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Testing Socially Acceptable Methods of Managing Predation: Reducing Predation on Caribou and Moose Neonates by Diversionary Feeding of Predators, Macomb Plateau, 1990–94

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PROGRESS REPORT (RESEARCH)

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SUMMARY

This study tests whether artificial feeding of grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), and wolves (*Canis lupus*) can reduce predation on newborn moose (*Alces alces*) and/or caribou (*Rangifer tarandus*). If successful, this technique could provide a means to enhance moose or caribou populations without resorting to lethal methods to control predation. The Alaska Department of Fish and Game is obligated to investigate alternatives to lethal predator control because of the high economic, political, and social costs of such control methods.

We distributed 26 metric tons of bait from 14 May to 5 June in 1990 and 16 metric tons during the same dates in 1991 in a 1,650-km² area, hereafter referred to as the "treated area." Bait consisted largely of train-killed or winter-killed moose unsalvageable for human consumption. During 1992 we distributed no bait; 1992 served as a control year to document calf survival without treatment.

Bears (mostly grizzly bears) and wolves consumed 79% of the baits by 14 June 1990, as evidenced by dismembered skeletons and aerial observations of bears and wolves at baits. In 1991, grizzly bear tracks were in evidence at 50% of 30 sites investigated on 3-4 June. Grizzly bears and wolves were common in the treated area.

Treatment apparently resulted in enhanced moose calf survival to November 1990; moose calf survival was the highest recorded (42 calves:100 cows $\geq$2 years old) in the area compared with similarly derived 1981-89 pretreatment values (19-38, $\bar{x}$ = 25, SD = 9, n = 8) when winters were less severe. The reduced level of treatment in 1991 did not significantly elevate moose calf survival in the treatment area. Data collected to date suggest that 20 or more metric tons of bait may be necessary to deter predators from preying on newborn moose calves in the 1,650-km² treated area.

Other data also suggest the treatment in 1990 increased moose calf survival. For example, elevated 1990 moose calf survival was not widespread. Untreated control moose populations and adjacent, partially treated moose populations experienced low calf survival in 1990 (11-31 calves:100 cows $\geq$2 years old). In contrast, in 1991,

one of the untreated control populations experienced higher calf survival than the treated area.

Caribou calf survival was extremely poor following treatment in 1990 and 1991, yet survival was similar to control herds. Caribou calf telemetry studies in the Alaska Range Denali herd indicated that poor environmental conditions favored reduced productivity, increased nonpredation perinatal mortality, and increased predation on adults, which together resulted in population declines in 1990 and 1991 (L. Adams, unpubl. data). Increased wolf numbers also occurred during recent years in Denali National Park, Alaska (T. Meier, National Park Service, pers. commun.). Feeding of predators apparently cannot deter high predation rates on Macomb caribou calves under these poor environmental conditions.

We recommend terminating this project pending 1 more year of control data. Further study is not recommended until funding levels and environmental conditions are suitable to test this technique in an area where moose are clearly limited by bear predation. A moose calf mortality study should be funded before treatment to ascertain if bears are the major predator on moose calves.

A draft manuscript that includes our conclusions was written during this report period and submitted for publication in the *Proceedings of the Second North American Wolf Symposium*. This manuscript is entitled "Methods for reducing natural predation on moose in Alaska and the Yukon: an evaluation" and is included as Appendix A.

Key Words: Alaska, baiting, bears, calf survival, calving, caribou, diversionary feeding, feeding, moose, predator-prey relationships, wolves.

CONTENTS

BACKGROUND

Humans manage wildlife populations to influence a desired outcome. For example, humans sometimes desire more ungulates than occur naturally. The elevated numbers of ungulates may be important to help protect habitat from competing land uses and/or to provide for consumptive and/or nonconsumptive uses of wildlife.

Moose (*Alces alces*) populations in much of Alaska and the Yukon are limited below food-limited densities by predation (Gasaway et al. 1992). For example, predation limits moose populations at chronically low densities where moose are a primary prey of lightly exploited wolf (*Canis lupus*), black bear (*Ursus americanus*), and grizzly bear (*Ursus arctos*) populations. In areas where wolves and bears were at near-natural densities, the mean density was only 148 moose/1,000 km^2 ($\underline{n}$ = 20 areas, range = 45-417, SD = 81), compared with a mean of 663 moose/1,000 km^2 ($\underline{n}$ = 16 areas, range = 169-1,447, SD = 389) in areas where humans maintain wolves and, in some cases, bears below food-limited densities (Gasaway et al. 1992).

Apparently moose do not occur at a high-density equilibrium without continued predator management, except where moose are (1) preyed on by only one predator species (Messier and Crete 1985, Crete 1987, Bergerud and Snider 1988, Messier 1988), (2) preyed on by black bears and grizzly bears (wolves extirpated) with or without alternate ungulate prey (Houston 1968, Bailey 1978, Peterson et al. 1984), or (3) minor prey in wolf-bear multiprey systems (Crete 1987, Bergerud and Snider 1988). In Alaska, wolves, moose, and one or both species of bears occupy the same habitats. Caribou (*Rangifer tarandus*) are rarely the primary prey, except in portions of the Brooks Range and arctic coastal plain. Therefore, Alaskan moose populations can be expected to occur at low densities, except where wolf and/or bear populations are strongly manipulated by humans.

To manage for elevated densities of caribou, managers must also counter strong natural processes (Bergerud and Elliot 1986). Although some Alaskan caribou populations have periodically increased with little human intervention (Skoog 1968), caribou population growth is limited at low densities by predation, and increases are temporary (Bergerud 1980, Bergerud and Elliot 1986). Mainland caribou densities (i.e., $\leq$400 caribou/1,000 km^2 in areas where wolves are nearly unexploited) are frequently well below those where food limitation caused a reduction in caribou populations (Bergerud 1980, Skogland 1986).

Reductions in predator populations by the public (e.g., same-day-airborne shooting) and/or the Alaska Department of Fish and Game (ADF&G) have contributed to recent increases in many Alaskan caribou herds (e.g., Nelchina, Delta, and Fortymile) (Gasaway et al. 1983, Ballard et al. 1987, Boertje et al. 1987, Valkenburg and Davis 1988). Recent controversy over these methods highlights the need for socially acceptable alternatives to lethal control if moderate caribou densities are to be maintained.

The Division of Wildlife Conservation is obligated to provide the long-term conservation of large carnivore populations throughout Alaska as well as to reduce the controversy surrounding management of large carnivores. The division established a framework for citizen involvement in developing a strategic wolf management plan. Evaluating more nonlethal ways to manage predator-prey relationships was integral to this process in areas where the public requests ungulate-predator systems to be managed for increased human use of ungulates (Boertje et al., in press).

Several alternatives to intense, lethal, government-conducted or public predator control have been proposed for managing predator-prey relationships (Gasaway et al. 1990; Boertje et al., in press). This study assesses if, and to what extent, diversionary feeding of predators reduces predation and facilitates management of caribou-moose-predator relationships.

Preliminary evidence indicates that diversionary feeding of predators may increase survival of caribou and/or moose neonates. During May and June 1985, we air-dropped approximately 12-15 tons of train-killed moose and scrap meat to attract grizzly bears for collaring purposes in and near Mosquito Flats, an important moose calving area north of Tok. We observed that grizzly bears, wolves, and black bears consumed much of this meat and that fall moose calf:cow ratios were higher than normal. The 1985 early winter calf:cow ratio was 53:100 ($\underline{n}$ = 17 cows), compared with a range of 11-15:100 ($\underline{n}$ = 26-39) during the 3 preceding years and a range of 26-36:100 ($\underline{n}$ = 25-27) during 1986 and 1987. Also, the 1985 response was not observed in untreated adjacent areas (10-19:100, $\underline{n}$ = 25-70); however, some of the increase in calf survival may have resulted from immobilization and slow recovery of bears (4-5 days), rather than the introduction of meat.

Other circumstantial evidence also suggests that diversionary feeding for 1 month during and immediately following the calving season may increase caribou and moose calf survival. Most mortalities among caribou and moose populations in central and southern Alaska and the Yukon occur on neonates during the first 2-3 weeks of life. Predation is the major cause of these mortalities (Franzmann et al. 1980; Ballard et al. 1981; Boertje et al. 1987, 1988; Adams et al. 1988; Larsen et al. 1989).

The Macomb caribou herd has been small (≤800 caribou, 200 caribou/1,000 km²) for 2 decades or more, yet management goals for the herd call for increasing the herd to 1,000-1,500 caribou by 1997. The herd's location along the road system makes it ideally suited to this study. Substantial public benefits would be incurred from increased caribou, moose, and wolves in this area. Since intensive wolf removal during winter 1980-81, the herd may have grown from 500-600 caribou to about 800 during October 1988; however, neonatal calf mortalities have remained high since wolf removal ceased. Causes and chronology of these mortalities are probably similar to those recently documented in the Denali caribou herd where predators (i.e., primarily grizzly bears) killed about 39% of the collared calves by 1 June during 1984-88 (Adams et al. 1988).

OBJECTIVES

Objectives for this study are to:

1. Estimate the change in survival of neonatal moose and density of the moose population resulting from diversionary feeding of wolves and bears on and adjacent to the Macomb Plateau from 1990 to 1994.

2. Estimate the changes in the survival of neonatal caribou and size of the caribou population resulting from diversionary feeding of wolves, bears, golden eagles (*Aquila chrysaetos*), and bald eagles (*Haliaeetus leucocephalus*) on and adjacent to the Macomb Plateau from 1990 to 1994.

STUDY AREA

We distributed food for predators in a 1,650-km² portion of the Alaska Range and adjacent lowlands between elevations of 400 and 1,550 m (Fig. 1). This treated area includes the calving ground of the Macomb caribou herd (Fig. 2) and portions of the Knob Ridge and Robertson River moose calving grounds. The treated area is centered around 63° 35'N latitude and 144° 30'E longitude.

Moose populations used as controls in this study include the Central Creek and eastern Subunit 20E moose populations, which are 80 km north and 120 km east of the treated area, respectively. Caribou herds used as controls include the Denali and Delta herds, which are 290 km west and 160 km west of the treated area, respectively. The Macomb, Denali, and Delta herds share the northern slopes of the Alaska Range.

A subarctic and continental climate occurs in the treated and control areas. "Winter" occurs from October through April. Leaves emerged on most shrubs on the Macomb Plateau during 26-27 May 1990 and 15-20 June 1991, and leaves usually fall in late August. Total annual precipitation averages 24 cm at Tok, 60 km east of the plateau (National Oceanic and Atmospheric Administration 1986).

Wolves, black bears, and grizzly bears occur at near natural densities in the treated and control areas; i.e., predator-prey relationships had not been strongly manipulated by humans during the 8-9 years before this study. One exception is that grizzly bear density has been reduced by harvest in recent years in the Delta herd's range (Reynolds 1990). Moose, caribou, and Dall sheep (*Ovis dalli*) are the major prey in the treated and control areas, except the Central Creek and eastern Subunit

20E areas where there are no sheep. Minor prey in these areas include snowshoe hares (*Lepus americanus*), beavers (*Castor canadensis*), hoary marmots (*Marmota caligata*), and, except in the Central Creek and eastern Subunit 20E control areas, arctic ground squirrels (*Citellus parryii*).

METHODS

Carcass Collection and Storage

During winter 1989-90, 26 metric tons of bait were collected. The Alaska Railroad Corporation collected 60 train-killed moose, using a crane or ditcher mounted on a railroad car. These carcasses were stored in the town of Willow until they could be transported to Cummings' Sawmill near Delta Junction (Fig. 1). An additional 30 unsalvageable carcasses were collected near Delta Junction and Fairbanks; most of these carcasses were winter-killed moose calves. About 4% of the bait were spawned red salmon carcasses collected from the Paxson Hatchery; carcasses were frozen and stored in Fairbanks until April. Upon arrival at the sawmill (Jan-Apr 1990), bait was covered with sawdust for cold storage until distribution.

During winter 1990-91, 16 metric tons of bait were collected. Most of this bait consisted of unsalvageable starved or road-killed moose collected in and around Fairbanks by a local volunteer organization, the Moose Mobile. In addition, the Alaska Railroad Corporation collected several unsalvageable train-killed moose. Twenty adult and 43 calf moose carcasses were collected by these two methods. Less than 5% of the bait consisted of outdated, unsalvageable dog food contributed by Kobuk Feed Company of Fairbanks. Carcasses were stored at Cummings' Sawmill under sawdust from April until distribution in May and early June.

Bait Distribution and Use Monitoring

During 1990, bait ($\underline{n}$ = 87 baits, $\bar{x}$ = 300 kg) was distributed using Army UH-1 helicopters (40 flight hours) on 14 and 15 May ($\underline{n}$ = 29 baits), 21 and 22 May ($\underline{n}$ = 25 baits), and 30 May 1990 ($\underline{n}$ = 33 baits). We baited in a 1,650-km^2 area around Macomb Plateau near calving caribou and moose (Fig. 1). To aid relocation of carcasses, we directed the helicopters to each bait site using light fixed-wing aircraft (Bellanca Scout or Piper Super Cub). One bait was deposited at each site ($\underline{n}$ = 61 sites) and replenished as necessary during successive baiting periods; some sites received up to three baits (Fig. 1).

To monitor 1990 bait use, we made several low passes over bait sites using light fixed-wing aircraft at 4- to 10-day intervals through 14 June. We deemed a bait "largely consumed" when it was over 50% gone. In a large majority of these cases, only hair and scattered bones remained, but in a few cases hides and a low percentage (<20%) of meat remained.

In 1991, bait ($\underline{n}$ = 68 baits, $\bar{x}$ = 256 kg) was distributed using ADF&G equipment, including a DeHavilland Beaver aircraft, riverboat, and 4x4 pickup truck. Baits were distributed 14-17 May ($\underline{n}$ = 16), 21-24 May ($\underline{n}$ = 28), 28-31 May ($\underline{n}$ = 20), and 5 June ($\underline{n}$ = 4) in the 1,650-km^2 treated area (Fig. 2). We monitored bait use along the Alaska Highway and Tanana River before distributing new baits. Some sites ($\underline{n}$ = 43 total) received up to three baits (Fig. 2).

Between 15 and 30 May 1991, we distributed chemical scents throughout the treated area at weekly intervals to distract predators from preying on calves. We used skunk essence and Carman's Canine Call Lure (CCCL) and distributed the scents on rocks (n = 67) and cotton-tipped arrows (n = 85) along the Alaska Highway and Tanana River. We also placed about 4 cc of CCCL and 10 cc of water in water balloons (n = 94) and distributed these across the subalpine portions of the treated area using a DeHavilland Beaver aircraft. In addition, scent was placed adjacent to carcass sites along the Alaska Highway and Tanana River (n = 25, Fig. 2).

Monitoring Moose Calf Survival

Between 18 October and 13 November 1990 and 1991, moose surveys were flown in the Knob Ridge treated area, the upper Robertson River partially treated area, and the Central Creek and eastern Subunit 20E control areas. The Knob Ridge and Central Creek survey areas were 181 km^2 and 161 km^2, respectively, and were flown at 1.5 to 1.9 min/km^2 as prescribed by Gasaway et al. (1986). In contrast, the Robertson River and eastern Subunit 20E survey areas were much larger (350 and 900 km^2, respectively) and flown less intensively, about 0.8 min/km^2.

Monitoring Caribou Pregnancy and Survival

1990 Methodology:

Using a Piper Super Cub and Bellanca Scout, we examined the 18 adult ($\geq$3 years old) radio-collared Macomb caribou on 14 and 20 May for evidence of pregnancy; i.e., retention of antlers and presence of distended udders. Pregnant collared caribou were radio-tracked after 20 May at 2- to 6-day intervals through 8 June to determine calving distribution and survival of calves. Using a Hughes 500 helicopter, we classified 600 caribou on 14 June and 734 on 9 October.

1991 Methodology:

Using a Piper Super Cub, we examined 16 radio-collared Macomb caribou for evidence of pregnancy or newborn calves on 16, 21, and 23 May and 11 June. We also used a Hughes 500 helicopter on 11 June to classify 319 caribou and on 25 September to classify 560 caribou as either calves, females $\geq$1 year old, or males $\geq$1 year old.

RESULTS AND DISCUSSION

Consumption of Bait

Most observations on bait consumption occurred during 1990. Scavengers largely consumed 76 (88%) of the 87 baits by 14 June 1990 (Fig. 3). Approximately 45-50% of the baits were largely consumed within 10 days of distribution, and an additional 30-40% during the following 10 days. Bears (mostly grizzly bears) and wolves consumed 79% of the baits, as evidenced by observations of these animals at baits and dismembered moose skeletons. Removal and/or burial of baits occurred at 44% of the 87 drop sites, indicating grizzly or black bear use; however, because bears did not always move or bury baits, they may have consumed >44% of the baits. We estimated that golden and bald eagles consumed about 9% of the baits. During 1991, we observed grizzly bear sign at 15 of 30 sites checked on 3-4 June. Black bears, wolves, and eagles were minor scavengers at several of these sites.

Predator Densities

Grizzly bears and wolves are common in the treated area. In 1990, 13 different grizzly bears ≥2 years old were observed on a 1,000-km² area on and adjacent to the Macomb Plateau (eight adult bears, four 3-year-olds, and one 2-year-old). This is a high density for grizzly bears in the Alaska Range (Reynolds 1990) and adjacent Fortymile River drainage (Boertje et al. 1987).

We estimated 19 wolves ranged within the treated area in fall 1989, 25 in fall 1990, and 16 in fall 1991. Ten percent of these were single wolves (Mech 1973). The wolves ranged over a 2,000-2,500 km² area, indicating a high wolf density relative to adjacent areas (Boertje et al. 1987, Gasaway et al. 1990). One pack member was radio-collared in April 1990 to help distinguish packs in the study area, but this wolf was shot in March 1991.

Moose Calf Survival

Treatment with 26 metric tons of bait in May and June 1990 resulted in enhanced moose calf survival to November 1990; moose calf survival was the highest recorded (42 calves:100 cows ≥2 years old) in the area compared with similarly derived 1981-89 pretreatment values (19-38, $\bar{x}$ = 25, SD = 9, $\underline{n}$ = 8) when winters were less severe (Table 1). In contrast, following treatment with 16 metric tons in May and June 1991, only 32 calves:100 cows ≥2 years old survived to November 1991. We conclude that 16 metric tons of bait may have been insufficient to elicit a response in calf survival.

Other data also suggest the 1990 bait treatment increased moose calf survival. For example, elevated 1990 moose calf survival was not widespread (Table 1). Untreated control moose populations and adjacent, partially treated moose populations experienced low calf survival in 1990 (11-31 calves:100 cows ≥2 years old). In contrast, in 1991 one untreated control population experienced higher calf survival than the treated area.

Caribou Calf Survival

Caribou calf survival declined significantly in 1990 in several Alaska Range herds, including the Macomb herd. Caribou calf survival remained low in 1991 (Table 2). Diversionary feeding of predators in 1990 and 1991 failed to improve Macomb caribou calf survival. In 1990, 15 (83%) of 18 collared female caribou ≥3 years old were pregnant and 12 calves (80%) survived to 8 June (Fig. 3). However, 1990 calf survival in the herd was poor (about 50% survival by 14 June, 32 calves:100 females, $\underline{n}$ = 600; Boertje et al. 1990). In 1991, 10 (83%) of 12 collared female caribou ≥3 years old were pregnant, but only 1 of the 10 calves was alive on 12 June. Calf survival in the herd was estimated at 25% on 12 June 1991 (64 calves:100 females ≥1 year old born and 16 calves:100 females alive on 12 June, $\underline{n}$ = 319).

Mortality studies of telemetered caribou calves in the Alaska Range Denali herd indicate that calf birth weights declined during 1990 and 1991 possibly because of drier summers and/or deeper than average snowfall (L. Adams, unpubl. data). Average age of first reproduction has also increased in the Denali herd. These poor conditions for caribou favored increased wolf numbers (T. Meier, U.S. National Park Service, pers. commun.). Initial declines in caribou numbers caused by poor environmental conditions can be exacerbated quickly by elevated wolf numbers and wolf predation. The result can be prolonged accelerated declines in caribou because of rapidly changing wolf:caribou ratios. Predation management using diversionary feeding appears incapable of reversing this declining trend. No data were available from June 1992 during this writing.

CONCLUSIONS

Our evaluation of diversionary feeding as a management tool is summarized in Appendix A. Diversionary feeding appears to hold promise as a tool to reduce bear predation on moose calves, but costs may be prohibitively expensive.

RECOMMENDATIONS

We recommend terminating this project until funding levels and environmental conditions are suitable for testing this technique in an area where moose are clearly limited by bear predation. Commercial bear food costs may total about $40,000 for annual treatment of a 2,000-km^2 area, and these costs currently prohibit intensive testing of this technique. Also, collaring moose calves is currently cost prohibitive. A moose calf mortality study prior to baiting is necessary to determine if bears are the major source of mortality.

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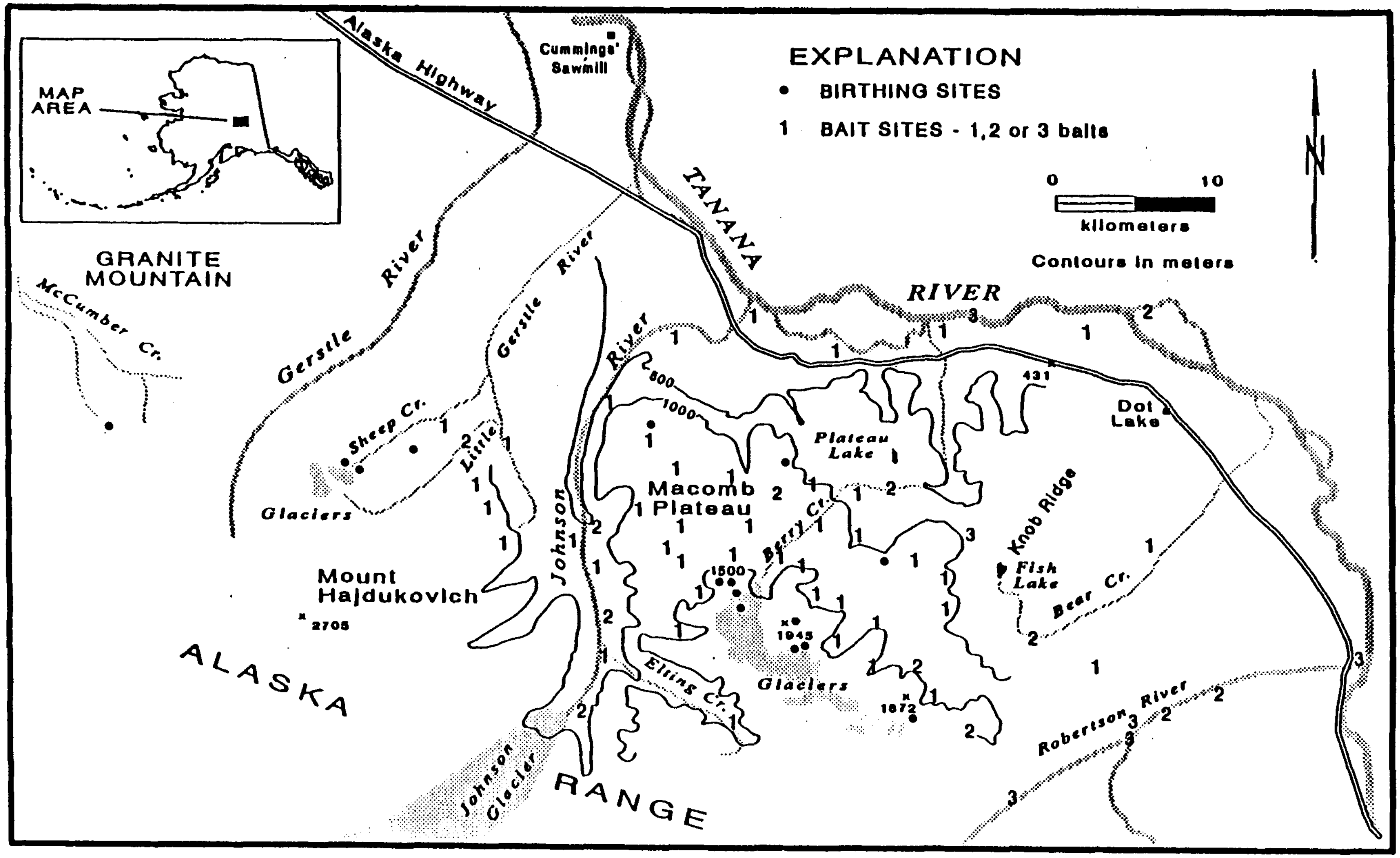

Figure 1. Birthing sites (.) of 15 adult radio-collared Macomb caribou and location of bait sites (1, 2, or 3 baits), eastcentral Alaska, May 1990. Bait sites ($\underline{n}$ = 61) were replenished up to 3 times at weekly intervals ($\underline{n}$ = 87 baits, $\underline{x}$ = 300 kg).

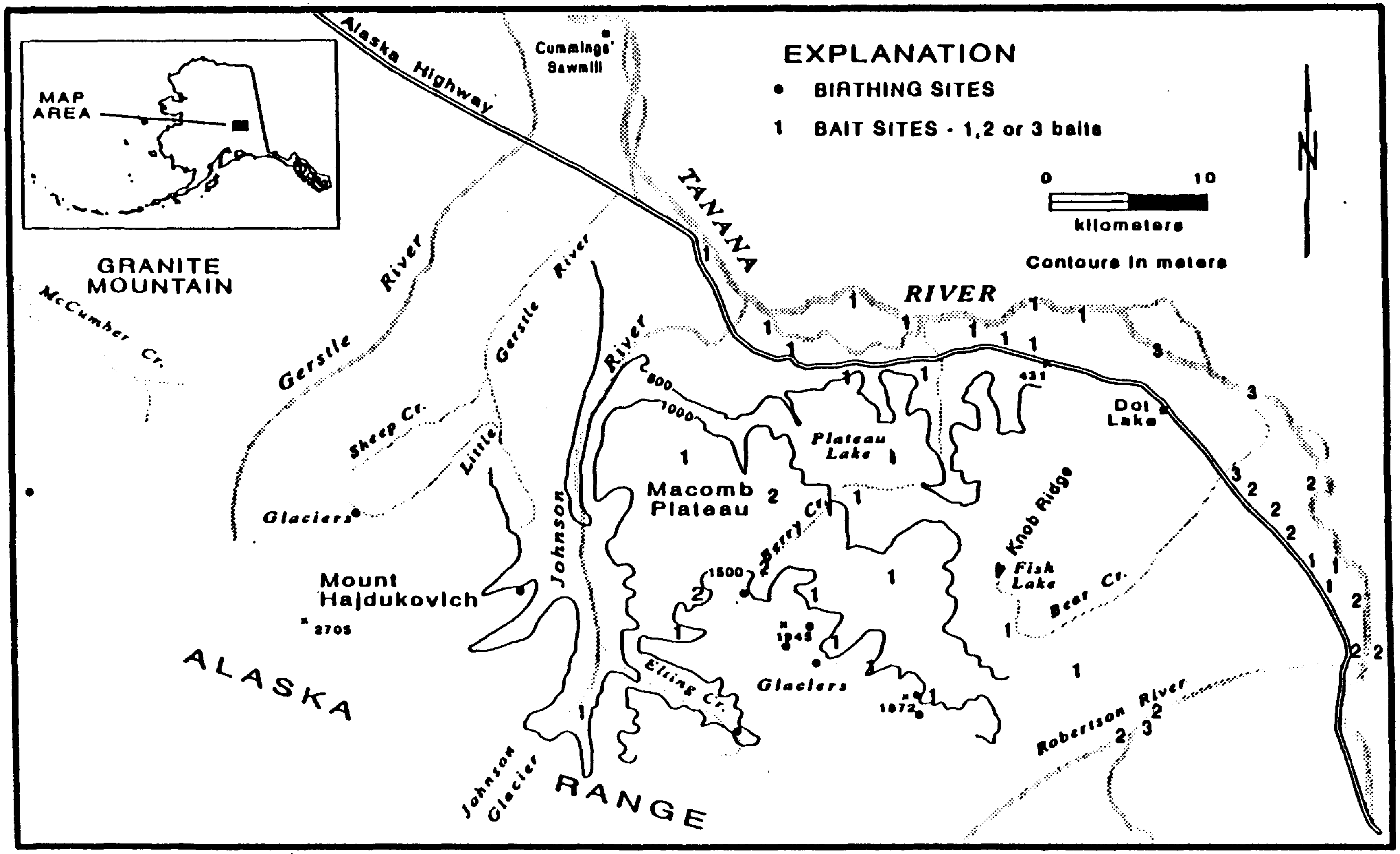

Figure 2. Birthing sites (.) of 10 adult radio-collared Macomb caribou and location of bait sites (1, 2, or 3 baits), eastcentral Alaska, May and June 1991. Bait sites (n = 43) were replenished up to 3 times at weekly intervals (n = 68 baits, x = 256 kg).

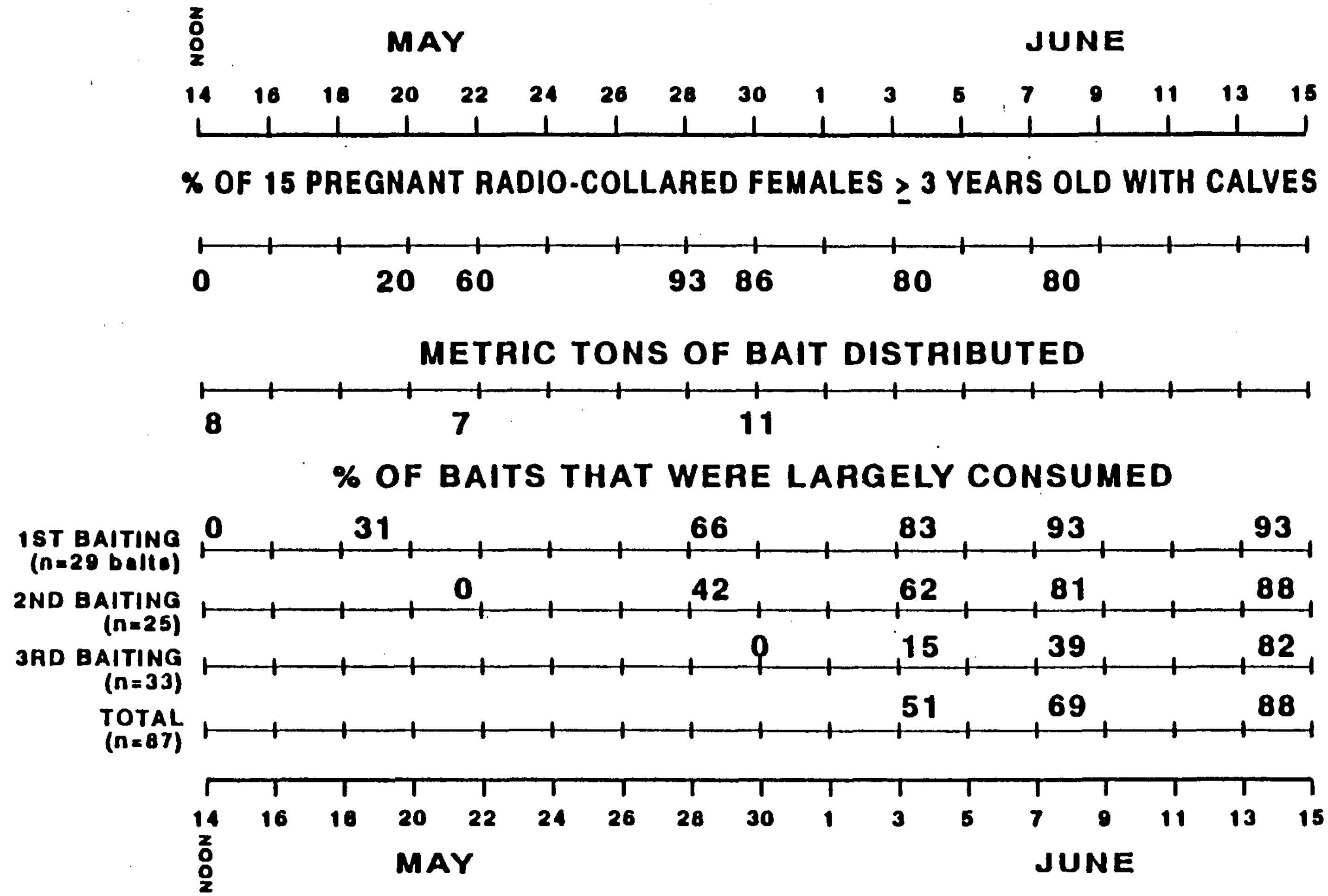

Figure 3. Chronology of caribou calving, calf survival of collared adults, baiting, and consumption of baits on and near the Macomb Plateau, eastcentral Alaska, 1990.

Table 1. Calves:100 cow moose ≥2 years old in the treated, partially treated, and control survey areas during October or November, 1981-91, eastcentral Alaska. Dashes indicate no data were collected.

	Treated area		Partially treated area		Control areas			
	Knob Ridge		Robertson River		Central Creek		Subunit 20E East	
Year	Calves:100 females ≥2 yrs old	No. females ≥2 yrs old	Calves:100 females ≥2 yrs old	No. females ≥2 yrs old	Calves:100 females ≥2 yrs old	No. females ≥2 yrs old	Calves:100 females ≥2 yrs old	No. females ≥2 yrs old
Pretreatment								
1981	19	31	--	--	--	--	--	--
1982	19	51	16	43	--	--	--	--
1983	34	35	--	--	11	37	--	--
1984	31	64	14	49	12	52	--	--
1985	20	51	26	19	27	52	17	133
1986	12	75	28	78	--	--	29	146
1987	--	--	--	--	--	--	24	142
1988	29	79	48	71	13	90	23	144
1989	38	66	15	89	21	85	--	--
Treated								
1990	42	86	31	67	11	85	27	204
1991	32	100	36	83	16	58	37	225

Table 2. Calves:100 cow caribou ≥1 year old in the Macomb, Delta, and Denali herds during September-November 1981-91, Alaska Range. Dashes indicate no data were collected.

	Treated herd		Control herds			
	Macomb		Delta		Denali	
Year	Calves: 100 cows	n	Calves: 100 cows	n	Calves: 100 cows	n
Pretreatment						
1981	33	445	41	1,451	--	--
1982	26	217	31	1,565	--	--
1983	24	238	46	1,208	--	--
1984	40	351	36	1,093	36	1,608
1985	31	518	36	1,164	28	1,205
1986	--	--	29	1,934	38	1,062
1987	--	--	31	1,682	37	1,221
1988	32	671	35	3,003	33	1,350
1989	34	617	36	1,965	30	1,504
Treated						
1990	17	734	17	2,411	17	1,307
1991	9	560	6	764	7	1,548

Appendix A. Paper submitted for publication in the Proceedings of the 2nd North American Wolf Symposium, Edmonton, Alberta 1993 (with minor format changes).

Methods for reducing natural predation on moose in Alaska and the Yukon: an evaluation

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Abstract

We evaluate several proposed and current methods of reducing natural predation on moose (*Alces alces*). These include (i) artificial or "diversionary" feeding of predators, (ii) enhancement of moose habitat, (iii) allowing alternate prey to increase, (iv) reducing predator birth rates, (v) conventional public hunting and trapping of predators, and (vi) aircraft-assisted wolf (*Canis lupus*) harvest. We discussed and ranked each method as low, moderate, or high in terms of relative effectiveness in elevating predation-limited moose populations, social acceptability, cost-effectiveness, and ease of implementation.

Diversionary feeding of black bears (*Ursus americanus*) and grizzly bears (*U. arctos*) received moderate to high rankings, except in terms of cost-effectiveness. Enhancement of moose habitat received high rankings in terms of social acceptability, but cost-effective tools are needed. Allowing alternate prey (i.e., caribou (*Rangifer tarandus*)) to increase and reducing wolf birth rates received potentially low ratings in virtually all categories. Before reducing wolf birth rates, cost-effective, safe, species-specific, and socially acceptable tools need to be developed. Conventional hunting of bears received potentially high marks in all categories. Aircraft-assisted wolf harvest also received high marks, except in terms of social acceptability. We outline a management strategy for reducing predation.

Introduction

Today, the potential role of reducing natural numbers of wolves (*Canis lupus*), black bears (*Ursus americanus*), and/or grizzly bears (*U. arctos*) to enhance moose populations is well recognized when predation is a major limiting factor and (i) moose (*Alces alces*) are below food-limited densities or (ii) moose are declining (Gasaway et al. 1983, 1992; Ballard and Larsen 1987; Crete 1987; Van Ballenberghe 1987; Bergerud and Snider 1988). Subarctic wolf-bear-moose systems after predator control have several times higher densities of moose and can support higher hunter harvests compared with similar systems without predator control (Gasaway et al.

1992). We believe that the long-term viability of wolf and black and grizzly bear populations can be safely protected while practicing localized predator control.

To help mediate the controversy over predator control, Gasaway et al. (1992) listed five potential alternatives to lethal predator control by government agencies, and recommended that they be evaluated. In this paper, we attempt this task using current knowledge and with the goal of directing future predator control research and management. We evaluate six methods of controlling wolf and/or bear predation: (i) artificial or "diversionary" feeding of predators, (ii) enhancement of ungulate habitat, (iii) allowing alternate prey to increase, (iv) reducing predator birth rates, (v) conventional public harvest of predators, and (vi) aircraft-assisted wolf harvest. We provide details where these techniques are specific to bears or wolves.

We chose not to evaluate five discontinued methods of reducing predation on moose, i.e., the use of poisons, paying wolf bounties, trapping of bears, translocation of bears, and euthanasia of pup wolves. These methods either have low social acceptability, questionable biological effectiveness, or low cost-effectiveness (Miller and Ballard 1982; Harbo and Dean 1983).

Methods

Evaluations are based on four criteria:

(i) How biologically effective will the technique be in elevating low-density, predator-limited moose populations or reversing predator-driven declines in moose (Gasaway et al. 1983, 1992)? We acknowledge that substantial population control will be needed in these cases, e.g., reducing the original wolf population by 60-85% annually for 4 to 6 years (Gasaway et al. 1983; R. Farnell, pers. commun.) or an equivalent impact on predation rates. Less intensive predator control is often sufficient to maintain moose at high densities, but this less intensive control, in anticipation of declines in moose, is more difficult to implement because no immediate problem is apparent.

(ii) Are the methods socially acceptable? We evaluate social acceptance in terms of the likelihood of gaining the political and public support necessary to implement a specific method (Archibald et al. 1991).

(iii) What is the relative, expected cost-effectiveness of the technique in terms of agency logistical operating costs?, and

(iv) Disregarding social acceptability, can the technique be easily implemented as the demand arises? Managers must have ready means of action for achieving population management objectives. Without accessible tools, managers will fail to manage in a timely fashion and will lose credibility.

Evaluation of techniques

Artificial or "diversionary" feeding

Clearly, feeding of predators can potentially increase moose numbers. High grizzly bear and black bear predation rates on neonatal moose calves (40-55%) are well substantiated in Alaska and the Yukon (Boertje et al. 1987; Schwartz and Franzmann 1989; Ballard et al. 1991), and this predation occurs even when moose are well-nourished (Gasaway et al. 1992). Because bears have well-developed scavenging skills, baits can be used to attract bears. Artificial feeding (hereafter "diversionary" feeding) of bears during moose calving should divert bears from killing calves and enhance calf survival. Bears kill relatively few moose calves after spring (Boertje et al. 1988).

We are aware of three studies where bears and wolves were artificially fed during moose calving and moose calf survival was monitored. During May and June 1985, Boertje et al. (1987) air-dropped about 12 metric tons of moose carcasses and scrap meat in a 1,000-km^2 area to attract bears for collaring in and around a concentrated moose calving area in east central Alaska. They observed evidence of grizzly bears, black bears, and wolves feeding at most carcass sites. The early winter 1985 calf:cow ratio increased to 53:100 (n = 17 cows) compared with 11-15:100 (n = 26-39, $P < 0.005$; Chi Square Test of Independence) during the preceding 3 years and 26-36:100 (n = 25-27, $P < 0.10$) during the following 2 years when baits were not available to predators. The 1985 response was not observed in three untreated adjacent areas (10-19:100, n = 25-70, $P < 0.005$). Although these results imply that diversionary feeding resulted in improved calf:cow ratios, some of this increase could have resulted from the slow recovery of bears (4-5 days) immobilized with drugs.

In 1990, Boertje et al. (1990) tested if diversionary feeding of bears and wolves could improve moose calf:cow ratios in a different 1,650-km^2 study area in east central Alaska. Feeding involved distributing 26 metric tons of moose carcasses (n = 87 baits at 61 sites, $\bar{x}$ = 300 kg) in about three equal proportions during 14-15 May, 21-22 May, and 30 May. Median calving date was about 21 May. Bears (mostly grizzly bears) and wolves consumed 79% of the baits by 14 June, as evidenced by disarticulated skeletons and incidental observations of both bears and wolves consuming baits. Moose calf:cow ratios increased in early winter 1990 (42 calves:100 cows $\geq$29 months, n = 86 cows) compared with 8 prior years ($\bar{x}$ = 25, range = 12-38:100, n = 51-75) and compared with 1990 control sites where feeding did not occur (11-27:100, n = 85-204).

This experiment was repeated in 1991 with 16 metric tons of moose carcasses (Boertje et al. 1992a). Early winter 1991 moose ratios were 32 calves:100 cows $\geq$29 months (n = 100) and did not exceed the ratios observed in 1991 control sites (16-37:100, n = 58-225). We believe the smaller amount of bait was insufficient, considering the size of the area and number of bears present.

Biologists in Washington have 6 years of experience with diversionary feeding of black bears to protect forest plantations (Ziegltrum 1990). A commercial bear ration was developed and field-tested, and feeding has largely replaced lethal control of bears. Bears were fed a complete, sugar-based pelleted ration *ad libitum* from mid-March through June to divert bears from stripping bark and feeding on exposed sapwood. Feeding proved more cost-effective and far more socially acceptable than lethal control of bears, and the program has been expanded each year.

We rank diversionary feeding as only moderately effective as a predator control tool (Table 1) for two reasons. First, diversionary feeding could actually increase predator numbers by enhancing predator physical condition, productivity, and juvenile survival, and by temporarily attracting predators from adjacent areas. Obviously, this would confound predator-prey management problems and requires study. If studies were designed to experiment with different levels of preferred food, then feeding levels could be adjusted to supplant only the nutrition naturally obtained from killing neonates. We envision that feeding would occur for only 3 to 4 weeks to minimize effects on predators and maximize benefits to moose.

Second, even if feeding is successful in reducing early predation on moose calves, wolves may compensate with increased predation later in the year. Moose survival usually improves substantially after 3 weeks of life (Boertje et al. 1987, 1988; Larsen et al. 1989; Ballard et al. 1991), but Hayes et al. (1991) found that wolves removed 64% of the moose calves in a low-density population during each of two winters in the southern Yukon.

Diversionary feeding ranked high in terms of social acceptability (Table 1) because no killing of predators is involved (Arthur et al. 1977). Public attitudes have been favorable in Alaska when predators were fed moose carcasses, but disfavor may arise if costly commercial food sources are used. Disfavor may also arise if bears are perceived as becoming conditioned or dependent on the feeding program, so feeding time should be minimal (3-4 weeks).

We ranked diversionary feeding low in cost-effectiveness and moderate in terms of ease of implementation (Table 1). It will be expensive and difficult to acquire, store, and distribute bait that is environmentally safe, socially acceptable, inexpensive, and effective. Local availability of suitable bait may determine which food source is used. Commercial bear food from Washington (about $2/kg) may be too expensive unless manufactured close to delivery sites. Data suggest about 20 metric tons of bait are needed to divert grizzly bears (16 bears/1,000 km^2, Boertje et al. 1987) from moose calves in a 1,650-km^2 area in east central Alaska. Using commercial food sources, annual bait costs ($40,000 plus transportation costs) would far exceed agency operating costs for aircraft-assisted wolf control in the same 1,650-km^2 area (about $15,000). Transportation costs would escalate dramatically if offroad areas were selected for feeding programs.

In the 1985 and 1990 programs described earlier, train-killed moose were collected during winter at the railroad's expense, stored under sawdust, and distributed at the U.S. military's expense during helicopter training missions. In 1991, starved moose and those killed in traffic collisions were collected by volunteer groups in Fairbanks, Alaska. These moose were distributed using Alaska Department of Fish and Game (ADF&G) vehicles, a DeHavilland Beaver aircraft, and a riverboat. These subsidized operations were affordable (about $4,000 to $9,000 per year), but large numbers of moose carcasses are seldom available. Alternative foods need to be tested. Development of chemical attractants for coyotes (*Canis latrans*) (Green 1987; Scrivner et al. 1987) may be useful in researching techniques to attract wolves, but detaining wolves is probably more difficult than detaining bears.

Enhancement of moose habitat

We list three potential mechanisms by which habitat enhancement could decrease the impact of predation, but we emphasize that further research is needed to test the widespread existence of these mechanisms. First, burning has been associated with improved moose nutritional status (Schwartz and Franzmann 1989), which may decrease the vulnerability of individual moose to predation. However, Gasaway et al. (1992) concluded that moose nutrition is apparently a minor factor affecting low-density moose populations in most of Alaska and the Yukon. Second, the hunting efficiency of predators may decline in large burns or commercially logged areas. Moose are often scattered widely throughout large burns in interior Alaska and the

Yukon. In contrast, in unburned habitat, moose density is highest in narrow zones of shrubs, e.g., riparian or subalpine areas, where wolves can easily travel and predictably find moose. Third, increased moose density following burning has been related to increased productivity (Schwartz and Franzmann 1989) and to increased time moose spend in burns (Peek 1974; Gasaway et al. 1989). These factors could indirectly reduce the impact of predation on a moose population by increasing local moose:predator ratios (Gasaway et al. 1983; Schwartz and Franzmann 1989).

Evidence that moose density may substantially increase as a result of burning is indicated by a moose density of 417 moose/1,000 km^2 in the large 26-year-old Teslin burn in the southern Yukon (2,515-km^2 survey area, Gasaway et al. 1992). This density is three times higher than the average density in 20 areas (>2,000 km^2 each) where wolves and bears were similarly lightly harvested and moose were the primary prey (Gasaway et al. 1992). Moose densities in these other areas ranged from 45 to 269 moose/1,000 km^2. No other area had the uniformly extensive, ideal habitat of the Teslin burn.

We ranked social acceptability of habitat enhancement as high (Table 1) relative to other techniques, although decreased air quality from burning is unfavorable. Cost-effectiveness of this method would likely be highly variable depending on the methods of habitat enhancement. Large burns have huge costs associated with containment. Funds from commercial logging could help pay for ways to encourage favored moose browse species.

Currently, habitat enhancement of large areas (>2,000 km^2) is not available as a management tool. Prescribed burning and extensive logging of moose habitat are in their infancy in Alaska and the Yukon but will probably increase in the near future. Managers and researchers need to be capable of implementing coordinated, long-term studies of predator-moose-habitat relationships before and after habitat enhancement before this technique can be evaluated as a tool to decrease predation. Simply allowing a natural fire regime does not provide for coordinated, long-term studies.

Allow alternate prey to increase

Gasaway et al. (1992) proposed allowing alternate caribou (*Rangifer tarandus*) prey to increase as a method for increasing moose numbers. Caribou have escaped predation-limitation without strong human intervention (Skoog 1968; Bergerud and Elliot 1986). Whereas, moose apparently require substantial human intervention to escape predation limitation by wolves and bears (Coady 1980; Yesner 1989; Gasaway et al. 1992). Slightly decreased predation on moose may, at times, follow large increases in caribou (Holleman and Stephenson 1981; Ballard et al. 1987:38; Boertje et al. 1992b), but exceptions occur when caribou change movement patterns (Boertje et al. 1992b). Also, wolf numbers correlate closely with ungulate biomass (Keith 1983; Fuller 1989; Gasaway et al. 1992). Therefore, it may be very difficult to reduce total predation on moose when caribou increase, unless measures to prevent increases in predator populations are implemented.

Hunters would have to forego opportunity to hunt caribou while waiting for moose to increase. This lowers the potential social acceptability and cost effectiveness of this method (Table 1). Also, we view this method as a waiting process, not a tool, and therefore rank it low in terms of ease of implementation (Table 1).

Reducing predator birth rates

Surgical neutering, implants, inoculations, and oral administration of drugs have been used to reduce predator birth rates (Stelflug and Gates 1987; Orford et al. 1988). However, wolf predation and movement studies indicate that birth control may have low to moderate effectiveness in reducing predation. For example, the maintenance of wolf pairs in an exploited population can result in significantly higher per capita wolf kill rates (Hayes et al. 1991). Also, ingress of subadult wolves into wolf control areas may partly offset the results of birth control. For example, in a highly exploited wolf population in southcentral Alaska, 28% of 135 wolves dispersed and 22% of dispersers were accepted into existing packs (Ballard et al. 1987). In an area where birth control is practiced, immigrating wolves may be accepted at a greater rate, and lightly harvested adjacent populations may have a greater percentage of dispersing wolves. Ingress would be less significant if treated wolf populations were insular or peninsular.

We do not recommend birth control for grizzly bears because of inherently low reproductive rates. Female bears also have much lower immigration rates than wolves (Ballard et al. 1987; Reynolds 1990); therefore bear populations would be slow to recover from birth control. Reducing birth rates of black bears may have some application in specific circumstances because black bear densities and productivity are generally higher than those of grizzly bears (Reynolds 1990; Schwartz and Franzmann 1991).

We ranked the social acceptability of predator birth control as low to moderate compared with other techniques (Table 1). We base this evaluation on numerous negative responses we received following a press release mentioning birth control as a potential predator control technique in Alaska. We ranked the cost-effectiveness of birth control as low because of relatively high implementation costs (Table 1). Implementation of the most common birth control techniques (surgery, implants, or inoculation) requires immobilization of individual predators, which is extremely difficult and expensive in remote areas of Alaska and the Yukon. For example, recent costs to collar a wolf or grizzly bear averaged $3,000 in a remote, largely forested study area in eastcentral Alaska.

Distributing baits containing chemosterilants is an alternative to immobilizing individual predators. However, this use of chemicals requires registration by the Environmental Protection Agency, and pre-registration research costs may total millions of dollars. Further, chemosterilants would likely not be approved if found to impair nontarget species, especially wolverines (*Gulo gulo*). Species-specific delivery systems will likely be required, necessitating further development costs.

Conventional public hunting and trapping

We define "conventional public harvest" of wolves and bears as hunting and trapping exclusive of aircraft-assisted or snowmachine-assisted hunting. As a predator control technique, conventional harvest receives relatively high marks in terms of social acceptability, cost-effectiveness, and ease of implementation in part because of minimal agency involvement (Table 1). Conventional harvest of wolves has effectively reduced or stabilized wolf numbers below food-limited levels, e.g., on the Kenai Peninsula (Peterson et al. 1984) and immediately north of Anchorage (Gasaway et al. 1991). Harvest of black bears using bait has reduced black bear densities near Fairbanks (Hechtel 1991). However, in remote, sparsely populated areas, conventional hunting and trapping usually fails to reduce wolf and bear numbers enough to allow ungulate population growth (Gasaway et al. 1992). In Alaska, recent attempts have been made in limited remote areas to encourage public harvest of wolves and grizzly bears to intentionally reduce predation and allow ungulates to increase. These cases are discussed below.

The ADF&G promoted trapper education programs to stimulate interest in wolf trapping and snaring and to increase success rates. This promotion included trapper workshops, the production and distribution of a video on canid trapping techniques, and cooperation with a nonprofit Native organization to provide wolf snares to trappers in select villages. Total numbers of wolves trapped did not increase substantially from these areas (ADF&G files). The inherent wariness of wolves and a relative lack of economic incentives for trapping wolves contributed to the failure of this program to substantially increase the harvest of wolves.

In contrast, hunters have recently increased the harvest of grizzly bears sufficient to reduce grizzly bear densities in three Alaska study areas. Reported annual harvests averaged about 8-9% (Boertje et al. 1987; Miller 1990; Reynolds 1990), which apparently can cause long-term, slow declines averaging about 2% annually (Reynolds 1990), or potentially as much as 5% annually if additional human-caused and natural mortality rates remain high (Ballard and Miller 1992). Methods used to encourage grizzly bear harvest included liberalizing hunting regulations on grizzly bears, increasing the number of hunters afield by increasing opportunity to hunt male ungulates, and encouraging hunters to harvest grizzly bears through information and education. Liberalized hunting regulations included lengthening the hunting season, deleting a resident grizzly bear tag (fee) requirement, and increasing the bag limit to 1 bear/year, exclusive of the statewide bag limit of 1 bear/4 years. The harvest of sows accompanied by cubs and yearlings was not authorized.

In one of these three areas, moose were far below food-limited densities and grizzly predation was a major factor limiting moose (Boertje et al. 1987; Gasaway et al. 1992). In this area, moose calves/100 cows during fall increased, apparently in response to decreased grizzly numbers. Grizzly harvests averaged 8% annually during 1982-88 (Boertje et al. 1987; Gasaway et al. 1992); assuming a 2-5% annual decline, the grizzly population declined 14-35% by 1989. Moose calves per 100 cows $\geq$2 years old increased from a range of 19-27 ($\bar{x}$ = 23) during 1982-88 to 32-48 ($\bar{x}$ = 38; $\underline{P}$ < 0.05, Mann-Whitney two-sided test) during 1989-91. Wolf numbers increased substantially during fall 1990 compared with the 1980s, alternate prey (caribou) declined (ADF&G files), and snow depths were greater during the latter two winters, so decreased grizzly predation appears to be the cause of increased moose calf:cow ratios.

Further studies are needed where (i) moose are far below food-limited densities, (ii) grizzly bear predation is a major factor limiting moose, and (iii) grizzly bear reductions are publicly sanctioned. Specifically, managers need to know the degree to which reductions in grizzly bear numbers affect moose calf survival under the above conditions. Managers also need to know whether decreasing trends in numbers of bears harvested per unit effort will provide sufficient information to manage grizzly bears, e.g., without expensive bear population estimates. We do not recommend increased grizzly bear harvests to reduce moose mortality (i) where bear predation accounts for a small fraction of total predation; (ii) where moose are near food-limited densities, unless additional moose harvest is desired; or (iii) in coastal areas where grizzly bears occur at much higher densities and are the primary species of management concern.

Aircraft-assisted wolf harvest

Public and agency wolf harvests using aircraft have proven effective at reducing annual fall wolf numbers and stabilizing populations below food-limited levels (Gasaway et al. 1983, 1992; Ballard et al. 1987; Hayes et al. 1991). In areas that contain high proportions of unforested, open area and suitable snow conditions for tracking and landing, the public has reduced wolf numbers using light, fixed-wing aircraft. However, large portions of interior Alaska north of the Alaska Range are ill-suited to this method. Where wolves are extremely vulnerable (e.g., portions of northern and northwestern Alaska), use of aircraft has been discontinued, and snowmachines have replaced aircraft as a tool to effectively reduce or regulate wolf numbers. Helicopters are restricted to agency use in Alaska.

Wolves are currently regularly held below food-limited densities using public, aircraft-assisted wolf harvest in only a portion of southcentral Alaska (Ballard et al. 1987). In more forested areas of interior Alaska, wary wolves are able to avoid aircraft-assisted harvest. The primary method used is land-and-shoot harvest in which the hunter lands near the wolf before shooting. Shooting from the air was discontinued in 1972 in Alaska, except under state permit in specific areas (Harbo and Dean 1983; Stephenson et al., this issue).

Agency wolf control programs have involved aerial shooting from light, fixed-wing aircraft and helicopters. Radiotelemetry has occasionally been used in these programs to help locate packs, especially where tracking conditions were poor. Only two ADF&G aerial wolf control programs survived court battles and reviews for 3 years or more. Moose numbers increased most notably in a 15,300-km^2 area where moose were declining rapidly and control was very intensive. The ADF&G shot 18-67 wolves (22-39% of the fall wolf population) annually during 5 years in this area (Gasaway et al. 1983). This program was followed by a four-fold increase in moose numbers (ADF&G files). The second lengthy ADF&G wolf control program, just north of Fairbanks, was also followed by enhanced moose numbers (Gasaway et al. 1992; ADF&G files). Likewise, the most lengthy (7 years) and intensive wolf control program by the Yukon Fish and Wildlife Branch (YF&WB) substantially elevated moose numbers (YF&WB files).

We view aircraft-assisted wolf harvest as having the lowest social acceptability of the six methods evaluated in Table 1. Harbo and Dean (1983) and Stephenson et al. (this issue) trace the history of court cases reflecting this low social acceptability. Indeed, the major rationale for investigating alternate techniques is the low social acceptability of this method (Gasaway et al. 1992).

Cost-effectiveness of this method is relatively high. For example, in portions of southcentral Alaska, the public can effectively regulate wolves at low densities without agency assistance. In interior Alaska and southern Yukon, operating costs of agency-sponsored aerial wolf reductions have ranged from about $500 to $1,000 per wolf, but returns have been high in terms of additional ungulate harvest (Gasaway et al. 1983, 1992; R. Farnell, pers. commun.). Administrative and education costs associated with aircraft-assisted wolf harvest are high, in part because of low social and political acceptability. Social and political factors also strongly affect how easily managers can implement this tool.

Management strategy

Where predator control is necessary to meet publicly sanctioned objectives for moose, we recommend (i) ranking areas based on suitable habitat, overall demand, management and research capabilities, and social and economic costs; (ii) evaluating the suitability of several combined techniques for a specific area; (iii) educating and informing public advisory groups; and (iv) adopting a formal process for approving area-specific wildlife management plans in areas with and without anticipated predator control. It is essential that the public be better informed about the trade-offs between social- and biological-based management decisions.

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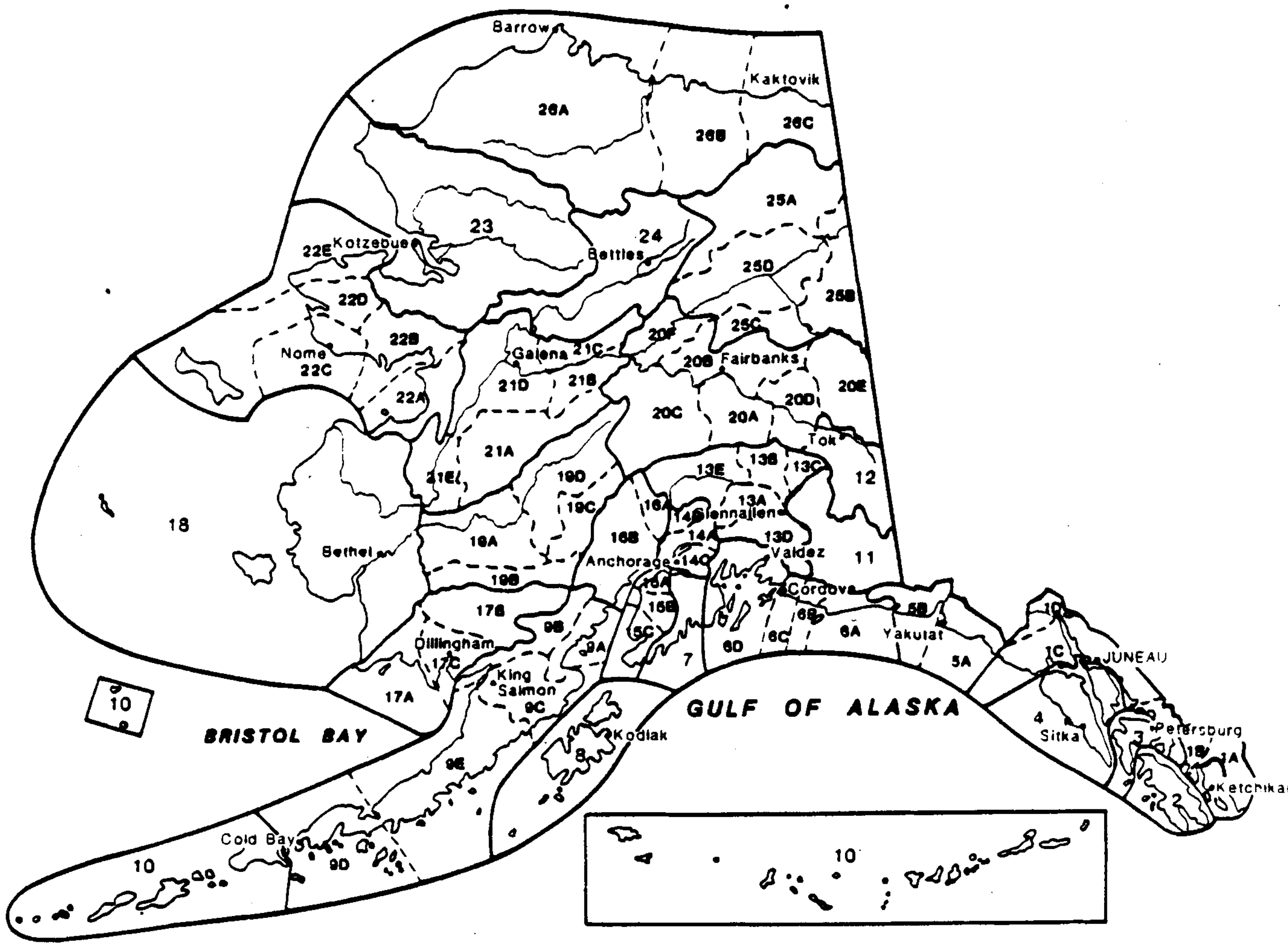
Table 1. Evaluation of six methods of increasing predation-limited moose populations in areas best suited to the particular methods, based on four criteria.

	Diversionary feeding of bears	Enhancement of moose habitat	Allow alternate prey to increase	Reducing wolf birth rates	Conventional public hunting of bears	Aircraft assisted wolf harvest
Biological effectiveness	Moderate	Low to moderate	Low	Low to moderate	Low to high	High
Social acceptability	High	High	Moderate to high	Low to moderate	High	Low
Cost-effectiveness	Low	Low to high	Low to high	Low	High	Moderate to high
Ease of implementation	Moderate	Low	Low	Low	High	High

Alaska's Game Management Units



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