MANAGEMENT OF MOOSE AND THEIR PREDATORS IN SOUTHWEST YUKON - A SUMMARY OF CURRENT INFORMATION

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INTRODUCTION

Moose populations in southwest Yukon are either declining to, or have stabilized at, low densities. A management-research program was introduced in 1983 to determine the most economical and biologically feasible methods of increasing the moose population. It is unlikely that we will know the initial cause(s) of the decline. Predation, primarily by grizzly bears and secondly, by wolves, likely in combination with sport and native harvest, appears to be keeping the moose population from increasing. Recommendations were made to:

1) reduce grizzly bear numbers by 50% in selected areas.

2) reduce wolf numbers by 70% for 3 consecutive years in selected areas.

3) reduce licenced sport harvest throughout the area.

4) reduce native subsistent harvest throughout the area.

To date we have reached the wolf reduction target for one year, and reduced sport hunting access to the resource. We have not reached the grizzly bear reduction target or adequately addressed native subsistent hunting.

These programs are under review, specifically the use of grizzly bear and wolf reduction to increase moose in southwest Yukon, and generally the use of predator reduction programs as a management tool to enhance moose populations in Yukon. The continuation of the moose-predator program and the direction of future moose management in Yukon will depend on the outcome of this review.

The purpose of this document is to summarize the salient biological information on the moose-predator study in southwest Yukon. A more comprehensive discussion of the background, study design, and rationale for the current direction of the study appears in Appendix I. It is not our intent in this document to rigorously evaluate the results from this study or to defend the current program. The information presented outlines the biological problem and puts it into a Yukon and North American perspective. In addition to information from the Yukon study, a list of moose-caribou/predator programs and results from North America have been compiled, and a discussion of general predator-prey management concepts (Appendix III) is presented. This critique will provide the reader with the necessary biological information to make a thorough assessment of the future management options presented in the preceding document.

BACKGROUND

Based on hunter questionnaire results, the demand for moose by resident hunters (native & non-native) in Yukon exceeds that for any other single big game species (Fig. 1). That demand is expressed by:

1. The number of hunting seals purchased;
2. The number of animals harvested annually;
3. The number of hunter days spent in pursuit of the species.

These are conservative values as the illegal harvest is not accounted for, and the subsistent harvest is possibly under-estimated.

The current strategy for managing moose in Yukon has been to identify areas where the demand for moose exceeds the supply. In those areas we have attempted to document the factors limiting moose population growth, and if feasible reduce those limiting factors allowing the population to grow to satisfy the demand. When we initiated this study, 30% of the resident harvest (approx. 900) and 30% of the resident days effort for moose occurred within the moose predator study (MPS) area. This area represents 4% of the Yukon land mass (Fig. 2). Non-resident harvest in Yukon averages 157 animals annually or 15% of the total moose harvested. Less than 2% occurs in the MPS area. Based on the concentrated resident hunting, the southwest Yukon was identified as an area where the demand for moose potentially exceeded the supply.

The MPS area is located next to Whitehorse which constitutes 70% of the Yukon human population. It is bordered on the north by the Alaska Highway which is the most important transportation route for tourists in Yukon. The location of this study area results in a high exposure to resident and non-resident, as well as consumptive and non-consumptive users.

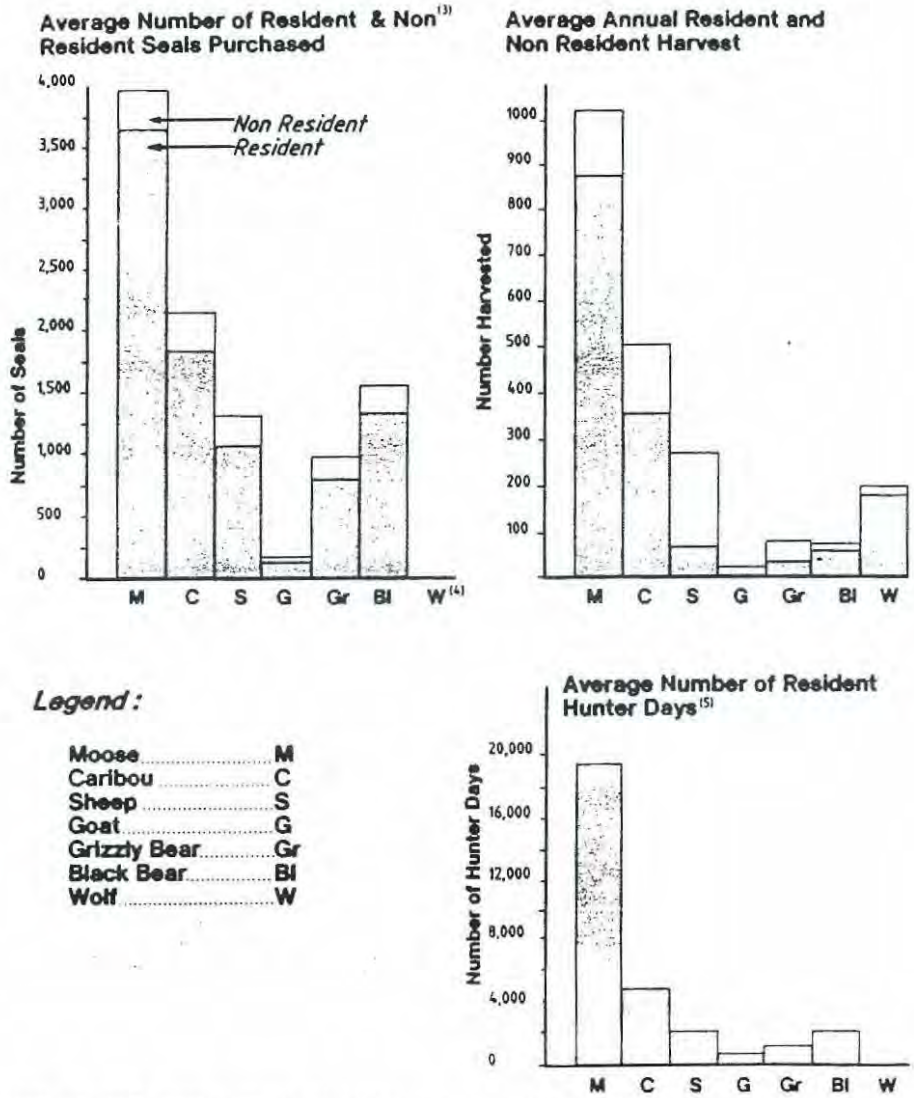
The MPS was a management program with an experimental research design. We recognize that moose exist in a complex, dynamic, interactive and poorly understood system. Therefore, any attempt to manage or study these systems must be approached from an experimental basis. The strategy used in the MPS was to determine through direct means as many of the potential limiting factors as possible prior to implementing a management program. The key results and pertinent aspects of the study design are discussed under the following titles:

1. Diagnosis of the potential limiting factor(s);

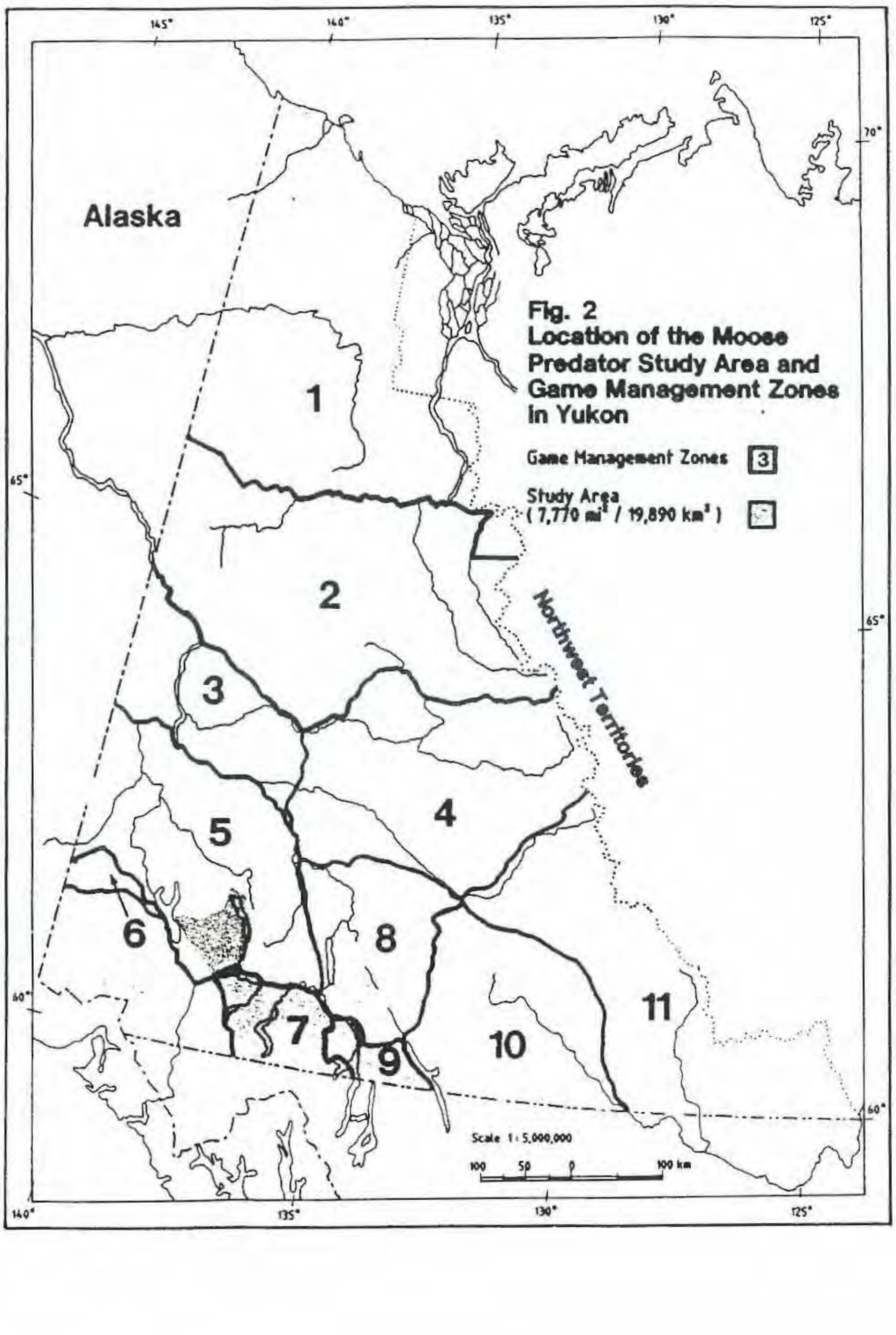
2. Prescription or manipulation of the potential limiting factor(s);

3. Evaluation of that manipulation.

Fig. 1 : Resident[1] and Non– Resident Consumptive Demand for Big Game[2] Species in Yukon (FIGURES ARE AVERAGE VALUES BETWEEN 1974 AND 1983)



(1) Resident harvest includes an estimate for native and non-native sport hunting. Information on native harvest is less reliable than non-native harvest. The illegal harvest is not accounted for in these data. (2) Barren ground caribou estimates have not been included in this analyses. (3) Average annual non-resident seals were based on the time period 1979-1983. (4) No seals required for wolves. (5) Non-residents do not report effort by species.



Alaska
Fig. 2
Location of the Moose Predator Study Area and Game Management Zones in Yukon
Game Management Zones 3
Study Area (7,770 mi² / 19,890 km²)
Northwest Territories
1
2
3
4
5
6
7
8
9
10
11
Scale 1:5,000,000
100 50 0 100 km
145°
140°
135°
130°
125°
70°
65°
60°

DIAGNOSIS OF THE PROBLEM

The objectives of the diagnosis phase were:

1. To assess moose population composition, distribution and changes in numbers over time, and;
2. To assess the influence of potential limiting factors on moose population growth.

The diagnosis has been an ongoing process, starting with Fall surveys in 1978 and progressing to more intensive surveys and a detailed investigation of the cause and rate of calf and adult mortality. Some predator reduction occured during the diagnosis phase (see prescription section). The following discussion is based on the combined data from 1978 to 1985. The study was conducted in the southwest Yukon (Fig. 3). Five contiguous blocks were chosen - Kluane, Haines Junction, Whitehorse, Carcross and Teslin. The combined results of Fall censuses conducted in the MPS revealed low calf numbers, averaging 22 calves/100 cows $\geq$ 30 months (range 0-60), and high calf mortality to 6 months of age, estimated average 82%, (range 46-100%) (Table 1). Low to moderate moose numbers (0.02 to 0.54 moose/km^2) and skewed adult sex ratios (29 to 92 males/100 females were documented (Larsen 1982, Markel & Larsen 1984, Johnston & McLeod 1983, Johnston et al 1984). Moose populations have declined since 1981 in the Carcross and Haines Juncion blocks, and probably in the Kluane block. Populations in the Whitehorse and Teslin blocks appear stable (Johnston & McLeod 1983, Johnston et al 1984, Renewable Resources Publication 1984). Surveys conducted by the Park Service in Kluane National Park, which borders the Haines Junction block, have also shown low calf/cow ratios (11-26 calves/100 cows) in Fall populations since 1974. Surveys conducted in other parts of Yukon have shown similarly low calf/cow ratios, (15-26 calves/100 cows), and high calf mortality (Table 1). Low densities of moose have been documented (0.06 to .12 moose/km^2) in these areas. These results suggest that high calf mortality is not limited to hunted moose populations, not restricted to the southwest Yukon, and probably not a recent phenomenon. Studies in Teslin, Whitehorse, Carcross and Haines Junction in 1983 and 1984 revealed the majority of the cows were old and therefore not at prime breeding age. This supports the idea that few calves have been recruited into the adult population in the recent past. In summary, in most areas of southwest Yukon, moose populations have either declined or are at a stable low-density with little prospect for increase due to poor recruitment and declining numbers of reproductive-age animals.

Population studies of large ungulates in North America describe six factors which have the potential to limit moose numbers. These factors are (a) forage and climate, (b) disease/parasites, (c) changes in reproduction and sex ratios, (d) movement of animals into a population (ingress) or movement of animals out of a population (egress), (e) human harvest, and (f) natural predators.

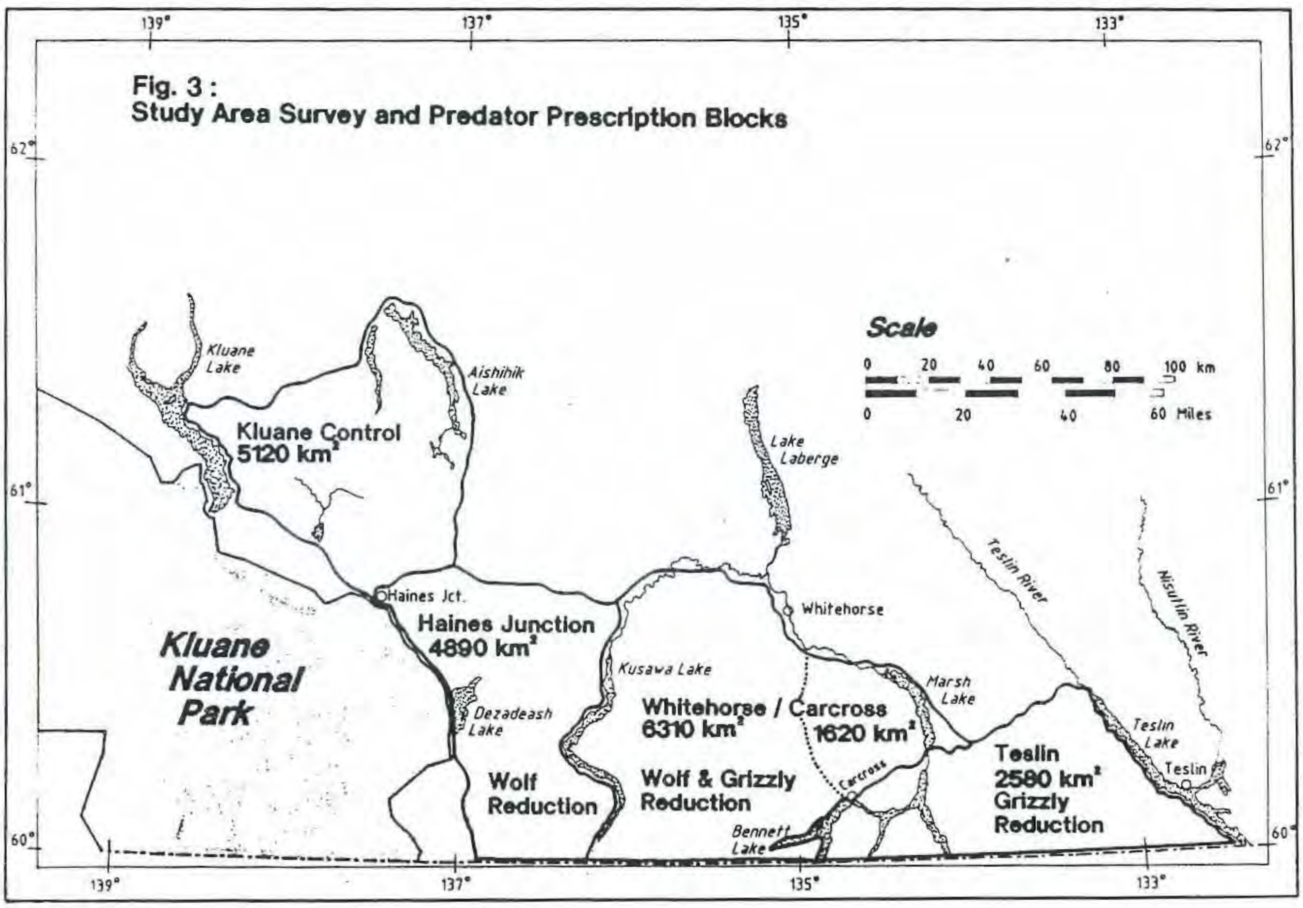


Fig. 3 :
Study Area Survey and Predator Prescription Blocks
139°
137°
135°
133°
62°
61°
60°
Scale
0 20 40 60 80 100 km
0 20 40 60 Miles
Kluane Lake
Aishihik Lake
Kluane Control
5120 km²
Lake Laberge
Teslin River
Nisutlin River
Haines Jct.
Haines Junction
4890 km²
Whitehorse
Kluane National Park
Kusawa Lake
Marsh Lake
Dezadeash Lake
Whitehorse / Carcross
6310 km²
1620 km²
Teslin
2580 km²
Grizzly Reduction
Teslin Lake
Teslin
Wolf Reduction
Wolf & Grizzly Reduction
Carcross
Bennett Lake

TABLE 1 EARLY WINTER (NOVEMBER) MOOSE DEMOGRAPHY FROM SURVEYED AREAS IN YUKON

Location (GMZ)	Year	Calves/100 cows (30 mo.)	Estimated[1] calf mortality %	Population status
4	1983	15	87[a]	unknown
5	1981	17	72[a]	unknown
Kluane	1983	0	100[a]	unknown
Block	1982	6	95[a]	unknown
6	1974-1981	11-26	N/A	unknown
	1982	14	88[a]	unknown
	1983	13	89[a]	unknown
	1984	20	82[a]	unknown
	1985	16	86[a]	unknown
7	1981*	28	76[a]	unknown
Haines	1982*	11	92[a]	declining
Junction	1983*	7	95[a]	declining
Block	1984*	18	87[a]	stable
	1985*	39	65[b]	unknown
Whitehorse	1981*	18	86[a]	unknown
Block	1982*	24	81[a]	stable
	1983*	30	76[a]	stable
	1984*	26	74[b]	unknown
	1985*	34	66[b]	unknown
9	1980*	23	83[a]	unknown
Carcross	1982*	9	95[a]	declining
Block	1983*	4	97[a]	declining
	1984*	0	100[b]	unknown
	1985*	18	85[b]	unknown
Teslin	1978*	33	71[a]	unknown
Block	1980*	21	82[a]	unknown
	1982*	19	84[a]	stable
	1983*	31	75[a]	stable
	1984*	37	69[a]	stable
	1985*	60	46[b]	unknown
10	1983	18	85[a]	unknown
11	1982	26	78[a]	unknown

*Survey areas within the moose predator study area.

[1] Calf mortality was estimated using two techniques: a. Average birth rates documented in GM's 7 and 9 between 1983 and 1984 were applied to the cow population (30 mo. of age) estimated from the fall surveys. The spring cow population was calculated by adding the summer mortality to the fall estimate. The number of calves predicted to be born was compared to the calves observed in the fall surveys to determine the rate of calf mortality. b. A sample of newborn calves was radio collared and monitored to determine the rate of mortality.

Each of these potential limiting factors were addressed (Appendix I). It was concluded that the following were not significant limiting factors on the moose population at this time. The rationale for rejecting them as significant factors are presented:

(a) forage - adult cows were in good physical condition, pregnancy rates were normal to high (approx. 90%, depending on area and year) and birth rates were normal to high (approx. 130 calves per 100 pregnant cows).

(b) climate - the effects of climate have not been thoroughly addressed as only a few years of information are available, however, at this time there is no obvious relationship between climate and changes in moose population size.

(c) disease and parasites - brucellosis and other blood diseases were not detected; heavy tick infestations were not evident.

(d) altered sex ratios and reproductive rates - high birth rates suggest that skewed adult sex ratios were not a significant factor.

(e) ingress/egress - movements of radio collared cows suggest that no massive, unilateral movement has occurred.

A more significant source of mortality, and thus a potential limiting factor was:

(f) Human harvest (native and non-native) annually removed a minimum average of 8% (range 3-10%) of the estimated pre-hunt Fall moose population between 1981 and 1983 throughout the MPS area. However, it was concluded that human harvest, by itself, was not likely a limiting factor to moose population growth, but may act to limit numbers in conjunction with other factors. Our estimation of total human harvest, however, may be low. Native harvest rates are poorly understood.

However, the most significant mortality factor was:

(g) Predation by wolves on all age classes of moose year round and by grizzly bears on moose calves immediately after birth.

The causes of calf mortality were determined from radio collared calves in the Whitehorse and Teslin blocks in 1983 and the Whitehorse block in 1985. The most intensive work was carried out in the Whitehorse block. In 1983, 54 radio collared calves died over a one year period. Grizzly bears accounted for 34 (63%), wolves 14 (26%), non-predator related causes 3(5%), unknown predators 2 (4%) and black bear 1 (2%) of the calves that died. In 1985, the cause of mortality was determined only to the end of July.

Of the 30 radio collared calves that died, grizzly bears accounted for 14 (47%), wolves 7 (23%), non-predator related causes 4 (13%), black bear 3 (10%), unknown predators 1 (3%) and capture-related causes 1 (3%). The 1985 results are still being analyzed and therefore should be treated accordingly. The causes of calf mortality in the Teslin block in 1983, based on 16 collared calves, were similar with grizzly bears as the primary cause of mortality followed by wolves.

The rate of calf mortality has been determined using two methods. The first method takes the number of adult cows documented from fall (Nov.) aerial surveys and estimates the number of calves that would have been born in the spring of the same year. The birth rates used in this extrapolation were documented from various blocks in 1983 and 1984. These rates were then applied to all cow estimated between 1978 and 1984. The number of calves observed in the fall surveys were then compared to the number of calves predicted to be born in the same spring to estimate calf mortality rates. The estimated rate of mortality to 01 Nov. throughout the MPS area (5 survey blocks) between 1978 and 1984 has been consistently high, averaging 82% (range 69-100%) (Table 1). No surveys were conducted in the MPS area in 1985.

The second technique used to determine the rate of calf mortality was radio telemetry. Both collared calves and uncollared calves accompanied by collared cows were monitored. In addition to documenting annual and seasonal mortality rates, this technique allowed us to determine mortality rates on a weekly and daily basis. The most intensive monitoring was done in the Whitehorse block. In 1983, 75 calves were monitored; 60 (80%) died by the 17 July, 65 (87%) by 01 Nov. and 68 (91%) died by the end of the year. In 1984, 74% of the calves were dead by 01 Nov. and in 1985 70% were dead by the same date.

The rate of calf mortality in Whitehorse, Haines Junction, Carcross and Teslin combined, between 1983 and 1985 averaged 70% (range 46-100%) between birth and 01 November. In all areas over the 3 year period (1983-1985) the majority of calves died within the first 6 weeks of life.

Based on documented birth rates, we estimated 463 calves were born in the Whitehorse block in 1983 and about 421 (91%) died before the end of the year, of which 265 (63%) were killed by grizzly bears. As already stated, the majority of the deaths occurred before mid-July. Based on the estimated number of bears (see below), the timing and extent of calf mortality and the observation that all age/sex bear groups killed calves, we suggest that a large proportion of the bear population were predatory. That is, we do not suspect that a few individual bears, or a particular age and sex class, preyed on calves.

The consistent high levels of mortality, the similar timing of deaths and the similarities in causes of mortality, suggests that the causes of mortality were the same among years and among survey blocks.

Throughout these studies, we have checked a number of potential biases which could have altered the results. We have determined that: 1) collaring of the cow did not effect the birth rate, 2) collaring the calf did not effect its survival, 3) the habitat that the calf was born in did not effect calf survival, 4) the age of the cow did not effect calf survival, and 5) the time period of birth (early or late born) did not effect calf survival.

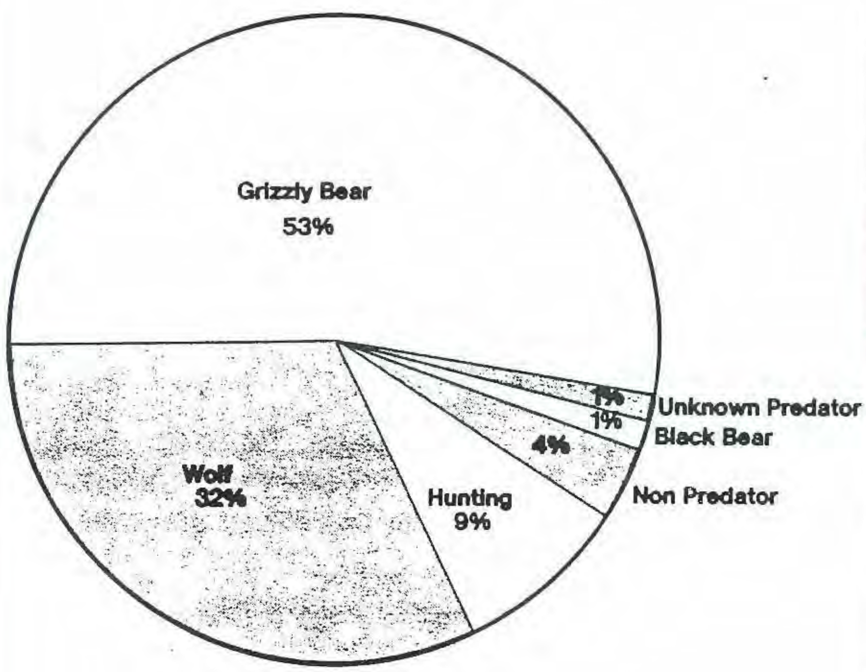
In addition to calf mortality, the cause and rate of cow mortality were determined. In 1983 and 1984, a total of 120 adult cows were radio-collared and monitored. The annual adult female natural mortality rate averaged 13% (range 8-39). All mortality was due to predation, of which 75% was caused by wolves and 25% by grizzly bears.

In order to identify the major source of mortality on the entire moose population, the rate and cause (natural and man-induced) of mortality to both adults and calves must be considered. The combined causes of mortality over one year were as follows: grizzly bears 53%, wolves 32%, hunting 9%, black bears 1%, and others 5% (Fig. 4). In the Whitehorse block production of calves in 1983 was 463 calves; predators were estimated to remove 470 calves and adults while hunters removed 50 adults from the population. At this time, predators are clearly the most significant source of mortality. The difference between production and mortality should result in a slowly declining moose population if these same conditions continued.

Wolf populations were aerially censused in 1983 and 1984, revealing a wolf density of 1 wolf/84 sq. km., (Hayes et al 1985) similar to the highest densities determined in other naturally regulated wolf populations in northwestern North America (Haber 1977, Gasaway et al 1983). Since 1983, studies of 20 radio-instrumented wolf packs in the study area have shown that moose and, secondarily Dall's sheep are the primary prey species. Wolves prey primarily upon calves and older age moose during the winter. The age groups preyed on reflect the availability of those age groups in the population. Based on bone marrow fat content, wolf killed ungulates were not in poor condition. Daily wolf consumption rates of ungulates are considered moderate by comparison to other North American studies (0.14 to 0.21 kg/kg wolf/day) (Hayes. and Baer 1985) Woodland caribou are only available in low numbers throughout the southwestern Yukon and do not represent an important prey species.

Grizzly bear densities probably vary in the southwest Yukon as a reflection of differences in bear food production in alpine, subalpine and valley floor areas. Highest densities occur in Kluane (1 bear/26 km^2) where glacier meltwater creates lush alpine areas and promotes broad shrub floodplains where soapberries and roots are abundant (Pearson 1975). Bear densities probably decline to the north and east over the study area. In the Whitehorse block, recent studies have documented approximately 22 adult females in a 6310 km^2 area. We extrapolated from this data to estimate a total grizzly population of approximately 80 bears or 1 bear/79 km^2.

Fig. 4 :
Causes of Annual Adult and Calf Moose Mortality



Conclusion:

It was concluded that the primary reason moose numbers were not recovering in the MPS area was insufficient recruitment to replace adult losses, and that predation, primarily by grizzly bears, was the major reason for low recruitment. While grizzly bears and wolves were identified as the major sources of moose mortality, the question remained as to whether predation was the major limiting factor to moose population growth. At first glance, these statements may appear contradictory, however, it is possible that if a major mortality factor was removed that a less significant mortality factor may become important enough to once again restrict the growth of the moose population. A short term method for determining if predators were limiting the moose population was to reduce the predators while at the same time monitor other factors which may potentially act concurrently to limit population growth.

PRESCRIPTION FOR RECOVERY

The objectives of the current phase (reduction) of the MPS have been:

1. To increase moose numbers in declining or stabilized low density populations to meet Yukon resident needs. This was to be accomplished through a reduction of wolves, grizzly bears and sport hunting.

2. To ensure the continued presence of self-reproducing predator populations in areas where their numbers are being reduced.

We recognize that "resident needs" is a sociological issue that requires senior administrative direction. Resident needs have not been defined and consequently the future moose population target has not been determined.

There are many study designs which would allow us to attain the goals stated above and to test the prediction that calf survivorship and population growth would increase with predator reduction. However, any study designed to assess that prediction should take into account the following factors. (See Appendix I for more detail).

(1) Short-Term (3 year) versus long-term (greater than 3 year) recovery programs.

The following facts should be considered when weighing this option: (a) There is an older age structure to the reproductive segment of the moose population in the study area. (b) Recovery of a declining, low-density moose population would certainly take longer than in a stable higher-density population and, (c) temporal changes in confounding effects such as weather, vegetation and movement of predators into the reduction block from adjacent unmanipulated areas were less likely to occur in a short-term experiment. We preferred to adopt a short term study approach for these reasons.

(2) Multi-block predator prescription design versus single predator prescription design

The study design should allow an evaluation of other limiting factors which may act to affect moose numbers, as well as the interaction among limiting factors. Assumptions which were inherent to our prediction were (a) that another potential limiting factor would not assume immediate importance in limiting moose numbers (for example, that moose numbers were not relatively close to the limiting effect of forage/climate), and (b) that there were no significant compensatory effects among limiting factors. For example, with a significant number of grizzly bears removed, wolves, black bears, and(or) remaining grizzly bears would not remove the surplus calves created by the removal of bears. As reported earlier, we have no evidence to suggest that other potential limiting factors (forage, climate, disease, etc.) would assume an immediate effect after reduction of predators.

In order to evaluate these potential limiting factors, we prosposed four areas in southern Yukon for use as different prescription blocks (Fig. 3): (a) the Whitehorse/Carcross block for both grizzly bear and wolf reduction; (b) the Teslin block for grizzly bear-only reduction; (c) the Haines Junction block for wolf only reduction; and (d) the Kluane block which was used as a control or unmanipulated area.

(3) Passive versus active management

"Passive" management in this context refers to the use of current or liberalized hunting and trapping regulations to reduce predator numbers. "Active" management refers to the reduction of predators directly by government personnel. To pursue a short-term strategy for increasing moose numbers, an active management strategy was recommended.

Sufficient grizzly bears and wolves had to be removed in order to detect a change in moose numbers. We proposed that 50% of estimated bear numbers in the bear reduction blocks should be removed over a two year period and that 70% of the wolves be removed for three consecutive years in the wolf reduction blocks. Maintaining the traditional level of grizzly bear harvest through hunting regulations would not have resulted in a sufficient reduction of predators over a short period. Wolf numbers were significantly decreased in 1983 by trappers and hunters (44%), however, it is not likely that conventional harvest techniques would reduce numbers further to 70%. (See Evaluation section). Incentive programs to enhance the harvest of these species would likely be inadequate to reduce numbers to the level and within the time period desired. Furthermore, gradual reduction of predators over a long period may be countered by movement of predators into the area. A short-term active management strategy would minimize this problem.

Greater liberalization of grizzly bear hunting regulations may be an effective short- term technique, but would require such regulation changes as reduction of trophy fees and tag fees, use of calf distress calls, spotting from aircraft and allowance of bear baiting. However, females with offspring would be protected under these regulations. Maternal bear groups represent approximately 33% to 50% of most bear populations, therefore a substantial portion of the population would not be effected by liberalized hunting regulations over the short-term. It is more likely that liberalization of hunting regulations would result in a long-term bear reduction program. Active government participation in bear reduction through field programs would provide the most efficient method of reducing bears in a relatively short time period as well as ensure that bear reduction targets are not exceeded.

We recognized only one acceptable method for bear reduction by Government personnel - live-trapping and relocation out of the reduction blocks. If the maximum opportunity for increases in moose numbers was desired then bears should be moved at least 480-650 km. (300-400 mi.) in order to prevent their return. If a temporary (1 year) increase in moose numbers was sufficient then bears should be moved 160-320 (100-200 miles). In Alaska 60% of the bears moved these short distances returned within an average of 58 days, and 75% of the cubs and yearlings died before returning (Miller & Ballard 1982).

A combination of Departmental involvement in reduction and(or) liberalization of grizzly bear hunting regulations was thought to be the most appropriate means of removing sufficient numbers of bears to effect a significant change in moose numbers over a short-term period.

As well, we recognized wolf reduction from aircraft by Government personnel, in conjunction with trapper and sport harvest to be a feasible method of decreasing wolf numbers.

(4) Applicability of results to other areas

We felt that the results of this study could be somewhat applicable to other areas with similar predator-prey numbers. That is, the reduction of the same predators in another study area with the same multi predator-prey system should achieve similar results.

(5) Reduction versus non-reduction of wolf numbers

Grizzly bear reduction by itself may not prove an effective technique due to practical limitations. Given that wolves account for 26% of total calf natural mortality and 75% of total adult natural mortality, and that reasonable success rates in removing wolves have been demonstrated, elsewhere, it follows that moose calf survivorship may be most significantly affected by reduction of both bears and wolves. If wolves are an important limiting factor, then substantial reductions in wolf numbers should result in a measurable change in moose numbers over an extended time period. Studies have shown that a minimum of 38-50% reduction is required to cause a stable wolf population to decline (Keith 1983). A 70% annual reduction level was chosen to ensure a significant decline in wolf numbers occurred in a short period.

Recommended Study Design & Prescription Options Which were Considered - Taking into account the study design considerations discussed above, we recommended a short-term reduction program for both grizzly bear and wolf which used active management techniques within a multi-block prescription design. Predator reduction was to employ government field programs to reduce grizzly bear numbers through translocation and wolf numbers through aerial hunting concurrent with liberalization of predator hunting and trapping regulations. Harvest restrictions on moose were imposed on licenced hunters.

Prior to initiating the prescription, five options were considered. With each of the following options, the potential for affecting a short-term recovery of moose was predicted.

1) Continue with traditional trapping and hunting throughout the study area, "status quo" management for bears and wolves - short-term recovery of moose not possible.

2) "Status quo" management for bears throughout the study area. Government reduction of wolves throughout the area, short-term recovery not likely.

3) Increased bear harvest by traditional hunting means throughout study area; Government reduction of wolves throughout study area - short-term recovery not likely.

4) Increased bear harvest through gross liberalization of hunting (e.g. baiting); Government reduction of wolves throughout study area - short-term recovery possible but not likely, depending on the effectiveness of liberalized hunting regulations.

5) Government reduction of bears and government reduction of wolves. Short-term recovery most likely.

It was our judgement that option 5 provided the best means of carrying out the recommended study design.

EVALUATION

The prescription phase of this study was only partially completed. We felt that the predator removal levels should continue for the durations recommended before any conclusions were drawn. Consequently, an evaluation of the effects of the predator removal to date on the moose population is premature. However, it would be useful to evaluate the levels of predator reduction that have been achieved through sport hunting/trapping and government field programs. As well, an evaluation of the proposed study design by research and management biologists is provided (Appendix II).

The objectives of the evaluation phase have been:

1. To determine the response of the moose population to the reduction of different combinations of predators over a short time period;

2. To determine the most cost-effective and biologically feasible type of predator reduction (ie. different combinations of predators and method of reducing predators).

Predator reduction levels - As previously described a multi block predator prescription was adopted, reducing different combinations of predators in different areas. The proposed and achieved levels and timing of predator reduction are discussed by prescription block. (Table 2).

(a) Grizzly/wolf reduction block (Whitehorse/Carcross)

A grizzly bear density of 1 bear/79 km^2 was estimated in the Whitehorse portion of this block in 1985 using radio telemetry techniques. Based on this density we estimate 80 grizzly bears in the Whitehorse portion and 20 bears in the Carcross portion, for a total of 100 grizzly bears in this block. We recommended to reduce the grizzly bear population by 50% over a 2 year period (Table 2). A 50% reduction would affect 40 bears from the Whitehorse portion and 10 from Carcross. A total of 16 bears have been permanently removed from the Whitehorse portion over the past 2 years through a combination of sport hunting (6), problem bear control (4), experimental translocation (3), and accidental deaths (3). This leaves 24 bears to be removed to meet the 50% target in the Whitehorse portion. Currently 21 bears are either radio-collared or accompanied by a radio-collared bear in this block. If all these bears were removed we would achieve the 50% reduction in the Whitehorse portion. If these bears were removed prior to calving, the effects of such removal would be known within two months of calving. No bears have been removed in the Carcross portion.

Sport hunting has not been an effective means of reducing grizzly bear numbers over the short term. The average (1974-1983) annual sport harvest of grizzly bears in the Whitehorse portion of this block was 2.0 bears. In 1984 the hunting regulations were liberalized to allow greater opportunities for hunting bears. Season length was increased, the 1 bear/lifetime restriction for non residents was reduced to 1 bear/yr., the 1 bear/5 years restriction for residents was reduced to 1 bear/yr.; permits were allotted to outfitters to hunt in this area and residents were allowed to guide Canadian relatives and friends. Under this new bear harvest regime, the average (1984 and 1985) number of bears taken annually by sport hunters increased to 3.0 animals. This represents 4% of the estimated population, a level which can be offset by annual production.

Liberalization of hunting regulations did not occur in the Carcross portion until 1985. The average annual sport harvest prior to 1985 was 0.4 animals. No grizzly bear kills were reported from this area in 1985.

A wolf density estimate of 1 wolf/84 km^2 or 75 wolves was obtained for the Whitehorse block in 1983. In 1982/83 a wolf reduction program was initiated by Government using aerial hunting techniques. A total of 33 wolves or 44% of the estimated population, was removed through a combination of sport hunting, trapping and government programs (Table 2). During the winter of 1983/84 an additional 33 wolves or 44% of the original population estimate were removed. In 1984/85, 42 wolves or 70% of the original population was removed. A 70% reduction for 3 consecutive years is the proposed target for this area.

Wolf reduction was not intensively started in the Carcross portion until the winter of 1984/85. Twenty-two wolves or 70% of the estimated population were removed (Table 2).

For maximum benefits to the moose population and for comparative purposes with other prescription blocks we recommended that a 70% reduction of wolves occurr for 3 consecutive years. On the third year 50% of the grizzly bears were to be removed. We have deviated from this schedule due to the problems experienced over the past 3 years in implementing these programs. The only target which has been achieved in this block is a 70% reduction of wolves over 1 year. At the time that both targets are realized reduction efforts would have stopped and the post reduction phase would commence.

(b) Bear-only reduction block (Teslin)

The purpose of the bear-only reduction was to test the effect of reduction of only that species in affecting moose calf survivorship relative to the other predator prescription blocks. This block also provided the opportunity to determine if wolves would compensate by killing the additional calves either in the summer or winter months. No collaring or census of bears has been conducted in Teslin to date. We proposed to apply the Whitehorse bear estimate to the Teslin block, and relocate 50% of the Teslin bears in the same year as reduction in the Whitehorse block. Based on a density of 1 bear/79 km^2 we estimate 33 bears in this block. This may be a liberal estimate based on our assumption that bear densities decrease from west to east within the study area. Prior to 1984 the average (1974 - 1983) annual harvest was 1.0 animal. Hunting regulations were liberalized in 1984 which resulted in an average annual (1984-1985) harvest of 3.5 animals or 11% of the population. Over the past 2 years 7 bears (21%) have been removed from this block (Table 2). Eleven more bears would have to be removed to meet the 50% target set for this area, assuming no significant ingress of bears has occurred.

(c) Wolf-only reduction block (Haines Junction)

The purpose of the wolf only reduction block is similar to that described for bears in Teslin. Reduction rates of 70% maintained over a three year period had been set as the goal for this block. A 43% reduction was realized in 1983-84 and a 70% reduction in 1984-85 (Table 2). Despite normal hunting regulations for grizzly bears, 15 bears were removed in 1984 and 1985 (9 harvested, 3 control kills, 3 study induced mortalities). If we assume a density of 1 bear/79 km^2 then 63 bears inhabit this area. The 15 bears removed over the past two years represents 24% of the estimated population. All but 4 of these kills occurred near the western border of the block, next to Kluane Park.

(d) Non-reduction block (Kluane)

Studies in the Kluane block were to provide evidence of moose population characteristics in an area undisturbed by predator reduction. No active predator reduction programs were implemented in this block. Moose surveys were conducted in this block in 1981 and in a portion of the block in 1983. In comparison, moose surveys have been flown annually between 1981 - 1984 in most of the other prescription blocks. Neither a calf or adult moose mortality study has been conducted in the Kluane block.

Yukon Wolf and Grizzly Bear Populations - a N.A. Perspective - The proposed prescription levels in Yukon should be put into perspective with the abundance of the three large predators throughout their range in North America. Based on crude estimates of the grizzly bear (53000-63000) (Peek et al 1985) and wolf populations (60,000) (Carbyn 1983) throughout North America, Yukon harbors 10-13% of the grizzly bears and 7% of the wolves. The moose-predator program has

TABLE 2 SCHEDULE OF PREDATOR REDUCTION PROGRAMS (achieved and proposed) IN THE MOOSE PREDATOR STUDY AREA (Reduction Values are expressed as a % of the original population estimate - (numbers removed).

			1982*/83		1983**/84		1984/85	
	PRESCRIPTION		Nov.- Mar.	Apr.- Oct.	Nov.- Mar.	Apr.- Oct.	Nov.- Mar.	Apr.- Oct.
Whitehorse	70% wolf/50% grizzly removal							
		WOLF	44 (33)		44 (33)		70 (42)	
		GRIZZLY		1 (1)		10 (8)		10 (8)
Carcross	70% wolf/50% grizzly removal							
		WOLF	approx. 25 (8)		0 (0)		70 (22)	
		GRIZZLY		0 (0)		0 (0)		0 (0)
Teslin	50% grizzly removal							
		GRIZZLY		0 (0)		15 (5)		6 (2)
Haines Junction	70% wolf removal							
		WOLF	34 (21)		43 (27)		70 (43)	
Kluane	non-reduction		NO REDUCTION					

* wolf reduction occurs during the winter months Nov-Mar while bear reduction occurs during the summer months Apr-Oct.

** wolf reduction by government aerial hunting was initiated in the winter 1983 - 84. In 1982, reduction was mainly caused by resident hunter and trapper harvest and near Whitehorse, problem wolves were killed by the Fish and Wildlife Branch.

annually removed or proposed to remove 3% of the Yukon wolves (permanent removal) or .002% of the North American wolf population; 1.0% of the Yukon grizzly bears (temporary or permanent removal) or .001% of the North American grizzly bear population.

SUMMARY

The primary goal of the Moose-Predator study was to enhance depressed moose populations that are important to consumptive and non-consumptive users. While the cause(s) of the initial decline is not known, it is likely that a combination of factors including natural predation and human harvest were important. Harvest restrictions were established, however, reducing the harvest alone is not enough to allow the moose population to increase in the short term. We have shown that the recovery appears to be limited by natural predation, especially predation by grizzly bears on newborn calves followed by predation by wolves on calves and adults.

An experimental design was chosen to reduce grizzly bear and wolf numbers in specific areas in an attempt to measure the effects of reducing different combinations of predators on the moose calf survivorship and overall population size. The results of such an experiment would allow managers to evaluate which method(s) were the most economical and biologically feasible.

The study is incomplete as reduction targets have not been achieved in the case of grizzly bear or just recently achieved in the case of wolves. It is premature to evaluate the response of the moose population to the reduction levels which have been achieved.

The study was attempting to increase moose numbers over the short-term. We emphasize that if a short-term recovery is expected by the Yukon public, then a treatment of all regulating factors should occur. Otherwise, the management strategy will not reach its short-term objectives. Due to the potential complexity of multi predator-prey systems, an increase in moose numbers over the long term may require the treatment of all or, at least, the most important regulatory factors. The enhancement of ungulates at the expense of large predators is the crux of the issue. The decision to exercise predator reduction or not will depend on how valuable ungulates and large predators are to the Yukon public. If we choose not to apply predator reductions and only restrict human harvest then the Yukon public should expect that depressed game populations may remain at low levels, and a reasonable harvestable surplus of these populations may not be available for perhaps decades.

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APPENDIX I

- MANAGEMENT PROGRAM DRAFT PROPOSAL -
OPTIONS FOR INCREASING MOOSE NUMBERS, SOUTHERN YUKON

Prepared by
D.G. Larsen and D.A. Gauthier

04/25/85

Submission of the Moose/Predator Technical Committee
Government of Yukon

(For Discussion Purposes Only)

Yukon
Renewable Resources

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STUDY GOAL

It is the goal of the Government of Yukon to increase the numbers of moose in low density populations in southern Yukon to meet resident needs. It is also the goal to ensure the continued presence of self-reproducing predator populations in areas of moose enhancement.

We recognise, (1) that moose exist in a complex, dynamic and interactive system, and therefore any attempt to manipulate their numbers should involve consideration of other ungulates, human harvest, predators, and alternate prey species of those predators, (2) that these factors may act in combination to affect numbers and thus should be studied concurrently, (3) that necessary information on the interaction of these factors can best be obtained through experimental means, and (4) that numerous options exist to potentially realize the dual goals.

Any options to be considered by Government of Yukon to increase moose numbers must involve to some degree consideration of factors that limit the growth of moose populations. With knowledge of those factors, we have the option of pursuing short- (1 to 3 years) versus long-term

(>3 years) programs to increase moose numbers, through either passive (manipulation through hunting regulations) or active (manipulation through Government field programs) means. Ideally, we prefer a short-term approach which is most likely to produce results uncomplicated by confounding effects and will allow evaluation of conditions in other areas of Yukon. We consider the active approach more feasible than the passive given the sparse human population and limited access within the study area. We present two options as means to increase low density, stable or declining moose populations in southern Yukon, and ensure the continued presence of predator populations. As background, we provide a brief summary of data from a completed research program in a 20000 sq.km. (7800 sq.mi.) area in southern Yukon conducted to (1) identify demographic characteristics of moose, and (2) identify limiting factors to moose population growth.

BACKGROUND INFORMATION

Prior to 1980, little information on moose numbers, distribution or population dynamics was available in Yukon. While the Yukon Fish and Wildlife Branch has jurisdiction relative to management of moose populations and the responsibility for establishing moose harvest regulations, it has had inadequate information upon which to base management decisions. Information gathered from hunter questionnaires revealed that moose were the primary game species for resident Yukon hunters (for example, 22000 man/days hunting moose compared to 5000 man/days for caribou, the next highest hunting effort). Hunting effort for moose is high (mean=30 days/moose kill). However, success rates are low (25%) relative to results from other regions of North America (Timmerman 1981). In addition, 30% of all moose harvested by resident hunters in Yukon, and 30% of the hunting effort, occurrs on 3% of total Yukon lands in southern Yukon. This area has the greatest human population.

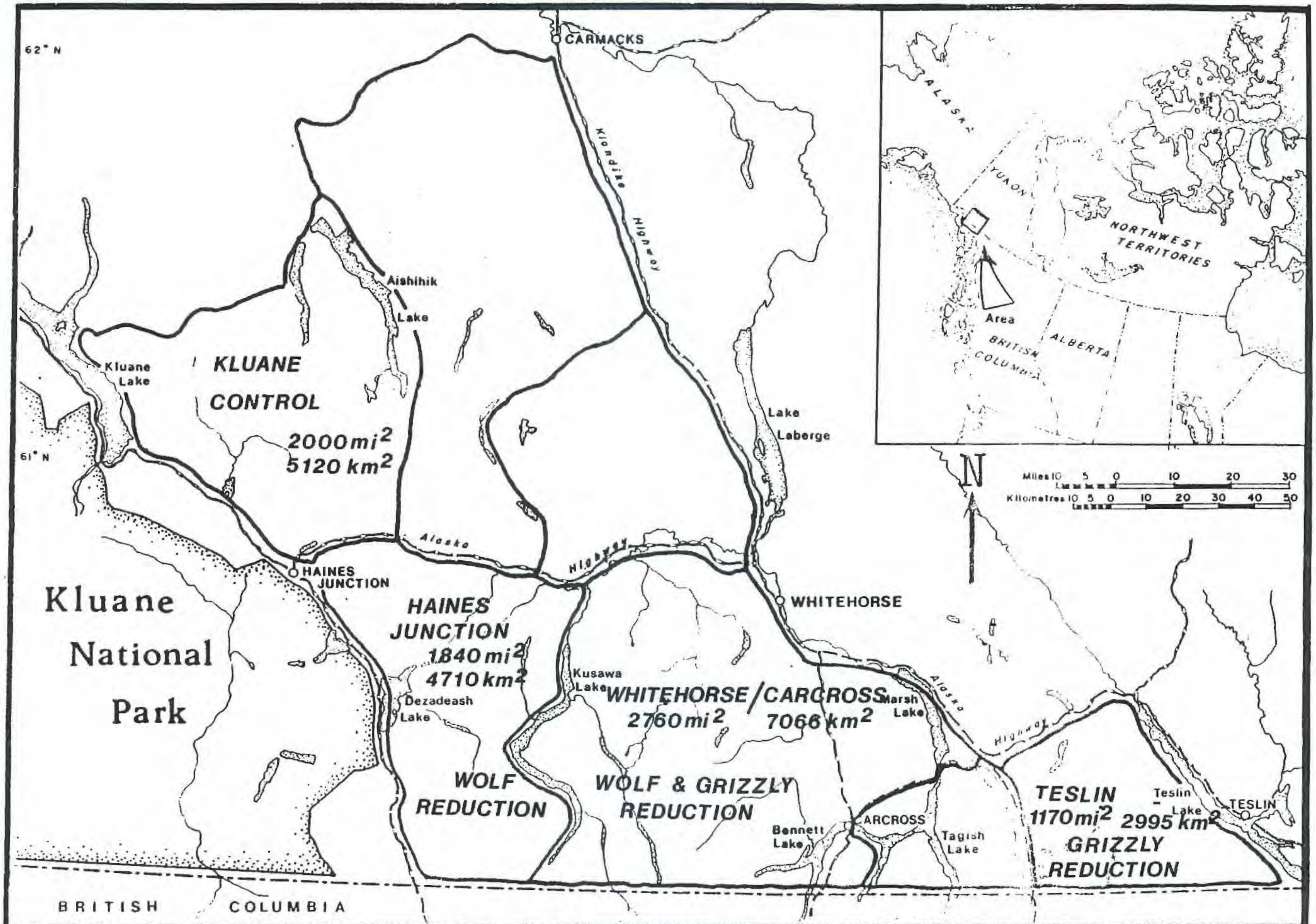
The low hunter success rate may be a relatively recent phenomenon since anecdotal data suggests relatively high success rates in the 1960's and early-1970's. Hunter harvest statistics from that period are either inadequate or unavailable and therefore the timing of the suspected decline are conjectural. Human harvest in southern Yukon has been traditionally directed to areas of road and river access, that is, primarily within the lowland-forested regions. Moose numbers in these accessible areas would, therefore, be subject to the greatest potential for reduction.

The high hunter effort and low success rates in recent years suggested that moose numbers were low. The importance of moose for both consumptive and nonconsumptive users, the concern that moose numbers had declined to low levels, and the lack of data upon which to base management strategies prompted the Fish and Wildlife Branch to initiate a study to document moose numbers and to investigate potential mechanisms influencing population size.

The study was conducted in a region of Yukon where moose utilization was heaviest (derived from hunter questionnaire results) and thus the potential impact of hunting the greatest. Five contiguous blocks (Fig. 1) were chosen - Kluane, Haines Junction, Whitehorse, Carcross and Teslin. Study area boundaries defining the five blocks were based on major physiographic and human barriers to moose movement suggesting the moose populations in each region were likely relatively discrete.

Population dynamics theory for large ungulates in North America suggests six factors which potentially act to limit moose numbers. These factors are (a) forage and climate, (b) disease/parasites, (c) changes in reproduction and sex ratios, (d) ingress/egress, (e) human harvest, and (f) natural predators. The objectives of the study were (1) to accurately assess moose population composition, distribution and changes in numbers over time, and (2) to assess the

FIG. 1. Map of moose/predator management program study area, southern Yukon.



62° N
61° N
CARMACKS
Klondike Highway
Aishihik Lake
Kluane Lake
KLUANE CONTROL
2000 mi2
5120 km2
Lake Laberge
Alaska Highway
HAINES JUNCTION
WHITEHORSE
Kluane National Park
HAINES JUNCTION
1840 mi2
4710 km2
Dezadeash Lake
Kusawa Lake
WHITEHORSE/CARCROSS
2760 mi2
7066 km2
Marsh Lake
WOLF REDUCTION
WOLF & GRIZZLY REDUCTION
CARCROSS
Bennett Lake
Tagish Lake
TESLIN
1170 mi2
2995 km2
GRIZZLY REDUCTION
Teslin Lake
TESLIN
BRITISH COLUMBIA
N
Miles 10 5 0 10 20 30
Kilometres 10 5 0 10 20 30 40 50
ALASKA
YUKON
NORTHWEST TERRITORIES
Area
BRITISH COLUMBIA
ALBERTA

influence of the above six factors on moose population growth.

Objective 1

An evaluation of existing census techniques led to the selection in 1980 of a Fall moose census technique based upon a stratified random sampling approach developed for moose in Alaska (Gasaway et al. 1983). This method was tested in the Carcross area of Yukon and modified to more practically suit Yukon physiography and climate (Larsen 1982).

The combined results of censuses conducted in the blocks between 1980 and 1984 revealed low moose numbers, low calf numbers, poor recruitment and skewed adult sex ratios (Larsen 1982; Markel and Larsen 1982, 1984; Johnson and McLeod 1983). This substantiated earlier concerns about low numbers. The results from radio-telemetry studies indicated that each block contained relatively discrete populations. Fall surveys using different survey techniques (Hoefs 1974) and dating back to 1974 revealed consistently low calf/cow ratios and low recruitment. Surveys in Kluane National Park, adjoining the Haines Junction block , have shown low calf/cow ratios in Fall populations since 1974 (unpublished Kluane National Park Warden Report Series). These results suggested that the problem was not limited to hunted moose populations and was probably not a recent phenomenon. Studies in Teslin, Whitehorse, Carcross and Haines Junction in 1983 and 1984 revealed relatively old-age cows (Larsen and Gauthier, in prep.). These combined results revealed that moose populations were either declining or at a low-density stability with little prospect for increase due to poor recruitment and declining numbers of reproductive-age animals.

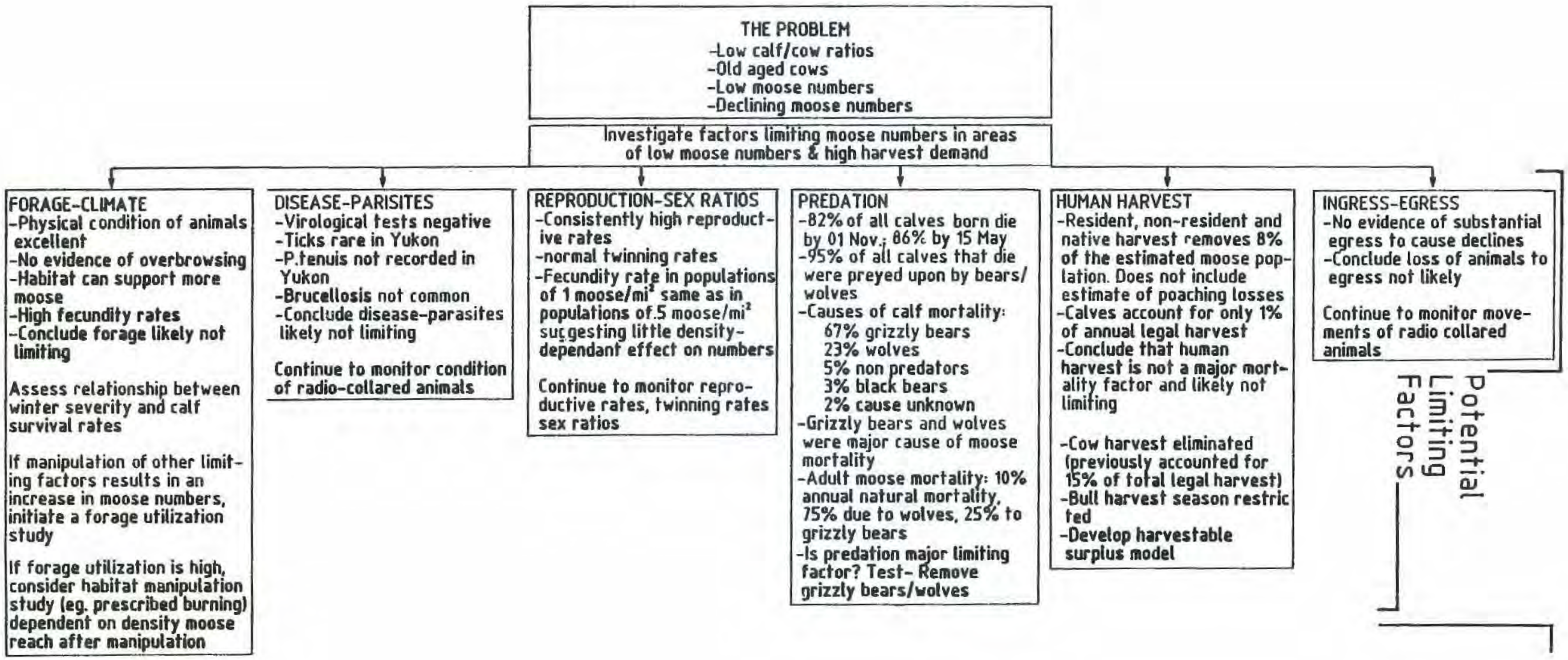
Objective 2

Forage and climate, disease/parasites, changes in reproduction and sex ratios, ingress/egress, human harvest, and natural predators were assessed. A summary is shown in Figure 2.

(a) Forage and Climate

If forage/climate effects were limiting moose numbers, we predicted some combination of the following, (i) evidence of poor physical condition, (ii) high utilization of habitat (for example, evidence of overbrowsing of preferred forage species, particularly on winter range); concentration of

FIG. 2. Summary of background information.



moose resulting in local overbrowsing should also be evident, and (iii) low fecundity and pregnancy rates.

Cows were equipped with radio-collars in 1983 and again in 1984. Gross external physical examination of these cows by a veterinarian revealed animals were in excellent physical condition in late-winter, the period when we would expect animals to be in poorest physical condition (Franzmann and LeResche 1978). There was no evidence from hematological and chemical analyses of blood samples to indicate that animals were in poor physical condition (Glover and Larsen, in prep.). Subjective evaluation of habitat revealed overbrowsing in concentrated rutting areas but no observations of concentrations of moose were noted in late-winter, nor was overbrowsing noted on ranges in late-winter, a period of high stress. Pregnancy rates were at normal-to-high levels (mean=89%) with normal-to-high fecundity rates (mean=1.3 calves in utero /pregnant cow), and normal twinning rates (23% of pregnant females).

Since none of the predictions were supported, it was concluded that forage effects were likely not significant in affecting moose numbers. It should be noted that habitat manipulation would, therefore, likely be ineffective in increasing moose numbers.

Climatic data to assess the influence of winter and calving climate severity on moose productivity and calf survivorship were collected in 1983 and 1984 and will continue to be collected during the winters and in conjunction with calf mortality studies. No evidence of climatic effects on productivity and calf survival are evident to date.

(b) Disease/parasites

Analyses of blood samples from captured cow moose revealed no evidence of disease. Major diseases and parasites which have been suggested as possible causes in moose declines (or at least to have definite detrimental effects on moose), are *D. albipitus* (Anderson and Lankester 1974), *P. tenuis* (Prescott 1974), and *Brucellosis* spp. (Anderson 1975). These diseases and parasites are rare to nonexistent in Yukon. We conclude that disease/parasites are not likely currently limiting moose numbers. However, physical condition of animals will continue to be assessed through samples taken from radio-collared moose.

(c) Altered sex ratios and reproductive rates

Sex ratios were approximately 50 males per 100 females, a relatively normal sex ratio for North American moose populations in which males are preferentially hunted (Bishop and Rausch 1974). Skewed sex ratios down to 30 males per 100 females do not have a negative short-term effect on reproductive rates or timing of birth in southern Yukon moose populations (Larsen and Gauthier, in prep.). Reproductive rates were consistently high. The fecundity rate in populations of 1 moose/sq.mi. are not significantly different from populations at 0.5 moose/sq.mi. in southern Yukon. This suggests that there has been little density-dependent effect on numbers, at least at those densities. We conclude that reproductive rates and skewed sex ratios were not likely significant factors influencing changes in moose numbers. Sex ratios, reproductive and twinning rates will continue to be monitored.

(d) Ingress/egress

Monitoring of radio-collared cow movements showed no significant movement between the 4 blocks intensively studied (n=30 cows/block). Therefore, neither ingress nor egress was a factor affecting numbers. However, seasonal movement of animals was documented between the Haines

Junction block and Kluane National Park. The magnitude and extent of this movement is currently being assessed. Adjustments to population estimates from Fall censuses for that study area will depend upon the results of the movement study. Current information indicates that ingress/egress are not likely significant factors influencing changes in moose numbers. The movement and distribution of moose will continue to be monitored by telemetry.

(e) Human harvest

Human harvest annually removes approximately 8% (240 animals) of the estimated prehunt Fall moose population. This figure includes an estimate of native harvest, although losses to poaching are unknown. Few moose calves were harvested (1% of the annual legal harvest, or approximately 6 calves/year). This represents <1% of the calf population for the entire study area. We conclude that human harvest by itself is not likely a limiting factor to moose population growth, but may act to limit numbers in conjunction with other factors. In response, the harvest of females has been eliminated (in the past, the harvest of females accounted for approximately 15% of total legal harvest or 1% of the total population), and the male harvest season has been restricted in accessible areas from a 90 day season to a 15 day season.

(f) Predation

If predation were acting to limit the growth of moose numbers, we would predict (i) that the number of moose killed by predators is significant in relation to moose productivity, that is, predators constitute the major source of mortality, (ii) that bears and wolves would be the major predators, (iii) that bears and(or) wolves would act to remove predominantly calves from the population, primarily in the calving/postcalving period, and (iv) that this reduction of calves would result in an increasingly older-aged moose population.

In 1983, 76 moose calves were radio-collared during the calving period and monitored for one year. Eighty-six percent of all calves that were born died over one year. Of the total mortality, 63% was due to grizzly bears, 26% to wolves, 5% to non-predators, 2% to black bears and 4% to unknown predators. Grizzly bear predation was the primary cause of moose calf mortality in the first six weeks of life. After 1 November, wolves were the only detectable cause of moose calf mortality. The majority of calf mortality occurred in the calving/postcalving period (15 May to 17 July).

In 1983 and 1984, a total of 120 adult cows were radio-collared and monitored. The annual adult natural mortality rate averaged approximately 10%, with the majority of adult mortality occurring in the summer. All mortality was due to predation, of which 75% was due to wolves and 25% due to grizzly bears.

Wolf populations were aerially censused in 1983 and 1984, revealing a wolf density of 1 wolf/84 sq.km. (Hayes et al. 1985), similar to the highest densities determined in other naturally regulated wolf populations in northwestern North America (Haber 1977; Gasaway et al. 1983). The ratio of moose per wolf was 10:1, suggesting that wolf predation was potentially limiting moose numbers based on a ratio index developed by Gasaway et al. 1983. Radio telemetry studies of 2 packs in 1983 and 1984 showed that moose were the primary winter prey species followed by Dall's sheep. Pack consumption rates were 1 moose per 7 days (Hayes, in prep.).

We have not censused grizzly bear densities within the study area. Research from Kluane National Park which abuts the study area documented a grizzly bear density of 1 bear/26 sq.km. (1/10 sq.mi.) (Pearson 1975). Smith (Government of Yukon, unpubl. data) concluded that a reasonable bear density estimate for the study area is likely one bear per 50 sq.km. (1/19 sq.mi.). Table 1 provides a brief review of bear density estimates from

TABLE 1. Northern interior grizzly bear densities (km^2/bear).

STUDY LOCATION	SOURCE	RESEARCHER POPULATION DENSITY
W.Alaska Range, C. Alaska	Reynolds,'83	41
Nelchina Basin, S.C. Alaska	Miller&Ballard '82; Miller et al. '82	41
Susitna Range, S.C. Alaska	Miller&McAllister,'82; Miller,	41-62
Denali Park, C. Alaska	Dean, '76	24-38
W.C. Alberta, boreal forest	Nagy, pers. comm.	50-75
Auriol Range, S.W. Yukon	Pearson,'75	23-28

* Adult female densities are based on data in publications and(or) communications with researchers.

northern interior grizzly bear studies in relatively similar habitat to the study area. Based upon a conservative density estimate of 1 bear/50 sq.km., we estimate 400 bears within the area. We propose in a later section a method to assess actual bear densities.

Sheep and caribou are additional prey species of wolves; hare and beaver may also be preyed upon. Sheep populations have been censused in the Kluane, Haines Junction and Whitehorse blocks, revealing a density range of .17-.47 sheep/sq.km.. Evidence over ten years of surveys reveals relatively stable sheep populations in those blocks. No sheep inhabit the Teslin and Carcross blocks. Caribou are found in all but the Haines Junction block. Densities range from .04-.05 caribou per sq.km. based on surveys conducted from 1978 through 1980. Hare densities in Kluane Park and the Kluane block reached a peak of 9.7 hares/ha in 1980 and declined to a low density of .05 hares/ha (Ward 1985) in 1983, the year of the first moose calf mortality study. The only information available for beaver is from Teslin and the northeast section of the Whitehorse block. Densities ranged from 3-15 km. per active colony (Slough, Gov. Yukon, unpublished data).

Conclusion

It was concluded that the primary cause of low moose numbers was insufficient recruitment to replace adult losses, and that predation, primarily by grizzly bears, was the major reason for low recruitment. While grizzly bears and wolves were identified as the major sources of moose mortality, the question remained as to whether predation was the major limiting factor to moose population growth, such that reduction of predator numbers would result in a positive rate of moose population growth. The most effective test to determine limitation is reduction of the factor(s) suspected to be limiting, accompanied by knowledge of changes in other factors which may potentially act concurrently to limit population growth.

CONSIDERATIONS FOR FUTURE RESEARCH

The above research findings suggest that reduction of grizzly bear and wolf numbers should result in increases in moose calf survivorship with resultant increases in recruitment and increased population growth rates. We recognise that there are many study design permutations which would allow us to attain the dual goals outlined initially, and to conduct an adequate test of the prediction stated above. However, any study designed to assess that prediction must take into account the following factors.

<u>(1) Short-term versus long-term recovery programs</u>

(a) There is an older age structure to the reproductive segment of the moose population in the study area. If a recovery program is not put in place, we predict that increasingly fewer reproductive females will be present in the population. A short-term recovery strategy is thus preferable to a long-term strategy.

(b) Recovery of a declining, low-density moose population will likely take longer than in a declining or stable higher-density population. Therefore, the most rapid recovery should result through short-term rather than long-term strategies.

(c) Temporal changes in confounding effects are less likely to occur in a short-term experiment.

Therefore, we would prefer to adopt an approach which allows a relatively short-term test of the prediction that reduction of grizzly bear and wolf numbers will result in an increase in calf survivorship with resultant increase in recruitment and population growth rates.

(2) Multi-block predator prescription design versus single predator prescription design

The test that we choose should allow an evaluation of the effect of possible changes in other limiting factors which may act to affect moose numbers, as well as the interaction among limiting factors. Assumptions which are inherent to our prediction are (a) that another potential limiting factor does not assume immediate importance in limiting moose numbers (for example, that moose numbers are not relatively close to the limiting effect of forage/climate), and (b) that there are no significant compensatory effects among limiting factors (for example, that with a significant number of grizzly bears removed, wolves, black bears, and(or) remaining grizzly bears do not remove a substantial number of calves that would otherwise have been taken by the grizzly bears which were removed). Regarding the first assumption, we have briefly reported on research findings which indicate that moose numbers are currently not likely limited by either forage or climate conditions, disease/parasites, changes in reproduction or sex ratios, ingress/egress and(or) human harvest. We are controlling human harvest and have no evidence to suggest that the other factors mentioned will assume an immediate limiting effect upon reduction of predators.

Regarding the second assumption, we have two alternatives, (i) we can ignore the issue of compensation and reduce both grizzly bear and wolf numbers across the study area in a short time period, that is, apply a single predator prescription reduction program, or (ii) we can test for compensation through the reduction of different combinations of predators either across different geographic areas (spatial option) or in the same area through time (temporal option). The first alternative has two serious disadvantages; we do not have the resources for such an extensive reduction program and it would not provide results which could be used with any assurance in other areas. The second alternative would overcome both of these obstacles through the use of either a spatial or temporal block design, that is, areas where grizzly bears and wolves are both removed, and areas where grizzly bears-only and wolves-only are removed. A control area where no prescribed manipulation is undertaken would serve to assess the effect of possible changes in other potential limiting factors which may act to affect moose numbers concurrently with the manipulation of predator numbers. We propose five areas in southern Yukon for use as different prescription blocks (see Fig. 1 and Table 2) - (a) the Haines Junction block for wolf-only reduction in the spatial option; in the temporal option, wolf-only reduction would be conducted first, followed at a later date by grizzly bear reduction, (b) the Whitehorse/Carcross block (hereafter referred to as the

Table 2. Predator reduction programs in each study block according to the spatial and temporal options.

STUDY BLOCK	SPATIAL OPTION	TEMPORAL OPTION
Haines Junction	wolf-only reduction	wolf reduction followed by grizzly bear reduction
Whitehorse/Carcross	both wolf and grizzly bear reduction	both wolf and grizzly bear reduction
Teslin	grizzly bear-only reduction	no predator reduction
Kluane	no predator reduction	no predator reduction

Whitehorse block) for both grizzly bear and wolf reduction, (c) the Teslin block for grizzly bear-only reduction in the spatial option; no predator reduction would be conducted in this block in the temporal option, and (4) the Kluane block which would be used as a control area.

Ideally, we would predict that calf and adult survivorship should increase in all reduction blocks, but should not increase significantly in the control block. These predictions are dependent upon three factors - the ability of monitoring techniques to accurately assess changes in mortality rates, our ability to detect compensation among other mortality factors, and our ability to successfully remove predators. Two independent techniques are proposed to assess changes in both calf and cow mortality rates and causes of mortality. The first involves radio-collaring both calves and cows. Calves would be collared in the calving period and their survivorship and causes of mortality would be monitored over time. In the grizzly bear-only reduction block, if nothing else shows a compensatory response, we predict an immediate increase in calf survivorship within this block relative to previous years and compared to the control block within the same year. If predators compensate for the bear reduction through either the remaining grizzly bears removing more calves, or other predators (wolves, black bears) removing more calves, then the predicted increase may not occur or be detectable. If wolves, for example, do show a compensatory response, then they should kill more calves than in previous years. The causes and rate of cow mortality will be monitored annually with spatial and temporal comparisons. This technique is useful as a measure of causes of calf and cow mortality and as a short-term measure of rate of mortality but may be inadequate as a long-term measure of the rate of mortality owing to sample size inadequacies. A second and more accurate long-term estimate of survivorship in calves and adults is provided by assessment of composition in Fall censuses of the moose population. The census results provide a measure of the accuracy of estimates, but can result in wide confidence limits around estimates. As a measure of significant increases in calf and adult survivorship, therefore, substantial increases in Fall survivorship are required. These substantial increases are predicted in both the grizzly bear/wolf and grizzly bear-only reduction areas. Any confounding effects of possible compensatory predation in the grizzly bear-only reduction block would be assessed in a collared-calf mortality study. It should be recognized that changes in survivorship in the wolf-only reduction block or control block may not be detectable in terms of their statistical significance owing to wide confidence limits on population estimates.

(3) Passive versus active management

"Passive" management in this context refers to the use of current or liberalized hunting and trapping regulations to reduce predator numbers. "Active" management refers to the reduction of predators directly by government personnel. If we wish to pursue a short-term strategy of increasing moose numbers through grizzly bear/wolf reduction, we recommend the active management strategy. Sufficient grizzly bears must be removed in order to detect a change in moose numbers. We propose that 50% of estimated bear numbers in reduction blocks should be removed over a maximum of a two year period. Maintaining the current level of grizzly bear/wolf harvest through hunting and trapping regulations would not result in a sufficient reduction of predators over a short period. The gradual reduction of predators over a number of years may be countered by ingress of predators into the area. A short-term active management strategy would minimize this problem. We have already reported that moose populations in the study area are declining with this "status quo" management of predators. Grizzly bear hunting regulations were liberalized in 1984 and did not result in a substantial increase in bears removed. This method is likely an ineffective short-term technique by itself. Greater liberalization of regulations may be an effective short-term technique, but would likely require such regulation changes as reduction of trophy fees and tag fees, use of calf distress calls, spotting from aircraft and allowance of baiting, some of which are not acceptable at this time. The effectiveness of further liberalization could be tested if allowed in one of the two bear reduction blocks, that is, the Whitehorse or Teslin blocks. Active Government participation in bear reduction through field programs provides the best opportunity for reduction of bears in a relatively short time period as well as an opportunity to estimate bear numbers and ensure that bears are not eradicated.

We recognise two feasible methods for bear reduction by Government personnel - killing of bears or live-trapping and relocation out of the reduction blocks. If bears are to be trans-located, they should be moved at least 480-650 km. (300-400 mi.) in order to prevent their return and therefore allow maximum opportunity for increases in moose numbers. A combination of Departmental involvement in reduction and(or) liberalization of grizzly bear hunting regulations may provide the most feasible means of removing sufficient numbers of bears to effect a significant change in moose numbers over a short-term period.

(4) Applicability of results to other areas

We should be able to assess the results of the chosen test as to whether they are applicable to other areas. For example, can we predict that the result of a reduction of predators in one study area may also be achieved by a similar reduction in a similar study area elsewhere?

(5) Removal of sufficient numbers of predators

The test should ensure that neither grizzly bears nor wolves in the study area are eradicated by the reduction program while at the same time ensuring that sufficient numbers of predators are removed to provide an adequate test of the hypothesis.

(6) Estimating or not estimating bear numbers

As mentioned earlier, actual bear numbers in the study area are unknown, although using a density of 1 bear/50 sq.km. yields an estimate of approximately 400 bears. When this density estimate is applied to the bear reduction blocks (Whitehorse and Teslin), the estimated populations are 141 and 60 bears, respectively, or reduction goals of 70 and 30 bears, respectively, in the two blocks.

There are no documented effective means of censusing grizzly bears over a large area in a short time period. One long-term method is a total census of bears, involving a multi-year telemetry study. The time, expense and lack of documented capability of this method to provide accurate estimates suggests it would not be an appropriate method to pursue. A second method based on sampling and use of radio-collared animals in a capture-recapture method of population estimation may provide a more practical short-term solution (Ballard and Miller 1981).

It is important to attempt an accurate estimate of bear numbers. If we did not have accurate estimates and if changes in moose numbers were documented following predator reduction , we would lack accurate predictive capability, that is, the percent bear reduction required to effect a desired change in moose numbers. Furthermore, we would not know the number of bears which must be left after bear reduction to ensure the continuation of a bear population in the region.

It must be recognized, however, that even with an accurate estimate of bear numbers, we have no information on what number of bears should be left to ensure their continued presence in the study area. The reduction of grizzly bears without an accurate estimate may, therefore, be an acceptable option given (a) the potentially high density of bears, (b) the relatively small size of the reduction area in relation to bear home ranges and dispersal capabilities, and (c) potentially poor capture success. It is more likely that we will be unable to remove sufficient bears (owing to logistical difficulties), than the alternative concern that too many bears will be removed.

(7) Reduction versus non-reduction of wolf numbers

We have suggested that there may be practical limitations to the reduction of bears such that the 50% bear-reduction goal is not achieved. Grizzly bear reduction by itself may not prove an effective technique due to practical limitations. Given that wolves account for 26% of total calf natural mortality and 75% of total adult natural mortality, and that reasonable success rates in removing wolves have been demonstrated, it follows that moose calf survivorship may be most significantly affected by reduction of both bears and wolves.

Estimates of wolf numbers between 1982-1985 have been based on total census counts. A reduction goal of 70% of estimated wolf numbers has been set for the Whitehorse block. Wolf populations can be reduced at harvest rates greater than 23-38% according to Keith (1983), greater than 20% according to Gasaway et al. (1983) and 50% according to

Mech (1970). Gasaway et al. (1983) removed up to 61% of wolf numbers in study areas in Alaska producing a rapid decline in wolves, and consequent increase in moose survivorship. It is an objective of this study to increase moose numbers over a relatively short time period. It is our judgement that to effect a change in wolf numbers which will be manifested in decreased predation rates on moose over a short time period will require a substantial reduction in wolf numbers. We have chosen a reduction level of 70% to achieve that goal. Population estimates obtained for moose from Fall censuses have confidence limits varying from 10-30%. Therefore, relatively substantial changes in moose numbers are required for us to be able to detect a measurable change in moose numbers following predator reduction. If wolves are an important limiting factor to the growth of moose numbers, then substantial reductions in wolf numbers (for example, 70%) should result in a measurable change in moose numbers. The post-reduction response of wolf numbers relative to any changes in their prey base has important management implications. For example, can wolf numbers quickly increase following reduction and through a numerical and(or) functional response act to significantly depress moose numbers?

The following proposals are based on a study design prepared by Hayes (1985). We propose that the ability of wolf populations to exert a limiting effect on moose numbers following wolf reduction be assessed and the mechanisms by which they achieve potential limiting effects. We identify four major components to that assessment.

(a) Given that there will be a significant increase in the proportion of wolf pups in the population as the wolf population declines from reduction, we hypothesize that such an increase would not be due to an increase in litter sizes. If there is an increase in the proportion of pups in the population, it may be due to two factors - (i) pack fracturing, (ii) ingressing wolves establishing smaller territories, or some combination of the two.

(b) Given that the mean age of females will likely decrease in the population as wolf numbers decline, we propose the null hypotheses that - (i) the mean age of reproductive females will not decrease, and (ii) the proportion of reproductive females will not increase.

(c) Given that sheep are an important prey base for wolves (shown from food habits studies), we hypothesize that the proportion of sheep to moose kills in wolf diet will not change following wolf reduction.

(d) If we pursue the spatial option within the experimental block design suggested in point (2) above, we have predicted that the highest moose population growth rate will occur in the Whitehorse block due to concurrent grizzly bear and wolf reduction, while the Haines Junction block will have significantly less moose population growth due to wolf-only reduction. Given this prediction, we will assess wolf population growth rates between Haines Junction and Whitehorse blocks. If a difference in wolf population growth rates is noted, we predict that higher growth rates will occur in the Whitehorse block. Differences between the two blocks may be due to increased availability of moose as a prey item in Whitehorse relative to Haines Junction. We predict that the proportion of younger-aged moose among wolf kills will increase following wolf reduction, and that this will occur in both Whitehorse and Haines Junction blocks. If the reduction rates for both bears and wolves are achieved in the Whitehorse block, then Fall censuses conducted subsequent to the reductions should demonstrate increased calf moose survivorship.

(8) Effect of predator reduction on other ungulate species

Although the primary goal of this program is to assess the effects of predator reduction on moose numbers, it is possible that such reductions may affect the numbers of other ungulate species (sheep, caribou) of management importance. Data are available on the population size, distribution and composition of sheep and caribou within the reduction blocks. During and after the period of predator reduction, inventories of sheep and caribou should be conducted to assess their response to that reduction. It is possible that wolf food habits may change as their overall density declines, with possible shifts among the three ungulate species. Wolf food habits should, therefore, be documented subsequent to wolf reduction.

OPTIONS FOR FUTURE RESEARCH

In the previous section, we identified eight major factors which affect the type of study design chosen to achieve the dual study goals. Although we initially identified numerous program designs, past actions partially dictate the range of actual options available. For example, wolf reduction which has already been conducted in the Whitehorse and Haines Junction blocks precludes a bear-only option in those blocks.

We recognize two realistic options which attempt to incorporate aspects of those major factors, and which may result in increased moose numbers. Option 1 describes a long-term, single prescription program, combining both active and passive approaches. Option 2, which is our preferred option for reasons to be discussed, describes a short-term reduction program within a multi-block design relying upon active management techniques.

Option 1

We propose 70% reduction of wolf numbers throughout the study area by active management combined with 50% reduction of grizzly bear numbers through the use of bear harvest regulations (outlined in point (3) above). Seventy percent reduction of wolf numbers will be achieved in the Whitehorse and Haines Junction blocks in 1985. Wolves have not yet been removed from the Carcross block. We propose that once the 70% goal has been achieved that wolf numbers be kept at that level until the bear reduction goal is achieved. In the wolf reduction blocks, the 70% goal should be maintained for three years. In this option, grizzly bear reductions would be conducted through liberalization of bear hunting regulations, preferably through gross liberalization of regulations, as opposed to "status quo" management or mild liberalization (as occurred in 1984). Changes in moose numbers would be monitored through Fall censuses in each block, and related to trends in numbers prior to predator reductions. Relative to the seven factors outlined in the previous section, this option suffers the disadvantage of being a relatively long-term recovery program. If we were to conduct bear-reduction through Government field programs, we would ensure the greatest chance of success in reducing bear numbers. If, however, we rely on liberalization of hunting regulations, we have less chance of success in removing the necessary number of animals. Without such estimates and given that we cannot conduct tests for compensatory predation in this option (since it is a single predator prescription design), the results would have limited applicability to other areas and thus would be of limited management value. Furthermore, without an accurate estimate of bear numbers, we lack the ability to predict if bear populations will be maintained in the area. Thus, while this option may result in an increase in moose numbers its many disadvantages weigh against its acceptance.

Option 2

Figures 3 and 4 provide a summary of this option and are useful in following the accompanying text description. We propose a five year study, commencing 1985, of the effects of predator reduction on the growth rate of moose in southern Yukon. This program will include an assessment of changes in predator populations and other ungulate populations. We propose that a multi-block predator prescription design be adopted, employing Government field programs to reduce grizzly bear and wolf numbers with liberalization of predator hunting and trapping regulations. This proposal will test the effect of removing different combinations of predators on moose numbers through the use of different predator prescription blocks, and allows the choice of either the spatial option (reduction of

FIG. 3. Flow chart of options for moose/predator management program, southern Yukon.

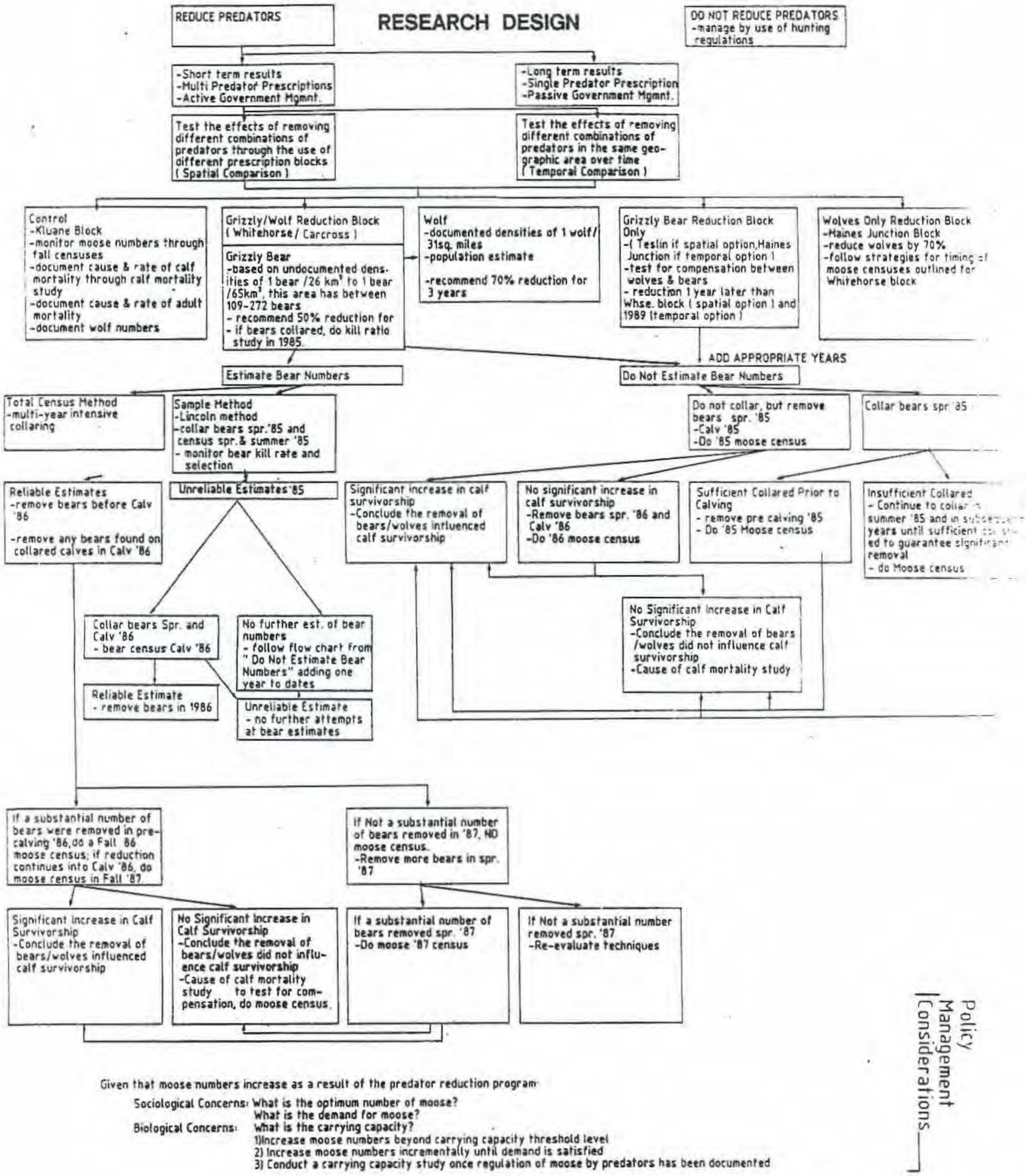
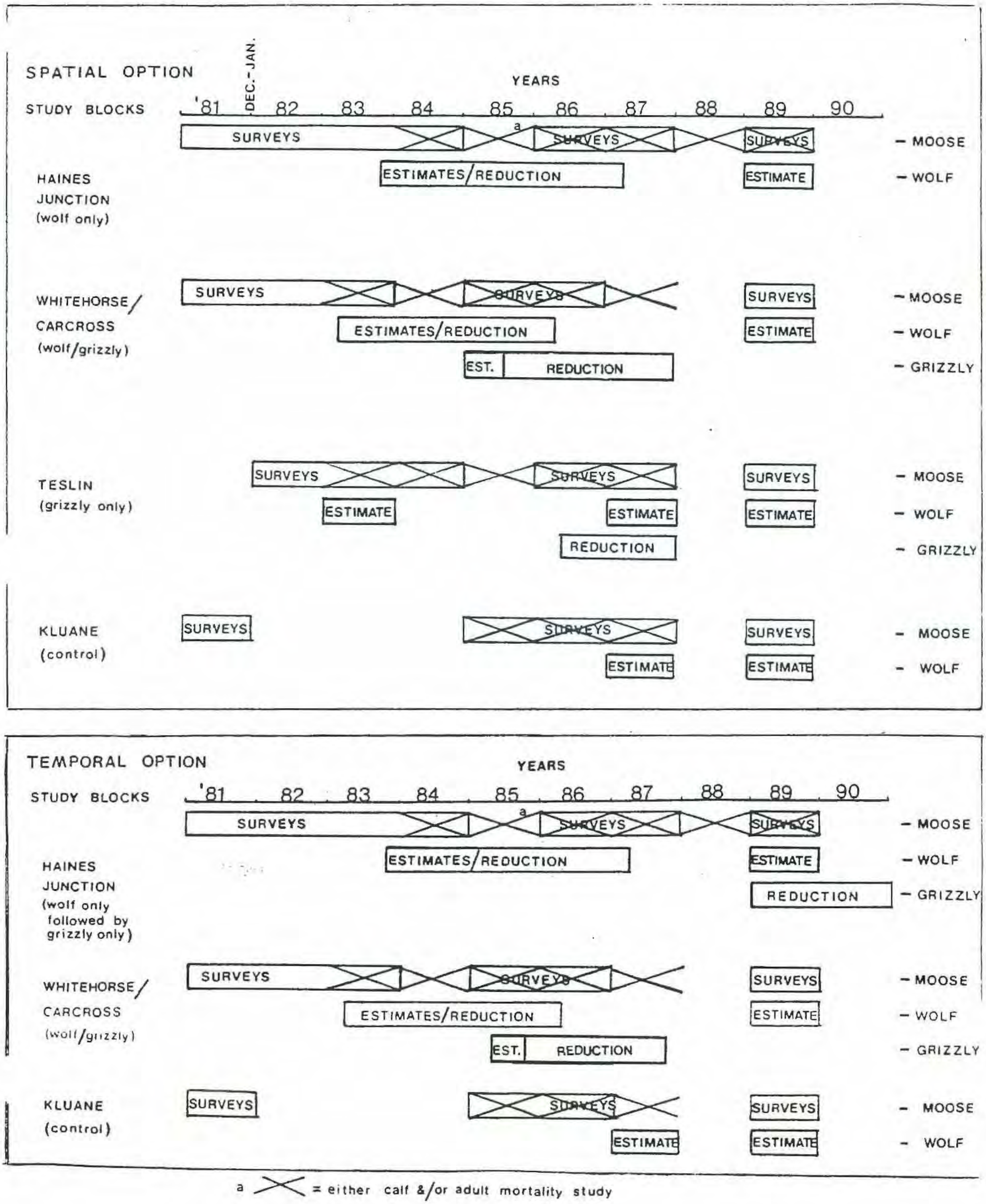


FIG. 4. Scheduling for moose/predator management program according to spatial and temporal options.



bears/wolves, bears-only, wolves-only and no reduction in spatially separated geographic areas over the same time period), or the temporal option (test the effect of removing different combinations of predators in the same geographic area over time). It also allows the option of whether or not to estimate bear numbers.

If the research findings summarized previously are correct, we predict that reduction of both grizzly bears and wolves should result in the greatest rate of increase in annual calf survival and of moose numbers, followed by the grizzly bear-only reduction block and then the wolf-only reduction block.

(1) Grizzly/Wolf reduction block (Whitehorse/Carcross)

Regardless of whether the spatial or temporal study design is chosen, the prescription in this block remains the same. We have crudely estimated from literature sources a bear density of 1 bear/50 sq.km. or 141 bears within this block. We have the option of whether or not to attempt a more accurate estimate. If we elect to estimate bear numbers, we have two possible techniques, outlined in Section 6, previously. We believe that potentially the best short-term method is a mark-recapture estimate. We suggest that subsequent to denning (Spring 1985), the Whitehorse block be searched for grizzly bears and all adult bears encountered be equipped with radio-collars. We propose collaring of moose calves during the calving period of 1985, monitoring of those collared calves and collaring of adult bears that prey upon those or any other observed calves (we note that 30 separate bears were observed consuming moose calves in 1983). Since we know bears prey significantly on collared calves, daily monitoring of calves should result in locating bears. We further propose that the type of prey taken by collared bears and the rate of kill be monitored on a twice-daily basis for three one-week periods (post-denning, calving, post-calving). The collaring of bears allows the opportunity to monitor the rate of kill of prey by bears, selection of prey of those bears over time, and the age/sex of bears preying upon moose. We recognise that the act of collaring and intensively monitoring bears may change their rate of predation on neonates, however, we have no adequate test of this relationship (see Section 2 below).

During the calving period, we would census bears using mark-recapture ratios for population estimation. We recognize the inherent difficulties regarding visual location of bears in both the collaring and censusing operations such that any estimate of numbers may be unreliable due to unacceptable confidence limits around the estimate. We will accept confidence limits of no greater than 20% around the estimate. Confidence limits greater than 20% are unacceptable for our use in relating possible prey increases to levels of predator reduction and in applying results to other regions. We have made a crude estimate based on literature sources of 141 grizzly bears in the Whitehorse block. We recommend that no less than 28 bears (20% of the crude estimate) be equipped with radio collars as a marked sample for use in the mark-recapture estimate.

If a reliable estimate of bear numbers is obtained (as defined above), we will relocate bears from the Whitehorse block in 1986, prior to moose calving. The question remains as to how many bears to remove. We have suggested a goal of 50% of the bear population. If we only removed those collared bears that had been captured at moose calf sites the previous year, we suspect this would account for only 11-27% of the total estimated bear population in the Whitehorse block. This is based on the number of bears seen at collared calf kills in 1983 (n=30) and crude estimates of bear numbers based on densities established from northern studies (range=1 bear/26 sq.km. to 1 bear/65 sq.km.). Based on an estimate of 1 bear/50 sq.km., there may be 141 bears in the Whitehorse block. Removal of 50% of that number would necessitate a reduction of 70 bears in the Whitehorse (n=60) and Carcross (n=10) blocks.

If a substantial number of bears are removed (judged as 50% of the 1985 bear estimate) prior to calving 1986, then a Fall 1986 moose census in the Whitehorse block will be done. If, however, it is necessary to continue to relocate bears to achieve the 50% target through the 1986 calving period, then a Fall moose census would not be done until 1987. If the results of the moose census in either 1986 or 1987 show a significant increase in moose calf survivorship when compared to the results of previous years, and surveys in the non-reduction block (see Section 4 below) reveal no significant changes in moose calf survivorship, then we will conclude that reduction of predators influenced moose calf survivorship. If no significant increase in moose calf survivorship is found and surveys in the non-reduction area reveal no significant changes in moose calf survivorship, then it is possible that reduction of predators did not significantly influence moose calf survivorship. We would then recommend a re-evaluation of the policy of bear reduction as a technique to increase moose numbers. However, lack of significant change in numbers does not necessarily indicate lack of influence by bears. Possible explanations may be that insufficient numbers of bears were removed, ingress of bears from surrounding areas and compensation among grizzly bears, or by wolves and(or) black bears.

If we are unsuccessful in removing 50% of the estimated bear population in 1986, no moose census will be conducted in that year. Additional bears will be removed in 1987. If the target goal is reached, a Fall moose census will be conducted in 1987. If, however, we fail to reach the target goal in this second attempt, we recommend a re-evaluation of techniques and the policy of bear removal.

If we obtain an unreliable estimate of bear numbers in 1985, we have the option of not attempting any further estimate of bear numbers. The alternatives available under that option will be discussed later. First, we will consider the option of repeating the bear collaring and census operations first begun in 1985. We could collar bears in Spring 1986 and conduct a bear census prior to the calving period. We could also continue collaring bears in during calving and conduct a bear census in that period. If a reliable estimate were obtained, we would relocate bears in 1986, although we would not conduct a Fall moose census until 1987 (assuming the 50% reduction goal for bears had been achieved). Our interpretation of the results of that Fall census would follow the description given earlier. It is possible that we could obtain an unreliable estimate again in 1986. If this occurs, we recommend that no further bear estimates be attempted. At this point, we would be in relatively the same position as if we had never attempted a bear estimate, or if we had decided after an unsuccessful bear estimate in 1985 to discontinue further attempts at obtaining bear numbers.

We have the option of not attempting to estimate bear numbers in 1985 or subsequently, and have outlined some of the problems associated with this alternative. The concern exists that bears may be eradicated in the bear-reduction blocks. We have given reasons as to why this is unlikely. Even in the unlikely event that bears were eradicated, reduction blocks are small enough to suggest that they may be repopulated from surrounding grizzly bear populations.

In the event that the decision not to estimate bear numbers is taken, we suggest two alternatives. The first is that bears be removed in the post-denning period and again in the moose calving period. If the results of a Fall 1985 census show a significant change in moose calf survivorship, with no significant change in calf survivorship in the non-reduction area, then we will conclude that reduction of predators influenced calf survivorship. If the Fall 1985 census reveals no significant change in calf survivorship, then we recommend further reduction of bears in Spring 1986 and calving 1986, and a Fall 1986 moose census. We have stated what our conclusion will be in the event that calf survivorship significantly increases. If it does not, then we recommend a calf mortality study in calving 1987 with no further reduction of bears until the results of that study are reviewed.

The second cption in the event that bear numbers are not estimated, is that, rather than simply removing bears, grizzly bears be radio-collared in Spring 1985. The movements of these bears should be monitored and any other bears they associate with would also be radio-collared. This approach would be taken due to uncertainty over our ability to remove sufficient bears in a short time period, that is, accumulate a sufficient number of bears which can be removed when desired. If sufficient numbers of bears have been collared then reduction can proceed. If, however, it is judged that there are insufficient numbers of collared bears, we would collar bears preying on collared calves in Summer 1985 and again after denning in 1986. If a sufficient number of bears are collared, bear reduction would take place in 1986. If it is felt that insufficient numbers of bears have been collared, then collaring would continue through calving of 1986 and into 1987. Even though we have the option of not attempting a bear estimate, it is our strong and unanimous recommendation that an estimate be attempted. If we are successful in estimating bear numbers we will monitor trends in bear numbers and composition in the post-reduction period.

The discussion to this point has dealt primarily with bears. We have proposed that wolves also be reduced in this block. Seventy percent reduction of wolf numbers has been achieved in the Whitehorse/Carcross block. At the time that both wolf and bear reduction goals have been achieved, reduction efforts will stop, and the post-reduction phase of the study will commence for both wolves and bears. We have outlined the hypotheses to be tested on wolves in the previous section.

(2) Bear-only reduction block (Teslin)

The purpose of bear-only reduction is to test the effect of reduction of only that species in affecting moose calf survivorship relative to the other predator-prescription blocks. The Teslin block also provides the opportunity to determine if wolves consume additional moose that would otherwise have died due to bear predation. Relative to reduction of bears, the same options apply as have been previously described. What ever options are chosen relative to bear reduction, they must be identical in both the Teslin and Whitehorse blocks.

We mentioned in the previous section our lack of ability to test the effects of capturing bears on their subsequent predation behaviour. This test cannot be conducted due to the lack of funding to conduct a study of the causes of moose calf mortality in Teslin in 1985 to compare with that done in the Whitehorse block. No collaring or census of bears will be conducted in Teslin in 1985. If an acceptable estimate of bear densities is obtained from the Whitehorse block, we propose applying that estimate to the Teslin block, and relocating 50% of Teslin bears in either 1986 or 1987.

(3) Wolf-only reduction block (Haines Junction)

The purpose of the wolf-only reduction block is similar to that described for bears in Teslin. Removal rates of 70% of estimated numbers maintained over a three year period have been set as the goal for this block.

If the spatial option is chosen, wolf-only reduction will be conducted in this block. Tests of hypotheses regarding wolves in the post-reduction phase will be similar to those described earlier in point (7) of the previous section. If, however, the temporal option is chosen, we propose a post-reduction period after wolf removal of only two years in which no reductions are carried out, to be followed by a reduction of grizzly bears, using methods described earlier for the Whitehorse block.

(4) Non-reduction block (Kluane)

The purpose of the non-reduction block is to provide evidence of moose population characteristics in an area undisturbed by predator reduction. Although we have inferred from research findings that such factors as forage, disease/parasites, reproductive rates/sex ratios, ingress/egress and human harvest are likely not the main factors acting to limit moose population growth, they may change over time in such a way as to increase their effect on moose numbers. Changes in those factors concurrent with predator reduction would confound interpretation of results. The non-reduction block allows some measure of changes in those factors which can be evaluated against results obtained from predator reduction blocks.

We recognize the necessity of having a substantially large geographic area somewhat removed from the predator reduction blocks. Moose numbers and population parameters such as calf-cow ratios, productivity, twinning rates and calf survivorship will be monitored prior to, during and after predator reduction in the predator-prescription blocks. A moose calf mortality study should also be conducted in the non-reduction block. Wolf numbers will be estimated; bear numbers will not due to funding constraints.

We are concerned that predator reduction in adjoining reduction blocks does not affect predation on moose in the non-reduction block. Unfortunately, we have no effective means of testing this potential.

In addition to this non-reduction block as a 'control', we have the ability in this study design to compare results before and after reduction in a block, as well as a comparison among the different prescription blocks.

The proximity of Kluane National Park, its status as an undisturbed predator-prey complex and the years of accumulated data on moose numbers provides the opportunity to use the Park as a check on the Kluane block data and as a comparison with data from the prescription blocks.

(5) Fate of translocated bears

Bears are to be relocated a distance of 480-650 km. (300-400 mi.) from the study area. We propose that 20 bears be equipped with radio-collars and their movements and fate subsequent to the relocation monitored by weekly survey flights until denning. The frequencies of the 20 collared bears will also be monitored by field staff within the study area to determine if any of these bears return.

(6) Additional prey species

We have identified the need to monitor the reponse of sheep and caribou populations to predator reduction, and changes in wolf food habits with reduced wolf numbers. Reduction of wolf numbers to 70% of pre-removal levels will be achieved in 1985. Sheep censuses will be conducted in Kluane (no wolf or bear reduction) and in Whitehorse (wolf-bear reduction) blocks in July of the year following successful achievement of the 50% bear reduction goal. Fall caribou censuses will be conducted in the same year as the sheep censuses. Comparisons for both caribou and sheep data will be made between data collected before and after the predator reduction in each of the blocks specified as well as between the control and treatment blocks.

MANAGEMENT IMPLICATIONS

Assuming that moose numbers show a positive increase due to predator reduction, the concern exists as to the utilization of those increased numbers, that is, can we set a goal for the optimum number of moose in a given area? Currently, moose densities range between 1.8 to 2.6

moose/sq.km. (0.5 to 1.0 moose/sq.mi.). These densities are perceived to be too low by users. We suspect from preliminary range assessment and the condition of animals that the study areas can support higher numbers of moose. Without detailed assessment of range carrying capacity, however, it is unrealistic to propose an optimum moose density. Furthermore, we cannot rely on user recommendations of optimum moose density. At least three options are available - (1) continue to increase moose numbers until they reach a forage limitation threshold with the clear danger of large-scale losses in numbers due to starvation, or numbers reach some other limiting factor below a forage limit, (2) increase moose numbers incrementally until demand by users is satisfied, assuming that such fine-tuning is within the control of managers', or (3) conduct a study of nutritional carrying capacity of the range to allow recommendations on the number of moose the range may support. Regardless of the chosen option, management prescriptions for optimum moose densities or numbers are based on values additional to biological considerations. A study to assess the ability of range to sustain moose can be conducted to provide direction on the maximum densities possible but cannot answer the question as to what densities are appropriate to meet societal needs.

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APPENDIX II

Appendix II

Solicited comments on Study Design - We have requested a critical verbal review (spring of 1983) and a written review (spring of 1985) of the study design by research and management biologist across North America. The following table summrizes all of the domments which we have received.

Name	Credentials	Comments in 1985
Dr. V. Van Ballenberghe	Research Wildlife Biologist, Institute of Northern Forestry, Fairbanks, Alaska - Moose-Predator Researcher	- Satisfied with the technical biological merits of the program in identifying the problem and testing the hypothesis that predator reduction will increase moose survival and thus population growth.
		- Concerned with the Socio-biological aspects of wolf control i.e. in Alaska the public expected and in fact demanded wolf control after it had been started, pointing out that these programs are very difficult to cancel once initiated.
Dr. T. Nudds	Assistant Professor University of Guelph. Theoretical Ecologist	- No comments on the theoretical aspects of the study design.
		- He is concerned with the socio-political aspects of predator reduction as a management tool.
		- Suggests that we dismissed "other potential limiting factors" without adequate justification.
Dr. C. Jonkel	Chairman, IUCN SSC Bear Specialist Group. Bear Researcher	- Concerned with the socio-economic aspect of predator control. Agrees that it is an extremely complicated problem.

Name	Credentials	Comments in 1985
Dr. C. Jonkel (contd.)	Chairman, IUCN SSC IUCN SSC Bear Specialist Group - Bear Researcher	- Sites the lack of management in the past as the reason for the present "dilemma". - Speculates that excessive hunting and poisoning programs in the past forced the moose population from its long term balance with predators (wolves, bears & primitive people). - Concerns expressed over the long term impact on the bear population.
Mr. R. Goulden	Director Wildlife Branch Manitoba	- Expressed satisfaction with the indepth proposal, however, would like to see the effects of spring green up on calf survivorship addressed. As well, he suggested that a longer time period may be required to address all potential limiting factors.
Dr. W. Gasaway	Game Biologist Alaska Fish and Game, Fairbanks, Alaska Moose-Predator Research Biologist	- Strongly supports the proposed multi-block study design - "That design will clearly provide the best insights for management of predator-prey systems. The results will be of great value not only to managers in Yukon, but also to managers across North America."
Dr. G. Holroyd Dr. L. Carbyn Dr. J. Stelfox	Research Scientists Canadian Wildlife Service Research Biologists	- Numerous comments and questions regarding specific biological data presented in the study design. Their main concerns were: (1) another prescription

Name	Credentials	Comments in 1985
Dr. G. Holroyd Dr. L. Carbyn Dr. J. Stelfox (contd.)	Research Scientists Canadian Wildlife Service	block with normal or increased hunting pressure was needed to test the effects of hunting on the moose population, (2) effects of radio collaring cows and calves on the resulting mortality rates, (3) Environmental factors (winter severity) should be more closely analysed, (4) long term strategies are required to predict and mitigate declining game populations before they reach artificially low levels.
Mr. K. Lloyd	Supervisor, Wildlife Population Manager, Dept. Renewable Resources, N.W.T. Mangement Biologist	- Expressed concern over the way wildlife agencies respond to an apparent hunter demand. (socio-biological) - Numerous comments and questions on specific data presented in the study design. - Suggested that it was a well thought out research proposal.
Dr. C. Krebs Dr. A. Sinclair	Professor of Zoology & Associate Professor, University of B.C. Theoretical Ecologists	- Commented on "the high standard of the proposal and in particular on the recognition that adaptive management is an important tool to be used ... in answering these difficult questions about predator control". - Suggested that the ambitious scale of the proposal and the shortage of money to carry it out may be a weakness.

Name	Credentials	Comments in 1985
Dr. J. Theberge	Prof. Ecology Univ. Waterloo Research Biol.	- Defines the situation as a hunting problem rather than a predator problem. Hunting should not exceed naturally occurring recruitment i.e. enhancement strategies are not preferred. Recommends using predator reduction as a last resort after attempting habitat improvement. He feels that a long term recovery program is more economically and socially acceptable compared to a short term recovery program. - Expressed concern over the proximity of the Haines Junction wolf reduction block to Kluane National Park. Due to movement between these areas, Park wolves will be killed. - Recognize the potential environmental differences among prescription blocks and our inability to control natural catastrophies during the experiment. These factors may lead to difficulties in the interpretation of results - Recognizes the complex nature of predator-prey relationships, the use of predator reduction as a managemet tool, and the efforts we have gone to in order to address this issue.

Name	Credentials	Comments in 1985

Names of people who did not respond to our request:

Mr. D. Sherratt, Wildlife Branch, Saskatchewan
Mr. B. Andrews, Wildlife Branch, Alberta
Mr. J. Walker, Wildlife Branch, B.C.
Dr. W. Ballard, Alaska Dept. Fish and Game
Dr. A. Bergerud, Professor, University of Victoria

		Verbal Comments prior to 1985
Dr. J. Theberge	Prof. Ecology University of Waterloo Research Biologist	- Expressed satisfaction with the study design and the biological basis to support wolf control. - Supports the concept of "plurality of strategies to achieve plurality of objectives".
Dr. L. Carbyn	Research Scientists Canadian Wildlife Service Research Biologist	- Supported the concept of predator manipulation as a research tool for studying predator prey systems. - Concerned over the sociological aspects of the proposal.
Dr. A. Bergerud	Professor University of Victoria Theoretical Ecologist specializing in predator-prey relationships	- Strong support for the predator manipulation study design.
Dr. D. Eastman	Management biologist B.C. Fish & Wildlife	- Support for the in depth proposal and manipulation experiement.

APPENDIX III

Appendix III

Summary of Pertinent North American Studies

A brief summary of relevant predator prey studies in North America are presented. The locations of these studies and the current distribution of moose, caribou and their predators have been documented. This was done to give the reader a geographic perspective of moose-caribou/predator research in North America.

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Wolf	(1) Isle Royale, Michigan	In early 1960's, wolves and moose appeared stable with wolves holding moose within range carrying capacity. In early 1970's, moose vulnerability to wolf predation increased due to severe weather and habitat changes. From 1969-1976, wolf numbers increased while moose declined. In 1982 the wolf population declined and the moose population increased. Recent authors have stated that relationships between wolves and moose are unstable cyclic interactions.	Mech. 1966, 1970 Peterson 1979 Peterson et el 1982 Peterson & Page 1983
Moose	Wolf	(2) Alaska	Moose declined primarily because of severe winters, wolves appeared to be preventing recovery. Approximately 86 percent of calves died in their first 2-3 months of life.	Coady 1976
Moose	Wolf	(3) Alaska Tanana Flats	Moose increased in the 1940's and 1950's in response to mild winters, favorable range conditions and predator control. Moose numbers peaked in 1960 and declined to a low	Gasaway et al 1983

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Wolf	(3) Alaska Tanana Flats (Continued)	in 1975. In that year, calf numbers went from 94 calves/ 100 cows at birth to 15 calves/ 100 cows by fall. Wolf predation was estimated to have removed a large proportion of calves, primarily during summer and 13 to 34% of the winter moose (calves and adults) population from 1973 - 1975. Wolf reduction was initiated in 1976 and wolf numbers were reduced by 61%. Calf and yearling survivorship increased 2-4 fold, adult mortality was reduced from 20% to 6% annually and the moose population increased as a result of wolf control. Calf cow ratios went from 15/100 prior to wolf control in 1975 to 51 calves/100 in 1976 following wolf control. Prior to wolf control early winter moose and wolf densities in 1975 averaged about 183 moose and 16 wolves per 1000 km2 resulting in a moose/wolf ratio of about 12/1. The authors concluded that when predator populations are naturally regulated, wolf predation can keep moose population at relatively low levels over long periods of time.	
Moose	Wolf	(4) Northern B.C.	Two areas were studied in northern B.C., (Muskwa and Kechika). In the Muskwa study area 60% of the wolves (pre-reduction density of 100 wolves/1000 km2) were removed in 1983/84. Moose calf to cow ratios increased from 10 calves/100 cows late winter 1984 to 35 calves/100 cows in 1985. In an adjacent area where wolf densities were less (11 wolves/ 1000 km2), then the pre reduction densities.	Elliott 1984a. 1984b.

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Wolf	(4) Northern B.C. (contd.)	The moose calf to cow ratio was substantially higher (29 calves/100 cows). In the Kechika area wolves were reduced by 80% between 1982 & 1984. Moose calf/cow ratios increased from 12 calves to 58 calves/100 cows between 1982 and 1984.	Ballard et al 1981a, 1981b,1985
Moose	Wolf	(5) Alaska Nelchina Basin	Moose increased between 1940 and 1960 followed by a decline through 1975. Wolf numbers increased from a low of .3-.8 wolves/1000 km2 in 1953 to a high of 8-11 wolves/ 1000 km2 by 1965. Between 1976 and 1978 wolves were reduced by 52% (7/1000 km2 to 2/1000 km2). Moose calf survival did not significantly increase in relation to non reduction areas. Two reasons were given for this negative response: first, wolf densities also declined in the non-reduction areas and, second, grizzly bears were identified as the most significant source of calf mortality.	
Moose	Wolf	(6) Alaska Mt. McKinley National Park	The dynamics and food habits of 2 wolf packs were studied from 1966-1974. Haber suggested that wolf predation in both winter and summer was of a compensatory nature. He maintained that wolf predation had little impact on moose under natural conditions but that it would lead to drastic declines when prey populations were overharvested by man. He maintained that winter severity by itself was not of sufficient magnitude to cause moose population declines.	Haber 1977

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Wolf	(7) Northern Alberta	Moose and wolf population dynamics were studied between 1975-1978. Moose and wolf densities averaged 180 and 6/1000 km2 respectively, resulting in a 30 moose/wolf ratio. Annual calf mortality was 73% of which 29% was due to wolf predation. Calves/100 cow ratios averaged 72/100 in May and June, then dropped to 39-43/100 in February and March. Approximately 15% of the adults and yearlings were dying annually, which approximated annual recruitment (19%) of yearlings. They concluded that the moose population was stable or slowly declining and that wolves were the major limiting factor to moose population growth. Black bears were numerous in the study area and were suspected to have caused appreciable calf mortality.	Fuller and Keith 1980 Hauge and Keith 1981
			A second study in Northern Alberta recorded the highest moose reproduction and calf survival rates in North America. Between 1965-1978 the average winter calf/cow ratio was 106 calves/100 cows. Annual adult and calf mortality rates were 16% and 33% respectively. They concluded that high reproductive rates were a result of abundant browse and the low mortality rates of calves due to the lack of predators. Both wolves and grizzly bears were absent from the area and black bears were scarce.	Rolley & Keith 1980 Mytton & Keith 1981

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Wolf Black bear	(8) Quebec	Moose populations in south-western Quebec were regulated largely by wolves and possible black bears. This influence of predators occurred at a time when habitat was not limited, demonstrating that predators can regulate healthy moose populations.	Messier & Crete 1985
Moose	Black bear	(9) Alaska Kenai Pen	A moose calf mortality study between 1977 - 1978 indicated that 57% of calves die and black bears account for 59% of the total mortalities followed by wolves (11%) and grizzly bears (6%). Predator densities were estimated at 189 black bear, 17 wolves, 12 grizzly bears/1000 km2. Moose densities were estimated at 750/ 1000 km2 resulting in a 45 moose/wolf and 4 moose/black- bear ratio.	Franzmann and Peterson 1978 Peterson 1982 Schwartz et al 1983 Schwartz unpubl. data
Moose	Black bear	(10) Saskatche-wan	Fall moose calf/cow ratios increased from approximately 25 calves/100 cows the year prior to black bear removal to 77 calves/100 cows following black bear removal. Ratios outside the removal area in the same year were significantly lower (38 calves/100 cows) then those in the removal area (77 calves/100 cows). Black bears were numerous in the study area prior to removal. Most bears were removed from the reduction area before the on-set of calving. Wolves occurred in low numbers and grizzly bears were non existant.	Kowal & Runge, 1981, Kowal pers comm.

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Grizzly bear	(11) Alaska Nelchina Basin	Between 1977 and 1978, 55% of 120 radio-collared moose calves died before November 1 with brown bears accounting for 79% of the mortalities. Ninety-four percent of all calf mortalities occurred prior to July 19. Bears preyed upon both calf and adult moose. In 1979, 60% of the grizzly bears were relocated 145-268 km from their capture sight. Sixty percent of these bears returned within an average of 58 days (range 19-133 days). Calf survival increased from 32 calves/100 cows in 1978 prior to the bear transplant to 52 calves/100 cows in 1979. Wolf densities prior to 1979 ranged from 2.5 to 6/1000 km2 and grizzly bear densities were estimated at 24/1000 km2. Black bears were uncommon. At this low wolf density, compensatory mortality on calves was not observed following the removal of grizzly bears. After 1979 both grizzly bear and wolf densities increased. As expected, calf survival declined in subsequent years. By fall 1981, calf survival (30 calves/100 cows) and presumably bear numbers had returned to pre-control levels.	Ballard et al 1980, 1981, 1985 Miller & Ballard, 1982.
Moose	Grizzly bear	(12)Alaska Tok	A moose calf mortality study conducted in 1984, after a major wolf reduction program (50%), documented an 82%	Gasaway pers. comm.

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Moose	Grizzly bear	(12) Alaska Tok (contd.	annual mortality rate. Grizzly bears accounted for 52% of the calves, wolves 15%, drownings 12%, and blackbears, 3%. Adult mortality over one year was 11% with grizzlies taking most of those. Radio collared bears (13) were monitored daily during the Fall of 1985. An average kill rate of 1 ungulate/57 days was recorded. Moose densities averaged .08 moose/km2. Habitat does not appear to be limiting moose population growth. He concludes that predation is likely limiting the moose population. Grizzly bears are the most important predator at this time, however, wolf numbers have been reduced prior to the study.	
Caribou	Wolf	(13) N.W.T.	High calf mortality, due primarily to wolf predation, prevented the herd from increasing.	Miller and Broughton, 1974.
Caribou	Wolf Man	(14) Alaska	Western Arctic herd declined between 1970-1976 due to predation by wolves and hunting by humans. Even without human harvest, wolf predation could continue the decline.	Davis and Valkenburg 1978
Caribou	Wolf	(15) Alaska Tanana Flats	The Delta caribou herd increased following wolf control in the 1950's peaked in the 1960's and began to decline about 1970 from 5000 animals	Davis and Valkenburg 1985

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Caribou	Wolf	(15) Alaska Tanana Flats (contd.)	to 2000 animals in 1975. High calf mortality was a major cause of the decline. Between 1970 and 1974 calf mortality progressively increased until few calves (2/100 cows remained prior to winter). A secondary cause of the decline was high adult mortality from hunting (7-19% annually). A 60-75% wolf reduction between 1976-1979 resulted in increased caribou calf survival and overall population growth. Wolf predation was the primary cause of low calf survival and the continued decline of caribou prior to 1976. Continued wolf control caused the herd to increase from 2000 to 6500 over six years at 20% exponential growth rate.	

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Caribou	Wolves	(17) Alaska Fortymile Herd	The Fortymile caribou herd underwent a continuous decline from 1960 to 1975. From 1954-1975 initial calf production was high. However the only years when calf survival to yearling age was "normal" or high was following intensive wolf control. The decline was greatly accelerated during 1970 to 1972 when harvest exceeded the yearling recruitment rate. Evidence from Fortymile herd studies suggest that predation was likely the major factor responsible for the decline. Wolves were likely the most important predator.	Davis, Shidelar and LeResche 1978
Caribou	Wolves	(18) Alberta West-Central	A caribou decline from an estimated 2000+ in the 1930's to less than 300 by 1950 was documented. During the late 1950's and early 1960's, caribou numbers increased, probably in response to low levels of hunting and a predator control program. Through the 1970's the caribou population declined from a high of 1200-1800 in 1968 to a present low of less than 300. The cause of the recent decline appears to be the cummulative affect of predation, hunting and disturbance on the winter range. The annual adult natural mortality rate was 21-22% with wolf predation implicated as the most likely cause.	Edmonds and Bloomfield 1984

SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Caribou	Wolves	(19) Yukon Burwash Caribou Herd	Wolves preyed primarily on ungulates. The consumption of prey determined through fecal analysis showed that caribou were the dominant prey type followed by moose and hare. Wolf predation accounted for 56% to 64% of total annual caribou mortality. An average of 56% of calves died within five months of birth. The natural mortality rates of adult/subadults varied between 6% and 9%. It was concluded that predation was likely the most important factor responsible for limiting herd growth. Wolves were the dominant predator. The Burwash herd was thought to be stable or slowly increasing. Hunting levels are light.	Gauthier 1984

Fig. 1: Location of Moose–Caribou / Predator Studies and Distribution of those species in North America

Moose – Wolf

Moose – Black Bear

Moose – Grizzly Bear

Caribou – Wolf

Numbers refer to studies described in Table 1.

General Predator/Prey Concepts

(Parts of this Discussion are Excerpts from Ballard and Larsen, 1985)

In this section we identify the key facts and concepts which we feel should be considered in the management of large mammal predator-prey systems. The studies presented in this appendix are in part reponsible for the concepts discussed below.

Few intensive studies have been conducted in North America on moose-caribou/predator systems and only a few of these were carried out on multi predator-multi prey systems involving the three large northern predators - grizzly bear, black bear and wolves - that are found in Yukon. The interaction of predators and prey with their environment further complicates our understanding of predation prey relationships. Our knowledge of these interactions in multi-predator prey systems is very limited. However, some advances have recently been made.

Studies conducted over the past decade indicate that predation by wolves, grizzly bear, and black bear, either singularly or in combination, can be a major source of mortality to large ungulates. Gasaway et al (1983) Ballard et al (1985), and Kowal (unpubl. data) have demonstrated through predator removal programs that under certain conditions predation can exert substantial control and even limit moose population size. The results from Gasaway et al (1983), indicated that caribou population growth as well can be limited by predation. The inverse relationship of wolf numbers to deer, moose, and caribou numbers in Alaska and Canada (Skoog 1968, Bishop and Rausch 1974, Olsen 1979, Bergerud 1978, Gasaway et al. 1983, and Ballard et al. 1985) is evidence of the impact wolves can exert on their prey. Such a relationship may exist between bears, moose, and caribou, although extensive evidence is lacking.

Contrary to earlier views, it is generally accepted that mortality by predators is additive rather than compensatory under most circumstances. Additive mortality would occur where an increase in the rate of predation results in an increase in the overall annual mortality rate. Mortality due to predation and mortality due to other factors are isolated events and are added together to determine the overall annual mortality rate. Compensatory mortality occurs where an increase in the rate of one mortality factor results in a decrease in the rate of another mortality factor, an increase in the reproductive rate or both in the remaining population. Keith (1974) concluded that in pristine ecosystems, predation constitutes a large source of additive mortality which at a minimum reduces prey density or may have a depressive effect on population growth.

Although most mortality by predators may be additive, there is little evidence that predation by itself causes moose or caribou populations to decline. All relatively long-term (10 years or longer) studies list combinations of severe winters, deteriorating range conditions, predation, or over hunting as the factors precipitating declines. Predation, however, is often identified as one of, if not the main factor which prevents population recovery from a decline.

Predation can sustain a decline or maintain prey populations at low numbers for long periods, even though the initial cause of the decline may no longer be a major limiting factor. Gasaway et al. (1983) suggested that some predator-prey systems lack sensitive, fast acting feedback mechanisms which regulate predators relative to declining prey. Thus "the balance of nature" concept where fluctuations in predator and prey numbers closely mimic one another does not necessarily apply to all predator-prey systems. Loose regulatory feedback systems have been demonstrated in recent studies on wolves and deer (Mech and Karns 1977) and on wolves and moose (Peterson and Page 1983). In these single prey-single predator systems, predator numbers did not decrease until approximately a decade after prey declines. Gasaway et al. (1983) documented a similar loose feedback response in a single predator-multiple prey system in Alaska. Feedback mechanisms in multi-predator-multi-prey systems are very complicated. Predator regulation in these types of systems could extend beyond decades.

Gasaway et al (1983) speculated that the escape of prey from control by predators may be infrequent and short-lived and may be cyclic in nature. Peterson and Page (1983) described predator-prey interactions as an unstable, cyclic phenomenon. Whether prey fluctuations are cyclic or not probably depends in part on the predator and prey densities, availability of alternate prey, the type of predation (obligate vs. facultative) and number of predators involved. An obligate predator is one that is restricted to one type of feeding behaviour, i.e. wolves are primarily carnivorous, as opposed to a facultative predator that has the ability to change its feeding behaviour as conditions change, i.e. bears can change from a carnivore to a herbivore. The dependency of an obligate carnivore such as the wolf on one or more ungulate species in winter and continued high dependency in summer has been well documented (Mech 1970, Peterson 1977, Fuller and Keith 1980, Ballard et al. 1985). In comparison, facultative carnivores like grizzly and black bears with a broader food base may prey on moose for relatively short periods in the spring, however, they do not rely on them year-round. Regulatory feedback systems involving those predators would likely be less well defined compared to systems involving wolves.

Continuous high levels of human harvest on moose and caribou are likely incompatible with naturally regulated wolf and bear populations in most northern ecosystems. Even in the simplest wolf ungulate system where wolves regulate ungulate numbers (Keith 1974), there would be greatly reduced harvests of ungulates by humans.

Periodic and short term harvest of ungulates would be allowed when the ungulate population was able to escape the restraints of predation. For example, hunting could have been allowed to occur on Isle Royale in the late 1960's and more recently in the early 1980's (Peterson 1977, Peterson and Page 1983) when the moose population escaped from predation. In these cases the manager would have to react quickly and harvest the additional increment. Conversely, when the ungulate population began to decline, the manager would have to react promptly by eliminating or reduce harvest to avert aggravating the decline through an overharvest. The alternative to accepting dramatic natural fluctuations in prey numbers and wait for more or less natural change in events, is to hasten the increase of prey by reducing predators (Gasaway et al 1983). These authors concluded that reducing or eliminating human harvests will have little effect once predation levels are sufficient to cause a prey decline or to maintain prey at low densities. They recommend that harvest control is best used in conjunction with other remedial actions, suggesting that predator reduction in conjunction with reduced harvest levels is an appropriate short-term management action. Keith (1983) stated that between 38 and 50 percent reduction is required to cause a stable wolf population to decline. Long term solutions may include increased predator harvest by hunters and trappers supplemented with more intensive periodic reductions by management agencies. The success of this type of program will depend on the ability of hunters and trappers to significantly reduce predator populations.

Most woodland caribou and moose managers in the north should consider wolves, grizzly bear and black bear as potential sources of mortality as the ranges of these ungulates will contain at least 2 of the 3 predator species (Fig. 1). Where wolves and bears are singularly important sources of mortality, it is likely that both would have to be reduced if long and short-term benefits to the ungulate population are desired. Further investigation into the possibility of compensation among and within predator species is needed. For example, if both bears and wolves were important predators the reduction of bear numbers may temporarily increase calf survival. However, high predation losses to wolves either in summer and/or winter could negate any increases. Also, if all bears are not removed from an area, the remaining bears may compensate by killing more moose calves as was partially the case in southcentral Alaska (Ballard et al. 1980) or by having bears which had not previously killed calves take advantage of the available prey.

Wolves are the most apparent source of mortality of the 3 predator species since wolf kills are more visible, particularly during winter months when snow cover facilitates spotting kills. For this reason they have long been a suspected major source of ungulate mortality. Because bears are effective predators on calves only for a short time period in the spring, their significance may not be recognized unless intensive studies are carried out. Recent advances in neonatal ungulate radio collar designs and telemetry systems have enabled biologists to discover that bears were significant causes of mortality, rather than merely scavengers. If we assume that bears have always been an important source of neonatal ungulate mortality, it may explain the failure of some control programs to increase the survival of ungulate neonates where bears were present but not removed. In reality the wrong predator species may have been controlled or it may have simply been a secondary source of mortality on the calves or perhaps only a significant source of adult mortality. In either case, measurement of young/adult ratios would prove misleading and changes in adult mortality would probably be too small for a manager to measure with the techniques available for short-term studies.

Results of experimental bear and wolf reduction suggest that managers could anticipate a large increase in calf moose and caribou survival if sufficient bear (50%+) of existing populations and wolf (50+%) numbers could be reduced. Whether large increases in calf survivorship would occur beyond the short term without continued predator reduction is not yet known.

Transplanting bears could be an effective tool for improving ungulate calf survival in small areas, but it is expensive and probably unpractical for large areas. Transplanting bears could have long-term consequences on the bear population they were removed from if the reduction level was high, the reduction area was extensive, ingress was limited, and the transplanted bears did not return. Both the transplanted bears and the bear population receiving them could be seriously effected directly through displacement. Under these circumstances the positive effects to the ungulate population and the negative effects to the bear population would both be long term in nature. If the reduction area was small, the reduction level moderate, ingress, moderate and the transplanted bears returned, the impact on the bears would be less severe. Some of the transplanted adult bears and a substantial portion of the young bears would not survive. Under these circumstances the positive effects to the ungulate population and the negative effects to the bear population would be short term.

If the transplanted bears are preying on ungulates, movement of these bears into other areas, unless widely dispersed, could impact ungulate survival in the receiving areas. This would only be a consideration if the receiving ungulate population was also being managed for maximum sustained yield.

The limited data available on grizzly bears suggest that most adult bears and family groups exhibit predatory behaviour (Ballard et al. 1981a). Therefore the reduction of a single age or sex class would probably not result in a substantial increase in calf survivorship. Some evidence suggests that removing certain age-sex classes of black bears, particularly large boars, may influence the dispersal of young male bears resulting in a net increase in the bear population (Young and Ruff 1982). Some bears are protected from hunting, i.e. females with cubs. These maternal groups constitute between 1/3 and 1/2 of a grizzly bear population. Therefore, it may not be practical to reduce bear populations over a short time period using existing hunting regulations.

If only a few predatory bears were responsible for extensive calf mortality, then it may be possible to identify and remove only those individuals. One study in Alaska documented a fold 6 difference in killing rates between individual bears. However, if a substantial number of bears from all age-sex groups were predatory, the removal would need to be more extensive.

Bear populations may be slow to recover from intentional reduction programs due to their relatively low fecundity rates (Murie 1944, Craighead et al. 1969, Pearson 1975). Wolves on the other hand have relatively high reproductive rates, can withstand heavy harvest, and can rebound from reduction programs within 1 or 2 breeding seasons (Keith 1983, Ballard et al. 1985). The low reproductive potential of bears might be considered advantageous because programs would have long-term benefits to ungulates. However, caution should be exercised given the potential for overharvest and long-term consequences for bear populations. Depending on the level of ingress, natural recovery of bear populations could take decades. In comparison, wolf reduction programs must likely be carried out initially for longer periods and may have short-term benefits to ungulates once reduction is discontinued (Ballard and Stephenson 1982).

The historical distribution of both the grizzly bear and wolf has been reduced over the past century. Both species are protected by law in some North American jurisdictions. As a result, programs to reduce these predators will cause alarm in some circles. The loss of grizzly bears in North America likely resulted from the destruction of large tracts of undisturbed wilderness coupled with uncontrolled harvest and killing of nuisance bears. Bears like any other wildlife species can be properly managed so long as adequate habitat remains and populations are adequately monitored. Most northern ecosystems are not attractive to large scale agricultural or forestry developments and consequently the habitat is not as threatened as in southern areas.

All predator prey studies should consider the interrelationship of the animals with their habitat. Both climate and vegetation can directly or indirectly influence predator and prey numbers, however, the mechanism by which this occurs is poorly understood. Predator prey studies should attempt to determine the significance of these potential limiting factors prior to implementing predator reduction.

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SUMMARY OF MOOSE-CARIBOU/PREDATOR PROGRAMS IN NORTH AMERICA
(Primarily from Connolly 1978; Ballard & Larsen 1985)

PREY	DOMINANT PREDATOR	LOCATION (see accompanying figure)	RESULTS	REFERENCE
Caribou	Wolves	(16) B.C. Level Mt. Horseranch Range	This project was designed to determine the effect of reducing wolf numbers upon the recruitment of caribou calves during 1978-80. Wolves were reduced by 61%-80% of pre-control Horseranch Range. Wolves were not reduced on another caribou range at Level Mountain. Comparisons were made. During the wolf control period, caribou on Level Mountain declined by an estimated 11% annually. During the same period, caribou on the Horseranch Range increased by an estimated 12% annually. Wolf numbers were significantly correlated with summer survival of calves. Newborn caribou calves were captured and radio-collared in the Spatsizi in 1979, and on Level Mountain in 1980. They were then monitored to determine the initial causes of mortality. The combined results from the two years showed that wolves accounted for 9 out of 22 (41%) deaths, accidents and unknown causes for 10/22 (45%) and bears 3/22 (14%).	Elliot 1984