose-caribou systems suggest that, without periodic predator control, moose will eventually decline in this area and remain within a low-density dynamic equilibrium far below food-limited densities (Gasaway *et al.* 1992). This low-density equilibrium occurs for moose because bears kill large proportions of moose calves and significant numbers of adults (Boertje *et al.* 1988) and wolves kill significant numbers of moose year-round. Both predators apparently kill moose that otherwise would not die, as evidenced by increases in moose following predator control (Bishop and Rausch 1974; Gasaway *et al.* 1983, 1992; Larsen and Ward 1993). Uncontrolled densities of both predators keep moose at a low-density equilibrium. This conceptual low-density model is supported by empirical data (Gasaway *et al.* 1992), archaeological data (Yesner 1989), early accounts from native Alaskans (Coady 1980), and prior reviews (Ballard and Larsen 1987, Crete 1987, Van Ballenberghe 1987, Bergerud and Snider 1988).

Alternatively, Haber (1977) proposed a multiple-density equilibrium model that suggests that moose will remain indefinitely at a high-density stable state following predator control if harvest rates are not excessive ($\leq$6%). Van Ballenberghe (1980, 1987), Crete (1987), Seip (1993), and Messier (1993) challenged Haber's model, but long-term case histories are required to test the appropriateness of this model. We present a long-term case history for moose, but no high-density stable state was reached during this study.

A predation-limited, single, low-density model also exists for Alaskan caribou where predators are common and not controlled (Bergerud 1980). Debate in caribou ecology has focused primarily on the causes of previous caribou declines to low density (Davis *et al.* 1978, Bergerud and Ballard 1989, Van Ballenberghe 1989, Eberhardt and Pitcher 1992), but studies were not ongoing during these declines. We present data on the causes of the decline in the Delta caribou herd; the decline occurred during this study period, simultaneous to declines in adjacent herds, and 8 years following the termination of wolf control.

OBJECTIVES

Objective 1: Review literature.

Objective 2: Analyze data and draft figures for written and oral presentations.

Objective 3: Publish a report synthesizing the long-term relationships of predators and prey following ADF&G wolf control in Game Management Subunit 20A and comparing these data with data from untreated areas.

STUDY AREA

The study area encompassed a treated area, where significant wolf control was practiced for five winters, and untreated areas, where predators were only lightly harvested or not harvested. All areas contained wolves, grizzly (*Ursus arctos*) and black (*U. americanus*) bears, moose, and caribou, and all areas were in Alaska or the Yukon. The treated area included an area of about 13,000 km^2 of moose habitat and included the Tanana Flats and northern foothills and mountains of the Alaska Range south of Fairbanks (Fig. 1; Gasaway *et al.* 1983). Untreated areas were depicted in Gasaway *et al.* (1992) and each area included at least 2,000 km^2 of contiguous moose habitat.

METHODS

Estimating Moose Abundance and Harvest

We estimated moose densities in the treated area using stratified random sampling (Gasaway *et al.* 1986) during 1978, 1984, 1988, and 1991 (Gasaway *et al.* 1983, 1992; McNay 1993). Prior to 1978, numbers of moose were estimated by linking the index of moose abundance to the 1978 population density using trend data from four survey areas (Gasaway *et al.* 1983:6-7). Methods for estimating moose densities were similar among the treated and untreated areas (Gasaway *et al.* 1986). The reported harvest of moose was the number of moose reported killed by hunters after reminder letters were sent to recipients of mandatory mail-in harvest reports each year. However, only 69-70% of harvest ticket recipients reported (Goodwin 1991:17). We multiplied reported harvest by an arbitrary 1.15 correction factor to include unreported moose and mortally wounded, unretrieved moose (Gasaway *et al.* 1983).

Estimating Caribou Abundance and Harvest

We estimated caribou numbers in the treated area during 1973 and 1979-84 using the aerial photo-direct count-extrapolation method, which can potentially overestimate caribou numbers (Davis *et al.* 1979, Davis and Valkenburg 1985). During 1975-78, the trend in caribou numbers was evaluated from postcalving and autumn composition surveys (Gasaway *et al.* 1983, Davis *et al.* 1991). During 1985-92, aerial photography and radio-telemetry were used to estimate minimum caribou numbers (Valkenburg *et al.* 1985, Davis *et al.* 1991, Valkenburg 1992). All caribou censuses were flown from mid-June to mid-July when caribou were aggregated. Experience has shown that we cannot accurately detect annual trends in caribou numbers by comparing two consecutive annual censuses. Instead, several years of census data are needed to accurately detect trend. To evaluate annual caribou population trends, we used harvest, recruitment, and natural mortality data (Davis *et al.* 1991). We estimated recruitment during September or October calf:cow counts using a helicopter, and mortality rates were estimated from a sample of radio-collared caribou (Davis *et al.* 1991, Valkenburg 1992).

Procedures for estimating caribou harvest varied depending on the type of harvest reporting system. We considered harvest reports from permit hunts to be accurate estimates of total harvest because reminder letters were sent to permittees and 97-98% of permittees responded (Goodwin 1991:18). In contrast, we applied a correction factor to general season hunts where harvest was reported by mandatory mail-in report cards without the benefit of reminder letters (Davis *et al.* 1991). Correction factors were derived annually during 1986-92 by interviewing successful hunters in the field. To avoid biased reporting, hunters were not told the purpose of these interviews. The interviews and mail-in harvest reports were treated as a mark-recapture sample to estimate actual hunter numbers and total harvest. To derive total harvest from general season hunts in 1983 and 1985, we multiplied reported harvest by 1.77, the average correction factor calculated during 1986 (1.79) and 1987 (1.75).

Estimating Wolf Abundance and Harvest

The primary technique used to estimate wolf abundance and distribution was to count wolves or wolf tracks in snow during aerial wolf and other winter surveys (Gasaway *et al.* 1983, 1992). Experienced pilots and observers flew wolf surveys in late winter (Feb-Apr) in bright light 1-5 days after fresh snow. We radio-collared (Telonics, Mesa, Ariz.) 40% of the wolf packs in the treated area during 1987 and 1988 and 20% of the packs in 1991 to assist with surveys. Techniques for radio-collaring and radio-tracking followed Gasaway *et al.* (1992). We solicited additional information from local trappers, hunters, and pilots each year.

Population size during late winter was the sum of observed wolves in packs, additional wolves enumerated based on tracks, and 10% of the autumn population to account for single wolves not associated with packs (Mech 1973). We estimated autumn population size from winter surveys plus the number of wolves harvested prior to the particular surveys. Wolf harvests occurred during 10 August-30 April; mandatory reporting forms contained information on wolf harvest locations and numbers of wolves in the pack prior to harvest. ADF&G staff killed significant numbers of wolves by shooting from helicopters during five winters, 1975-76 through 1978-79 and winter 1981-82.

Estimating Snow Depth, Length and Temperature of the Growing Season, and Rainfall

The National Weather Service recorded weather data. Snow depth was recorded at Fairbanks and used as an index of snow depth in the treated and adjacent, untreated areas (Fig. 1). Depth of snow on the ground on the first and fifteenth of each month was plotted, points were connected, and the area under the curve was measured. The area under the curve was used to compare severity among winters (Gasaway *et al.* 1983). Length and temperature of the growing season was calculated by summing degree-days in Fairbanks beginning when the average daily temperature exceeded $5^{o}C$ and terminating when the daily minimum temperature reached $0^{o}C$. Degree-days were calculated by averaging the minimum and maximum daily temperatures, subtracting $5^{o}C$ each day, and summing the results for the entire growing season. Total rainfall was calculated by summing rainfall in Healy (Fig. 1) during 15 June-15 August.

RESULTS

Moose Population Size and Harvest

Moose numbers in the treated area increased for the entire 16 years of surveys beginning with the initiation of wolf control (Fig. 2, Table 1; Gasaway *et al.* 1983). The average annual finite rate of growth (λ) was 1.09 during these 16 years based on initial and final estimates, but herd growth rate declined in the later years. The average finite rate of increase was 1.12 during wolf control (1975-82) and 1.07 after wolf control (1982-91). The prehunting moose population ranged from 2,900 in 1975 (223 moose/1,000 km^2), immediately prior to wolf control, to 11,500 in 1991 (885 moose/1,000 km^2), a four-fold increase (Table 1).

Harvest rates of male moose ranged from 2% to 7% and averaged 4% (Table 1). Harvests stabilized near 32 male moose/1,000 km^2 during the last 10 years. Higher male harvests in these years would have reduced the male:female ratio to below the desired 30:100. Regulations restricted hunting to male moose during this study.

Caribou Population Size and Harvest

Caribou numbers in the treated area increased for 8 years following the termination of wolf control and a total of 14 years from the initiation of wolf control (Fig. 2). The average annual finite rate of increase during these 14 years was 1.13. Subsequently, the herd declined for 3 consecutive years ($\lambda = 0.82$), simultaneous to declines in adjacent herds and the initiation of adverse weather.

No caribou were harvested during the year preceding wolf control, the 4 subsequent years, and the final year of this study (Table 1). Annual harvests averaged 548 $\pm$ 94 (SE) caribou (7% of the herd) during the 12 interim years and ranged from 104 to 1,324 (2-19% of the herd). About 85% of the 12-year harvest consisted of male caribou, but during the last 5 years of the study 95% of the harvest consisted of males (Table 1). During the herd's 3-year decline, harvest was reduced during the first and second years and terminated the third year.

Wolf Population Size and Harvest

Wolf numbers were effectively reduced from precontrol numbers during at least the first seven winters of this study; ADF&G staff removed significant numbers of wolves during five of these winters (Table 2). After each of the first five winters of this study, about 21-31% of the original precontrol wolf population remained in the treated area. During the subsequent two late-winter periods, 41-44% of the original wolf numbers remained.

No complete surveys were flown until four winters after the wolf control program; by this time the wolf population had recovered in most of the treated area. Wolves failed to recover in the extreme northern and northeastern portion of the treated area, where human activity was greatest. Two subsequent winter surveys confirmed that wolves had not recovered in the northern portions of the treated area. However, in the most recent survey, wolves had recovered in virtually all of the area and their numbers exceeded the original precontrol population size.

This recent increase occurred during a period of deep snow (Table 3). Deep snow in combination with increased functional and numerical responses by wolves probably caused the reduced moose and caribou recruitment (Table 1).

Effects of Weather on Moose, Caribou, and Wolf Populations

When moose attained moderate densities (790 moose/1,000 km^2), deep snow apparently caused reduced overwinter calf survival (Table 3). Significantly reduced moose recruitment ($P = 0.009$, $n = 16$, Mann-Whitney test) occurred simultaneous to significantly increased snow depth ($P = 0.017$, $n = 17$). However, the moose population continued to increase (Fig. 2). Calf moose survival to 5 months was not significantly affected by the deep snow ($P = 0.893$, $n = 16$).

Caribou calf survival to autumn declined significantly ($P = 0.009$, $n = 16$) during the 3 years of deep snow. Reduced caribou calf survival may have also been related to the significant reduction in summer precipitation ($P = 0.035$, $n = 14$), which occurred during the same 3 years, 1990-92 (Table 3). No significant difference occurred in the length or temperature of the growing season during these years ($P = 0.378$, $n = 17$). Reduced caribou calf recruitment was a major cause of the decline in the caribou herd during 1990-92.

Wolves increased substantially during the period of deep snowfall (1989-92), but surveys were too sporadic to determine if wolves increased early or late in this period (Fig. 2).

DISCUSSION

Effects of Wolf Control on Moose, Caribou, Harvest, and Wolves

To test the hypothesis that wolf control directly resulted in increased moose and caribou numbers and harvest, we compared data from the treated area with untreated areas. Gasaway *et al.* (1992) documented the occurrence of a low-density dynamic equilibrium for moose populations where moose were major prey of uncontrolled wolf and bear populations. These untreated moose populations ($n = 20$) averaged 148 moose/1,000 km² and ranged from 45 to 417 moose/1,000 km². In contrast, moose in the treated area increased from 223 moose/1,000 km² to 849 moose/1,000 km² following wolf control; this density is 6.7 times higher than the average moose density in comparable untreated areas in Alaska and the Yukon. This comparison suggests wolf control directly resulted in the prolonged increase in moose density in the treated area.

We also observed prolonged elevated and sustainable harvests of moose in the treated area (32 male moose/1,000 km², $n = 10$ years , Table 1) compared with untreated areas (0-18 male moose/1,000 km² for 3-year averages; Gasaway *et al.* 1992). If regulations had permitted hunting of female moose, sustainable harvest levels could have increased significantly in the treated area.

Bergerud (1980) reviewed the population dynamics of 31 caribou herds and reported that caribou only exceeded densities of about 400 caribou/1,000 km² when few wolves (<4 wolves/1,000 km²) coexisted in the ecosystem. Caribou densities in the treated area increased to 890 caribou/1,000 km² following wolf control. This increase was prolonged and recruitment increased coincidental to the initiation of wolf control (Table 3; Gasaway *et al.* 1983). In contrast, densities in the adjacent, untreated Denali and Macomb herds remained below 300 caribou/1,000 km² throughout the 17-year study period (DuBois 1992, McNay and Beasley 1992). These comparisons suggest wolf control directly resulted in the prolonged increase in caribou density in the treated area.

Caribou harvests per unit area in the treated area far exceeded values in adjacent, untreated areas. For example, sustainable harvests during 1980-89 in the treated area averaged 49 caribou/1,000 km² (range = 9-110, Table 1), in contrast to 0 harvest in the adjacent, untreated Denali herd (McNay and Beasley 1992) and 11 caribou/1,000 km² average harvest (range = 4-17, $n = 6$) in the adjacent, untreated Macomb herd (DuBois 1992). These data, together with data on the prolonged low density of the Denali and Macomb herds (<300 caribou/1,000 km²), indicate wolf control directly increased the sustainable yield of caribou in the treated area.

The long-term result of wolf control was to increase wolf density to 15.1 wolves/1,000 km², well above the average value (9 wolves/1,000 km²) reported for 15 Alaska and Yukon study sites where wolves were not controlled (Gasaway *et al.* 1992:39). Wolf densities increase proportionately with prey biomass (Fuller 1989, Keith 1983, Gasaway *et al.* 1992), so above-average wolf densities are expected following effective wolf control programs.

Differing Effects of Deep Snow on Moose

Historically, moose at high density in the treatment area suffered greater mortality rates from deep snow compared with moose at low or moderate densities. Moose were at high densities (1,800 moose/1,000 km² prehunting) in the treated area when deep snow (3.8 snow depth index) initiated a major decline in the moose population during winter 1965-66 (Bishop and Rausch 1974, Gasaway *et al.* 1983). Only 4 yearlings:100 adult females survived to autumn 1966 and adult mortality was high. Moose were above the long-term carrying capacity of the range in 1965 because of rapid increases in moose following federal predator control in the 1950s (Gasaway *et al.* 1983, 1992). The range may not have recovered prior to winter 1970-71, when a second snow-induced decline was observed (snow depth index = 4.9, 6 yearlings:100 adult females surviving, Bishop and Rausch 1974, Gasaway *et al.* 1983).

At low densities and after sufficient time for the range to recover, the moose population showed no adverse effects from deep snow. For example, when the prehunting moose population density was 623 moose/1,000 km², 26 yearlings:100 adult females survived through winter 1984-85 (snow depth index = 3.7, Table 3). At moderate densities of about 840 moose/1,000 km² during winter 1990-91, the deepest snowfall on record (snow depth index = 5.3) was followed by moderately reduced overwinter calf survival (17 yearlings:100 adult cows) and no population decline (Fig. 2, Table 3).

We suggest that, if managers want to safely avoid strong snow-induced declines in moose numbers, moose densities be held well below 1,800 moose/1,000 km² in the treated area. Strong snow-induced declines were avoided by keeping moose densities at densities below 900 moose/1,000 km², but significant reductions in overwinter calf survival were documented at densities of 840 and 885 moose/1,000 km². No data are available to test the effects of deep snow on moose densities between 900 and 1,800 moose/1,000 km².

Synchronous Declines in Caribou Herds at Various Densities

We examined calf survival in the treated Delta caribou herd and untreated adjacent Denali and Macomb herds to test the hypothesis that the decline of the Delta herd in 1990 was a density-independent response. All three herds exhibited significant declines in calves:100 females older than calves ($P < 0.02$, Mann-Whitney test) during 1990-92 compared with prior years (Table 4). However, 1990 densities varied from 758 caribou/1,000 km² in the Delta herd to 237/1,000 km² in the Macomb herd and 295/1,000 km² in the Denali herd (DuBois 1992, McNay and Beasley 1992).

We conclude that a decline in the Delta herd in 1990 would have occurred regardless of the herd's high density. Data previously reported here indicate that factors other than density, probably deep snow and reduced rainfall, reduced caribou recruitment in the northern Alaska Range caribou herds during 1990-92. Deep snow adversely affects caribou by increasing energy expenditure and reducing food intake, and reduced rainfall can adversely affect caribou by increasing insect harassment and reducing diet quality (Boertje 1984; 1985*a,b*; 1990). Valkenburg (1992) reported significant reductions in pregnancy rates of female caribou ≥ 3 years old ($P < 0.01$) and significant reductions ($P < 0.05$) of 10-month-old calf weights in the Delta herd during 1990-92 compared with prior years. Also, Adams *et al.* (1993) reported decreased caribou calf birth weights and increased perinatal mortality during 1990-92 in the Denali herd.

CONCLUSIONS

We conclude that wolf control resulted in long-term substantial increases in the moose, caribou, and wolf populations and in the harvest of moose and caribou. However, moose should not be allowed to increase to levels where deep snow can cause substantial declines in the population (1,800 moose/1,000 km² in 1965). Significant reductions in overwinter moose calf survival were documented at densities of 840 and 885 moose/1,000 km² during deep snowfall winters, but no population declines occurred. The caribou herd in the treated area showed no strong density-dependent responses at densities up to 892 caribou/1,000 km², but adverse weather initiated declines in caribou herds at low and high densities (237-892 caribou/1,000 km²).

Peer review of this final report will provide the basis for a manuscript to be submitted to the Journal of Wildlife Management. Objectives will be achieved upon completion of this publication.

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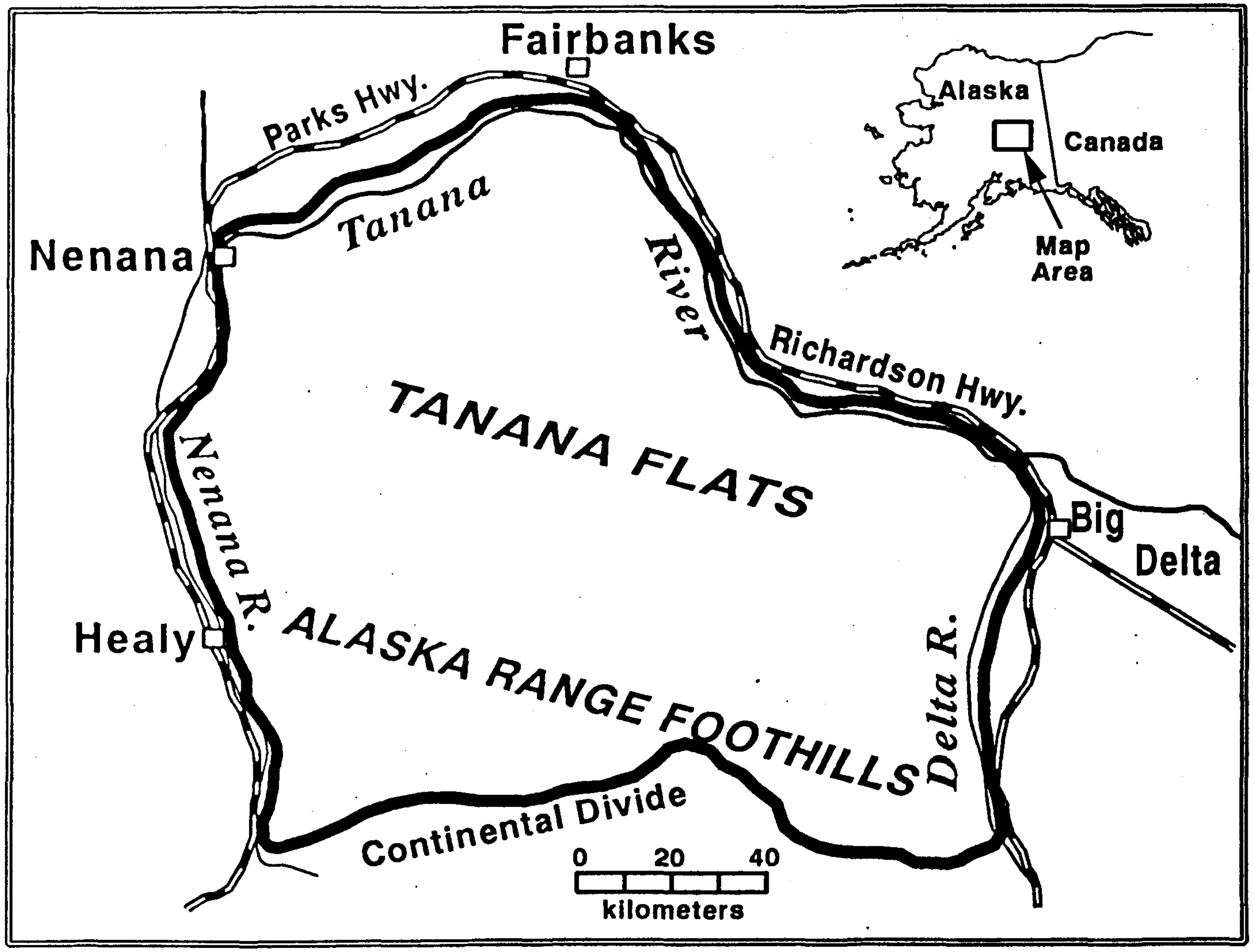


Fig. 1. Treated area in Interior Alaska containing 13,000 km^2 of moose habitat where agency wolf control occurred during five winters, 1975-76 through 1978-79 and 1981-82.

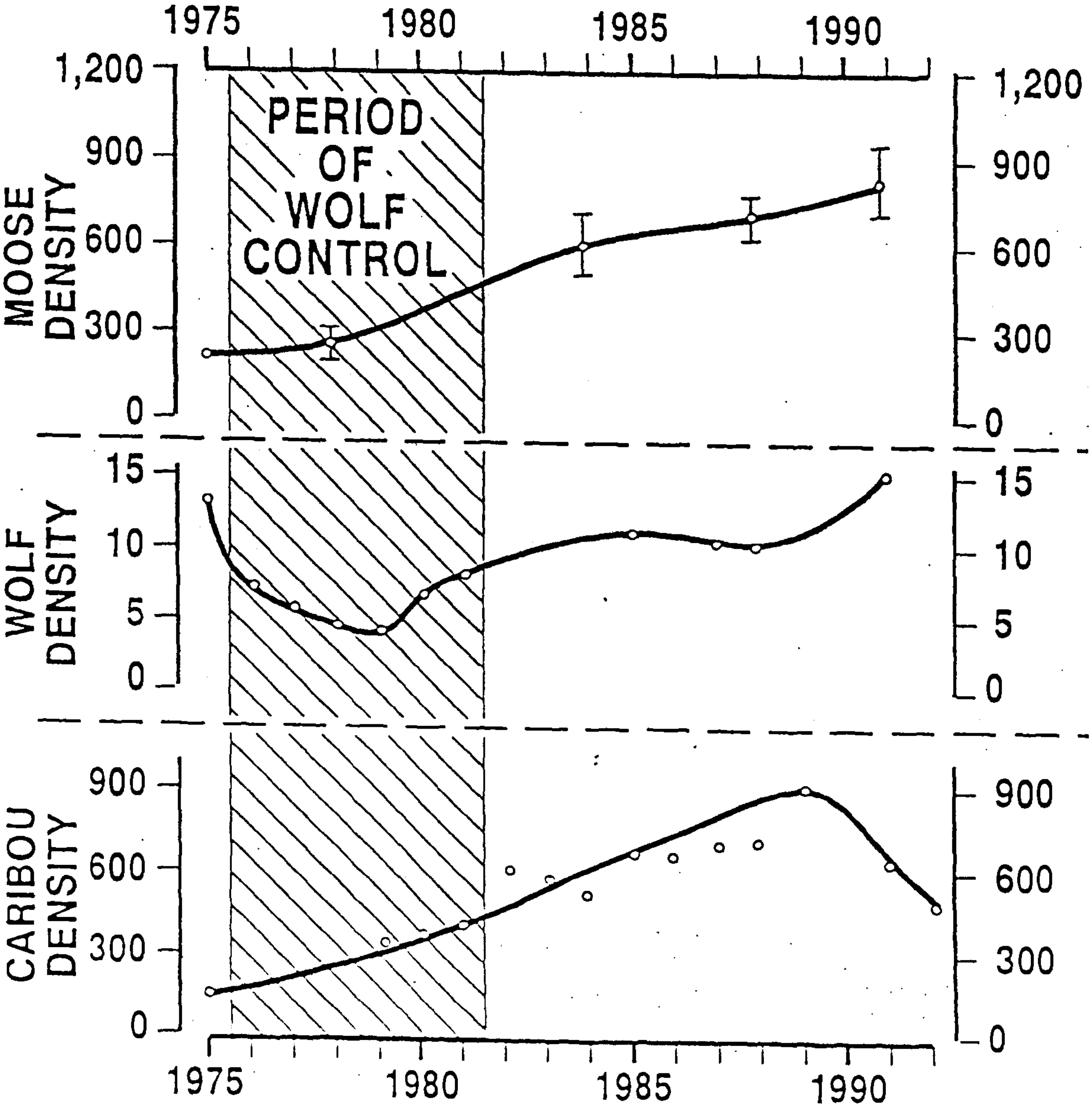


Fig. 2. Estimated and relative numbers of moose, wolves, and caribou per 1,000 km² in the treated area, Interior Alaska, 1975-92. The 90% CI's are shown for moose population estimates. Autumn wolf densities were based on use of 17,500 km², encompassing all wolf pack territories completely or mostly in the treated area. Early winter moose densities were based on an area of 12,419 km² in 1984, 12,065 km² in 1975 and 1978, and 13,044 km² in 1988 and 1991. Summer caribou densities were based on an area of 12,000 km².

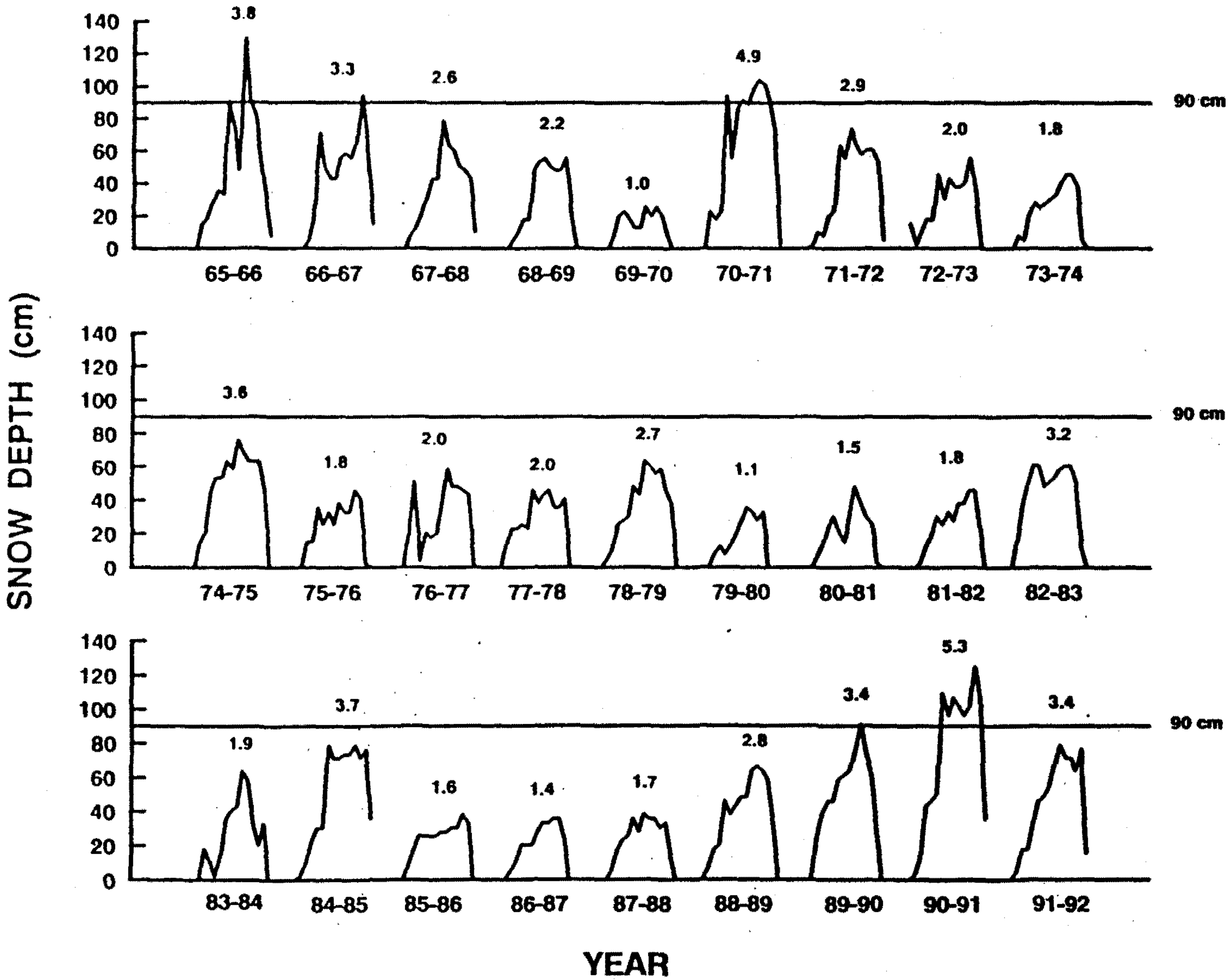


Fig. 3. Snow depth on the ground during winters 1965-66 through 1991-92 at Fairbanks, Alaska. Curves were constructed from snow depth measurements on the first and fifteenth of each month. Snow depth index (shown above each curve) was calculated by dividing the area under each curve by the area of lowest snowfall, 1969-70. Snow depth of 90 cm, indicated by the solid line, was considered the critical depth for calf moose survival (Coady 1974).

Table 1. Estimated number of moose and caribou harvested in relation to population size within the treated area during wolf control (1976-82) and after wolf control (1983-91), central Alaska.

Year	No. of moose prehunting[a]	No. of male moose harvested	Percent of moose population harvested	No. of caribou prehunting	No. of total caribou harvested	No. of female caribou harvested	Percent of caribou population harvested
1975	2,900	72	2	2,200	0	0	0
1976	3,100	71	2	2,700	0	0	0
1977	3,400	58	2	3,100	0	0	0
1978	3,600	92	3	3,500	0	0	0
1979	4,100	150	4	4,191	0	0	0
1980	4,800	238	5	4,478	104	0	2
1981	5,500	319	6	4,962	268	73	5
1982	6,200	335	5	7,335	274	77	4
1983	6,700	459	7	6,969	1,324	199	19
1984	8,100	449	6	>6,260[b]	565	186	<9
1985	8,500	414	5	8,083	596	119	7
1986	8,900	483	5	>7,804[b]	841	183	<11
1987	9,200	346	4	8,380	664	38	8
1988	9,700	404	4	>8,500[b]	555	21	<7
1989	10,300	429	4	10,690	681	16	6
1990	10,900	423	4	9,100[c]	552	64	6
1991	11,500	439	4	7,600[d]	452	21	6
1992	--	--	--	5,877	0	0	0

[a] Estimated by adding number of moose harvested to early winter population estimate from Fig. 2 and rounding to nearest 100 moose.

[b] Conservative estimates based on incomplete censuses and demographic data (Davis *et al.* 1991).

[c] Midpoint between 1989 and 1991 census because no 1990 census was conducted.

[d] Extrapolated estimate based on aerial estimates and independent spreadsheet modeling (Valkenburg 1992).

Table 2. Estimates of wolf population size and harvest in a 17,500-km^2 area, encompassing all wolf pack territories completely or mostly in the treated area, 1975-91.

Winter period	Autumn wolf population	No. of survey hours	No. of wolves killed			Late winter wolf population	Percent of pre-control population remaining by late winter (x)	Percent of autumn population killed	Autumn wolf density (wolves/ 1,000 km^2)
			ADF&G	Public	Total				
1975-76	239	324	67	78	145	60-80	25-33 (29)	61	13.7
1976-77	125	325	27	26	53	70-80	29-33 (31)	42	7.1
1977-78	100	111	39	4	43	55-65	23-27 (25)	43	5.7
1978-79	80	101	18	12	30	45-55	19-23 (21)	38	4.6
1979-80	64-84	60	3	11	14	50-70	21-29 (25)	19	4.2
1980-81	100-125	40	0	13	13	87-111	36-46 (41)	12	6.4
1981-82	130-157	60	20	19	39	91-118	38-49 (44)	27	8.2
1982-83	--	--	0	14	14	--	--	--	--
1983-84	--	--	0	24	24	--	--	--	--
1984-85	--	--	0	23	23	--	--	--	--
1985-86	195	50	0	24	24	171	N.A.[a]	12	11.1
1986-87	--	--	0	37	37	--	--	--	--
1987-88	191	100	0	36	36	155	N.A.	19	10.9
1988-89	184	215[b]	0	32	32	152	N.A.	17	10.5
1989-90	--	--	0	31	31	--	--	--	--
1990-91	--	--	0	55	55	--	--	--	--
1991-92	264	125	0	67	67	197	N.A.	25	15.1

[a] N.A. = not applicable.

[b] Value includes 150 hours of radio-tracking 11 packs.

Table 3. Indices to moose and caribou recruitment, snow depth, length of the growing season, and rainfall for the treated area, 1974-92. *n* equals total number of moose or caribou classified during the survey period.

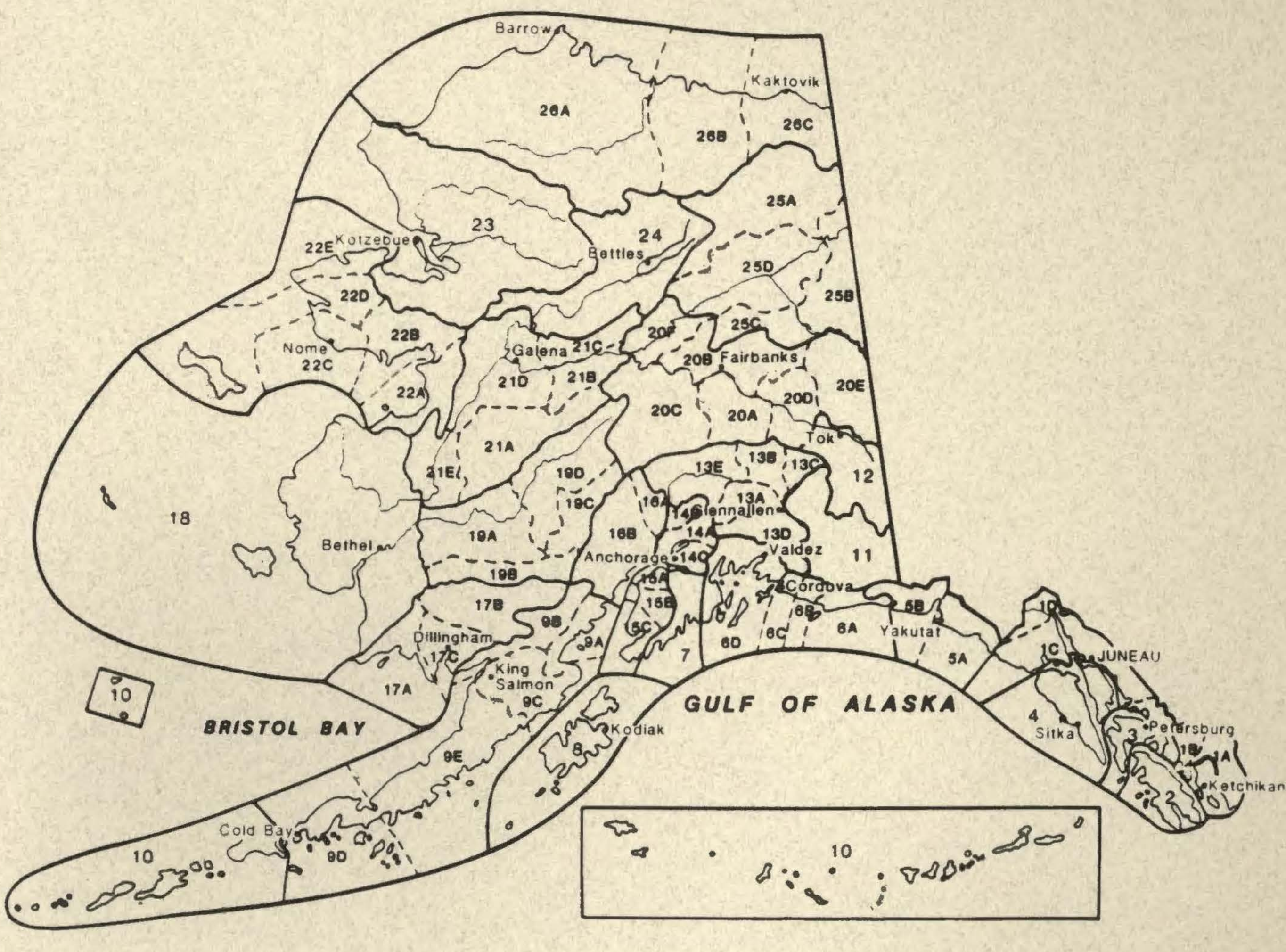
Year of Sep-Nov surveys	5-mo-old moose calves:100 adult females[a]	17-mo-old moose yearlings:100 adult females	*n*	Caribou calves: 100 females older than calves in Sep or Oct	*n*	Snow depth index for preceding winter	Total degree-days per growing season (°C)	Total summer rainfall (cm)
1974	19	5	629	2	1,141	1.8	1,146	--
1975	15	10	602	--	--	3.6	1,319	--
	Wolf control began							
1976	51	32	362	45	1,055	1.8	1,096	--
1977	49	44	700	42	1,365	2.2	1,191	6.5
1978	61	50	403	39	725	2.0	1,090	--
1979	57	52	316	--	--	2.7	1,110	15.2
1980	62	47	515	49	1,369	1.1	985	14.2
1981	46	39	672	41	1,553	1.5	871	13.9
	Wolf control ended							
1982	38	42	1,499	34	1,691	1.8	1,050	22.5
1983	40	43	248	41	1,333	3.2	1,135	13.9
1984	34	23	2,582	36	1,093	1.9	1,019	--
1985	36	26	623	36	1,164	3.7	1,038	12.4
1986	35	27	436	29	1,934	1.6	1,043	12.1
1987	37	20	1,582	31	1,683	1.4	1,206	12.2
1988	50	27	3,578	35	3,003	1.7	1,293	14.6
1989	--	--	--	36	1,965	2.8	1,188	17.0
1990	52	17	804	17	2,411	3.4	1,329	9.9
1991	37	17	2,480	8	1,705	5.3	1,105	9.4
1992	39	15	349	11	1,240	3.4	1,072	10.3

[a] Adult females are females $\geq$29 months old.

Table 4. Calves:100 female caribou older than calves in the treated Delta herd and untreated Denali and Macomb herds during September-November 1981-92, northern Alaska Range. Dashes indicate no data were collected.

	Treated herd		Untreated herds			
	Delta		Denali		Macomb	
Year	Calves: 100 females	*n*	Calves: 100 females	*n*	Calves: 100 females	*n*
1981	41	1,451	--	--	33	445
1982	31	1,565	--	--	26	217
1983	46	1,208	--	--	24	238
1984	36	1,093	41	1,608	40	351
1985	36	1,164	28	1,205	31	518
1986	29	1,934	38	1,062	--	--
1987	31	1,682	37	1,221	--	--
1988	35	3,003	33	1,350	32	671
1989	36	1,965	30	1,504	34	617
Herds Declined						
1990	17	2,411	17	1,307	17	734
1991	8	764	7	1,548	9	560
1992	11	1,240	16	1,028	14	455

Alaska's Game Management Units



Federal Aid in Wildlife Restoration

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. Alaska receives 5% of the revenues collected each year, the maximum allowed. The Alaska Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be reponsible hunters. Seventy-five percent of the funds for this project are from Federal Aid.