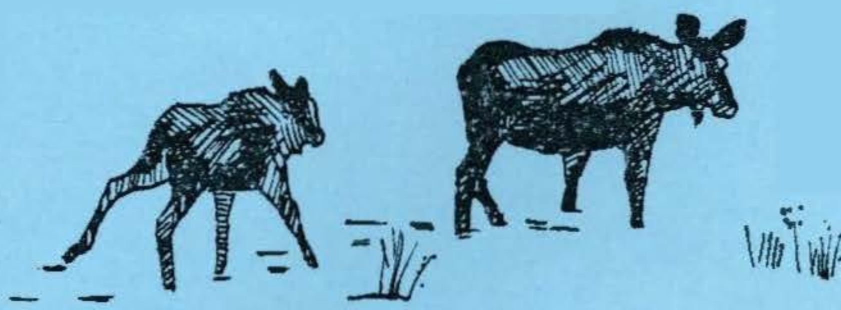
ALASKA DEPARTMENT OF FISH AND GAME

JUNEAU, ALASKA

MOOSE CALF MORTALITY STUDY



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FINAL REPORT (RESEARCH)

State: Alaska

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Project Nos.: W-17-9, W-17-10 W-17-11 and W-21-1 Project Title: Big Game Investigations

Job No.: 1.23R Job Title: Nelchina Moose Calf Mortality Study

Period Covered: April 1, 1977 through June 30, 1980

SUMMARY

During spring 1977 and 1978, 136 newborn moose calves were radio-collared in the Nelchina and upper Susitna River Basins in an effort to determine causes of mortality. Fifty-five percent of the calves died of natural causes, and brown bear predation accounted for 79 percent of the deaths.

Both the moose calf mortality study and brown bear feeding behavior studies identified brown bear predation as a major cause of moose calf mortality. Consequently, an attempt was made to evaluate the effects of reducing bear density on calf survival and to determine if compensatory mortality factors would replace bear predation. Forty-eight bears were captured and transplanted from a 1327 mi^2 area located within the Susitna River study area. The effects of the experimental bear reduction program were evaluated by continuing to radio-collar newborn calves and comparing subsequent causes of mortality with previous years' results, and by comparing fall calf:cow ratios within the bear removal area with other comparative count areas where bear densities were not manipulated.

Estimates of pre- and post-transplant bear densities are discussed. While bears were being transplanted, 32 newborn moose calves were radio-collared within the bear removal area. Two calves died as a result of our collaring activities, while contact with three other calves was lost in June due to radio failure and premature loss of collars. Of the 27 surviving calves, 15 (55.5%) died of natural causes and brown bear predation accounted for 80 percent of these deaths. Possible explanations for the observed high rate of bear predation following bear density manipulation are offered.

Fall calf:cow ratios within the bear removal area in 1979 revealed an increase of 24 calves:100 cows over 1978 levels. Other comparative moose count areas did not demonstrate increases in calf survival during the same period. A

significant relationship between snow depths and the subsequent fall calf:cow ratios from 1970-1978 was demonstrated for the bear removal area, indicating that fall calf survival would have been even greater had winter 1978-79 been only moderately severe.

Identification of brown bears as a significant cause of moose calf mortality creates problems for those attempting to manage moose. Some of the potential problems are discussed.

CONTENTS

BACKGROUND

In recent years, moose (*Alces alces*) populations in several portions of Alaska have exhibited downward trends in total numbers (McKnight 1976). Severe winters in the early 1970's precipitated these declines and low annual recruitment, due to poor calf survival prior to November moose sex and age composition counts, has been suggested as the predominant factor maintaining populations at low levels. Some biologists have suggested, more specifically, that wolf (*Canis lupus*) predation has been the most significant factor contributing to the low calf survival rates (McIlroy 1976 and Gasaway et al. 1977). One area where total population numbers have declined is Alaska's Game Management Unit (GMU) 13 in southcentral Alaska.

Moose population indices for the Nelchina Basin (GMU 13) from 1960 through 1975 exhibited downward trends in nearly all sex and age classifications examined (McIlroy 1976). Since the Basin has historically contributed substantially to the statewide moose harvest, it was desirable to determine the cause of this problem. Wolf predation was thought to be the most important factor contributing to low moose calf survival, although other factors, such as decreasing range quality, brown bear (*Ursus arctos*) predation, low bull:cow ratios, and periodic severe winters were not ruled out (McIlroy 1974). Studies designed to provide information on these facets of moose ecology were initiated in 1975.

Initially, these studies primarily focused on wolf-moose relationships. This involved experimentally reducing wolf densities in one area and then comparing subsequent moose calf survival with that in other areas where wolf densities were not manipulated (Stephenson 1978 and Ballard and Spraker 1979). Studies identifying individual moose populations within the wolf study areas were reported by VanBallenberghe (1978) and Ballard and Taylor (1978b).

These studies provided evidence that moose pregnancy rates were normal, suggesting that low bull:cow ratios were not influencing moose productivity. The parameters of physical condition measured (Franzmann and LeResche 1978), suggested that Nelchina Basin moose were in good condition and that deteriorating range conditions were not a problem. Because there was no large increase in calf survival where wolf populations were manipulated (Ballard and Spraker 1979) it became apparent that a more direct method of assessing the causes of calf mortality was needed. This moose calf mortality study was initiated to meet that need.

Results of the first year of the moose calf mortality study (Ballard and Taylor 1978a) indicated that predation by brown bears was a major cause of moose calf mortality. As a result, the calf mortality study was continued and a brown bear feeding behavior study was initiated in 1978 (Spraker and Ballard 1979). Both studies demonstrated brown bear predation as a major cause of calf mortality.

While these studies were in progress, evaluation of the effects of wolf reductions on calf survival continued. Although calf survival increased the first 2 years, this trend did not continue in 1978. Furthermore, increases in calf survival were not large and could not be entirely related to wolf control because other comparative count units exhibited similar trends (Ballard and Spraker 1979). Once bears had been identified as the primary cause of calf mortality and because wolf densities remained low in the Susitna River study area, an attempt was made to determine if compensatory mortality factors would replace bear predation if bear densities were reduced. The purpose of this report is to present the findings of the moose calf mortality study and our preliminary evaluation of the affects of bear removal on moose calf survival (the latter experiment was conducted using State funds).

OBJECTIVES

To determine the extent and causes of moose calf mortality in the Nelchina Basin and, more specifically, in an area of low predator density.

Study Areas

Descriptions of boundaries, topography and vegetation of areas where moose calf mortality was studied were reported in Ballard and Taylor (1978a, b) and Ballard (In Press). Additional information concerning climate, geology, range conditions, etc. was provided by Skoog (1968).

Brown bear density was experimentally lowered through transplants in a core area of the Susitna River study area described by Ballard and Spraker (1979). The evaluation area, referred to as Moose Count Area (CA) 3, basically encompassed the drainages of the Susitna River north of the Denali Highway (Fig. 1). Two additional count areas were utilized as comparative areas: CA-7, located next to CA-3, and CA-13, which encompassed the upper drainages of both the Little Nelchina and Little Oshetna Rivers.

PROCEDURES

Methods utilized during the calf mortality study were similar to those presented by Ballard and Taylor (1978). During this reporting period a paper comparing techniques utilized to assess the causes of moose calf mortality on the Kenai Peninsula (Franzmann et al. 1980) and in the Nelchina Basin was presented at the 15th North American Moose Conference (Appendix I).

During late spring and summer 1979, an effort was made to remove, by transplant, as many brown bears as could be found in a 1,327 mi^2 (3,397 km^2) area, including all of CA-3 (Fig. 2).

Bears were first located from fixed-wing aircraft (Piper Super Cub PA-18). Typically, search efforts were concentrated in the early morning and late afternoon hours and two aircraft were utilized, each with a pilot and an observer. Once located, bears were darted from a helicopter (Bell 206B) following procedures described by Spraker and Ballard (1979). Immobilized bears were transported in a sling under the helicopter to Susitna Lodge on the Denali Highway where they were weighed and measured, had a premolar extracted for age determination, had identifying markers or radio collars applied, and were transported by pickup truck and/or aircraft (Cessna 206) to release sites 100-160 miles (159-254 km) distant. Details of capture and transplant techniques are presented in Appendix V.

Forty-seven bears were captured from 22 May to 7 June 1979. Additional efforts on 21-22 June resulted in the removal of one additional bear (#276) and the recapture of one radio-collared bear (#237) which had returned to the experimental area. This second removal period was quickly terminated because greening of the vegetation made bears difficult to find. All observed bears were captured with the exception of an unmarked female in the company of male number 237; she escaped during the second capture period.

Search efforts for bears were neither uniform nor random but were concentrated in CA-3 and in areas thought to be good bear habitat (Fig. 2). Some bears were also located at moose kill sites, including kills of radio-collared calves equipped with mortality-sensing radio collars. Of seven brown bears captured and radio-collared within the Susitna River Study Area in 1978 (Spraker and Ballard 1979),

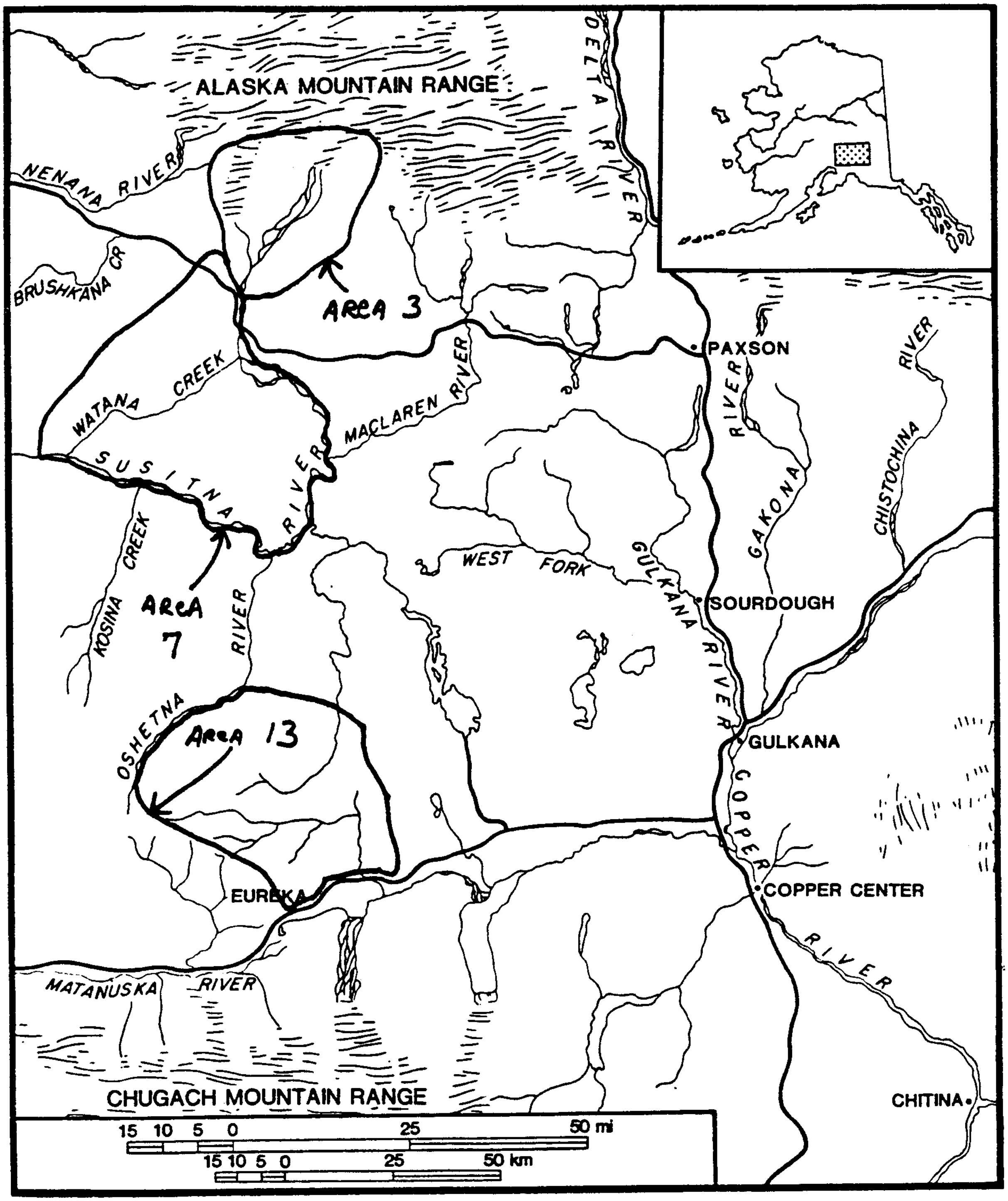

Fig. 1. Moose count areas utilized to evaluate effects of bear removal on calf survival in the Nelchina and upper Susitna River Basins.

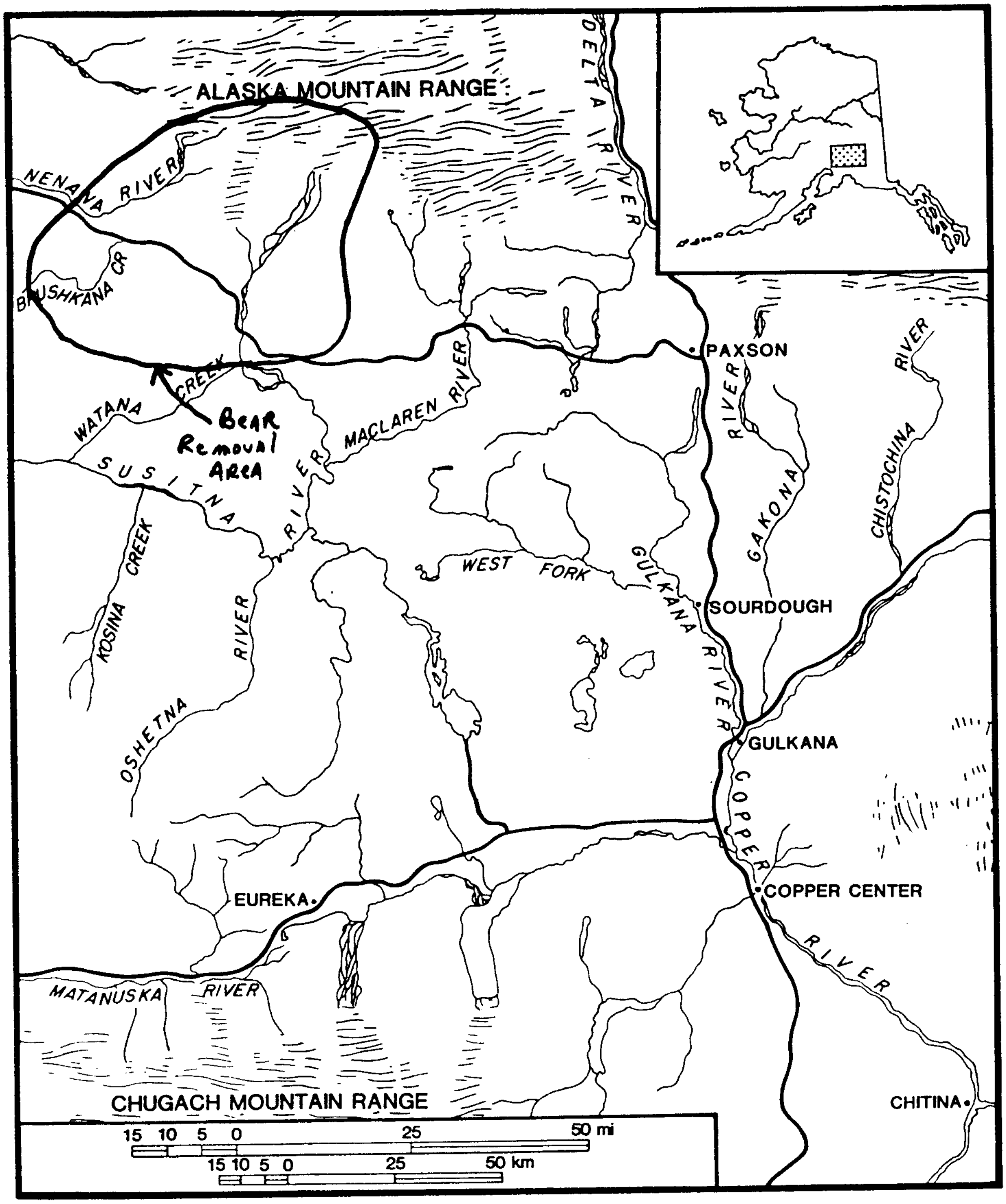

Fig. 2. Boundary of area from which brown bears were captured and transplanted in late spring and early summer 1979 in the upper Susitna River Basin.

only two retained functioning radio collars; both of these animals were recaptured on the first day of the removal effort.

The effects of bear removal on moose calf survival were evaluated by two methods: (1) newborn moose calves were radio-collared in CA-3 and subsequent causes and rates of mortality were compared with those of previous years; and (2) fall calf:cow ratios were determined from aerial surveys (CA-3) and compared to ratios from previous years, and to those from two other comparative count areas (CA-7 and CA-13). The latter method was similar to that utilized to evaluate the effects of wolf reductions (Ballard and Spraker 1979). Because yearling cow moose cannot be accurately identified from fixed-wing aircraft, the number of cows older than 2 years of age was calculated by subtracting the number of yearling bulls observed (representing the number of yearling cows) from the total number of cows observed. This method assumes an equal sex ratio at birth and does not include yearling bulls taken by hunters prior to the survey, therefore, the estimate of cows older than yearlings is still exaggerated. Nevertheless, calf:cow ratios generated from these estimates are more meaningful because they exclude at least some of the sexually immature cows.

Both CA-3 and CA-7 had wolf densities of approximately 1/350 mi^2 (1/909 km^2) in 1979 as a result of Department wolf reduction efforts since 1976 (Stephenson 1978 and Ballard and Spraker 1979). Wolf densities in CA-13, however, were not manipulated by the Department and roughly approached 1 wolf/75 mi^2 (1/194 km^2) (Ballard unpub. data). Because CA-7 was adjacent to CA-3 a few bears were removed from it as well. Therefore, we expected some influence on calf survival in CA-7. However, no bears were removed from CA-13. Our initial hypotheses were that fewer radio-collared calves would be killed by bears following reductions in bear densities and that fall calf:cow ratios would exceed 50:100 if bear predation were as significant a calf mortality factor as we suspected.

Statistical differences between annual calf:cow ratios were tested using arcsine transformation of observed ratios in calculations of the statistic t_s (Sokal and Rohlf 1969:607). Comparisons of trends in calf:cow ratios within and between areas were done using analysis of residuals (Sokal and Rohlf 1969:46) to determine which cells of a chi-square table were significant in rejection of the null hypothesis. The latter analysis was conducted using BMDP canned programs (Univ. of California, Los Angeles, Dept. of Biomathematics, School of Medicine). Confidence intervals around predicted y values were obtained by linear regression analysis following procedures described by Freese (1974).

RESULTS AND DISCUSSION

Five manuscripts concerning different aspects of the moose calf mortality study have been prepared and submitted for publication. Causes of moose calf mortality, as determined from data collected under this study during 1977 and 1978 and from brown bear studies conducted in 1978 (Spraker and Ballard 1979), were combined and submitted to the Journal of Wildlife Management (Appendix II). Morphometric and physiologic data on moose were combined with those from the Kenai Peninsula Study (Franzmann et al. 1980) and presented at the 16th North American Moose Conference at Prince Albert, Saskatchewan. In addition, a paper dealing with factors influencing cow:calf movements was also presented at the same conference. Copies of these papers are presented as Appendices III and IV. The following discussion is limited to those aspects of the study not covered in these papers.

Effects of Reduced Bear Densities on Calf Moose Mortality Rates

Forty-eight brown bears were transplanted from the study area from 22 May to 22 June 1979. Sex and age composition of the transplanted bears is presented in Appendix V along with a discussion of bear densities and population estimates. Of the 48 captured bears, 32 were adults (3 years old or older) 19 of which were fitted with radio-transmitters in an effort to monitor their movements following transplant. It was estimated that perhaps 83 bears (1/16 km^2 or 1/41 km^2) (both sexes and all age classes) occupied the 1,327 mi^2 (3,397 km^2) capture area prior to bear removal. If correct, the initial capture effort reduced the early summer bear density by about 58 percent to approximately 1/38 mi^2 (1/98 km^2).

During 1979, 32 moose calves were radio-collared in CA-3 while bears were being transplanted. Two of these 32 calves died from starvation resulting from collaring activities which disrupted the cow-calf bond. Of the 30 remaining calves exhibiting normal cow:calf bonds, radio contact with six calves was lost (3 in June, 1 in August, and 2 in December) due to the collars prematurely falling off and/or radio failure, therefore, we do not know their ultimate fate. However, contact with three of these calves was lost after 1 August, well after the period when most mortality normally occurs (Appendix II). These three calves were assumed to have survived in our calculations.

Fifteen of 27 (55.6%) calves died of natural causes during the 1979 season, with predation by brown bears accounting for 80 percent of these deaths. As in 1977 and 1978 (Appendix II), most predation occurred prior to 19 July. Surprisingly, the preparation of radio-collared calves killed by bears was essentially the same as that recorded in both 1977 and 1978 when bear densities were not manipulated. Reasons for this unexpected level of predation on radio-collared calves can only be surmised.

During 1979, calves were collared only north of the Denali Highway within CA-3, whereas, in previous years collared calves were more widely distributed. Therefore, collared calves were concentrated in a much smaller area than in previous years and could have been exposed to predation by a few bears. This concentration in combination with the relatively small sample size could have resulted in a biased survival index. Another possible explanation for the large number of bear kills in 1979 is that, for some reason, the reduction in bear density allowed an increase in the rates at which the remaining bears killed calves. During our calf monitoring flights we were able to identify, on the basis of size and pelage characteristics, two bears which remained in CA-3 after the initial bear capture period. These two bears were responsible for at least 6 of 12 radio-collared calves killed by bears. Based upon our observations of these two bears, their minimum kill rates were 1 moose kill/5.8 and 2.5 days, respectively. These minimum rates exceed the average kill rate of 1/6.1 days observed for 23 radio-collared bears in 1978 (Ballard et al. In Press).

The relationship of moose calf movements to bear densities was discussed in the paper presented at the 16th North American Moose Conference (Appendix IV). Once moose calves reached approximately 6 weeks of age, they became better able to evade brown bears. By 15 August, 5 of 12 radio-collared adult bears, with which we still had radio contact, were known to have returned to the bear removal area. An additional three adult bears were known to have been close to, or heading toward, their original capture sites when radio contact was lost. Therefore, 66.7 percent of the adult bears with which we maintained radio contact had returned and could have been preying upon moose. In fact, two radio-collared bears were observed on adult moose kills, but they did not appear to constitute a major cause of calf mortality after they had returned.

Temporary reduction of brown bear density during late spring and early summer in CA-3 resulted in a significant ($P<0.05$) increase in moose calf survival as indicated by fall calf:100 cow ratios. This increase was evaluated by comparing 1979 CA-3 fall calf:cow ratios with those obtained in 1978 and by comparisons with 1979 data from two comparable count areas (7 and 13) where bear reduction did not occur.

In CA-3, calf:100 cow ratios increased from 34.3 in 1978 to 58.0 in 1979 ($T_s = 5.9$, $P<0.05$); no corresponding increases were observed during the same period within the two comparative count areas (Fig. 3).

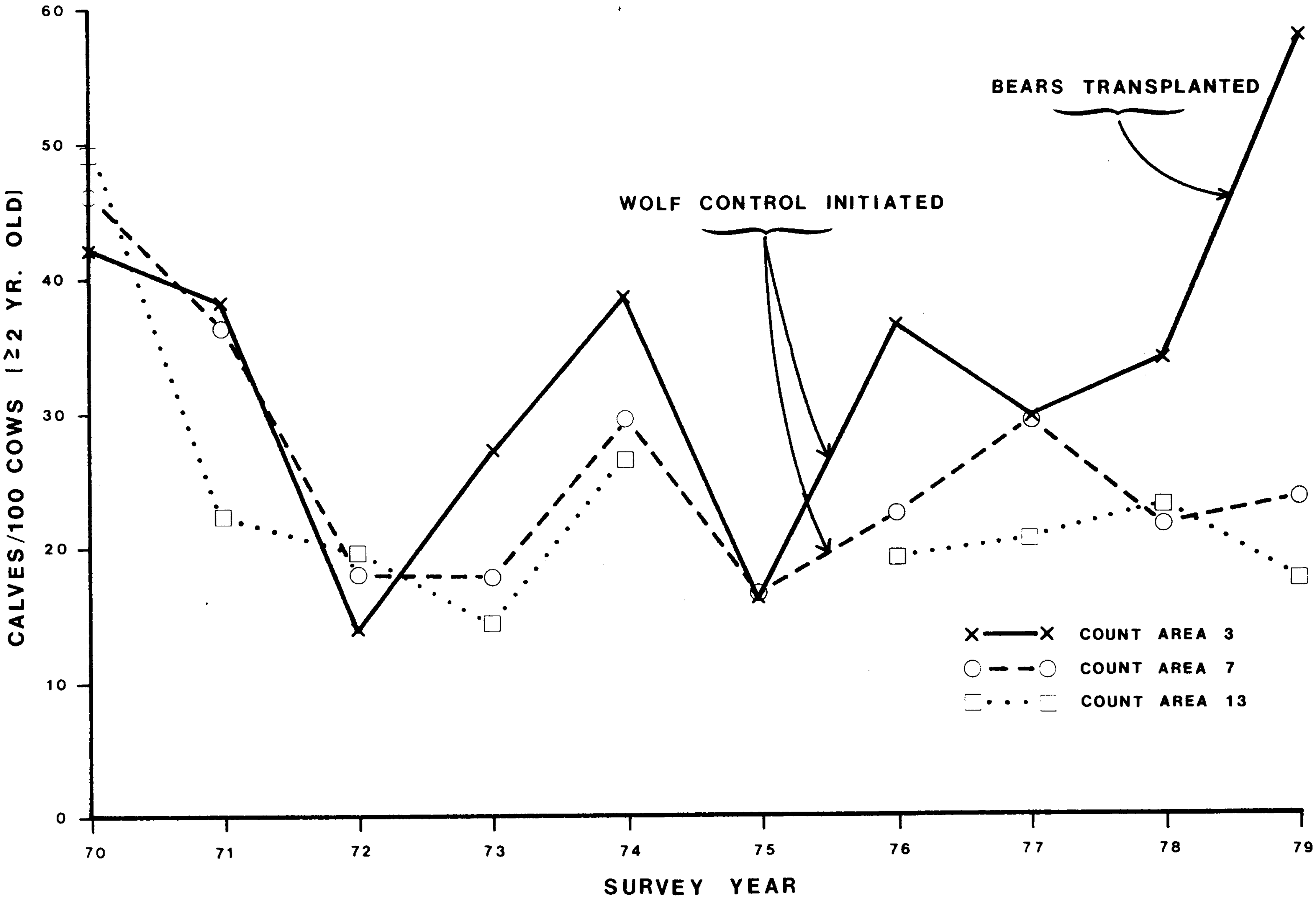

Fig. 3. Comparison of annual calf:100 cow (≥2 yr. old) ratios for 3 count areas located in the Nelchina and Upper Susitna River Basins of Southcentral Alaska from 1970-1978.

Prior to bear removal in 1979, calf:100 cow ratios from 1970 through 1978 were significantly correlated between CAs 3 and 7 ($r = 0.75$, $P<0.05$) (Fig. 4). Based upon this relationship, the predicted fall 1979 calf:cow ratio for CA-3 was 28.7:100. The observed ratio of 58.0:100 fell outside the 95 percent confidence interval (11.4 to 46.0 calves:100 cows), suggesting that the 1979 increase in CA-3 was the result of the bear reduction program.

Although only a few bears were removed directly from CA-7, a larger impact on that area's bear and moose populations was anticipated because an unknown number of bears from CA-3 had home ranges which overlapped into CA-7. These activities apparently did impact overall moose calf survival in CA-7 but only to a limited extent (Fig. 3). During fall aerial surveys in CA-7, high calf:cow ratios were observed only in areas immediately adjacent to CA-3. For example, the calf:cow ratio in CA-7 north of the mouth of Wickersham Creek to Butte Lake was 56.3:100 ($n = 54$), while in the remainder of CA-7 it was 22.1 calves:100 cows ($n = 784$) (S. Eide pers. comm.).

Although calf:cow ratios in CAs 3 and 13 were not significantly correlated ($r = 0.55$, $P>0.05$) (Fig. 5), the two areas often exhibited similar trends (Figs. 3 and 5) and some gross comparisons were possible. CA-13 was not influenced by either bear or wolf removal. Based upon the non-significant correlation between the areas, a calf:cow ratio of 29.5 would have been predicted for CA-3 in 1979. The observed value of 58.0 calves:100 cows fell outside of the 95 percent confidence interval (8.8-50.2 calves:100 cows) providing additional evidence that increases in calf survival were the result of reductions in brown bear and/or density.

Numbers of calves and cows ($\geq$ 2 yr. old) observed in CAs 3, 7 and 13 from 1970 to 1979 were tested with an analysis of residuals to determine significant deviations from expected values based on comparisons of CA-3 to CA-7 and CA-3 to CA-13 (Table 1). The null hypothesis was that for any year the calf:cow ratio was equivalent to that obtained by lumping all years in all count areas. Significant deviations ($P<0.05$) in numbers of calves observed between CA-3 and 7 occurred only in 1979 following reductions in bear density in CA-3. However, between CA-3 and CA-13 significant deviations ($P<0.05$) occurred not only in 1979 but also in 1970 and 1972. Differences in 1970 and 1972 cannot be explained on the basis of available data. However, we believe the differences in 1979 resulted from a reduction in bear predation on moose calves.

Significant deviations ($P<0.05$) in numbers of cow moose observed also occurred for CA-3 in 1979, indicating that fewer cows were present. However, this analysis was based

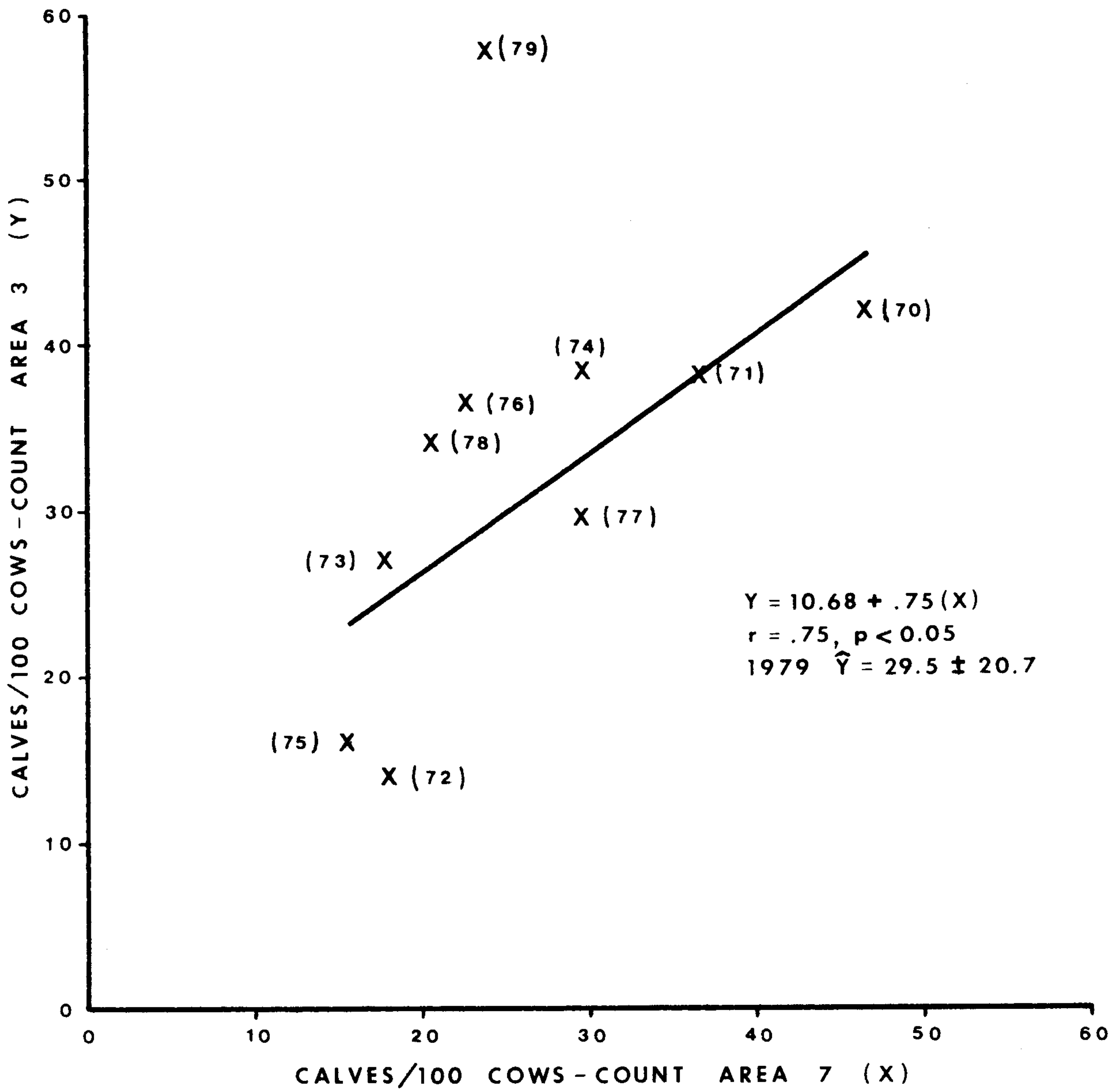

Fig. 4. Relationship between fall calf:cow (≥ 2 yr. old) ratios n moose count areas 3 and 7, located in the Upper Susitna River Basin from 1970-1978 (survey year indicated in parenthesis).

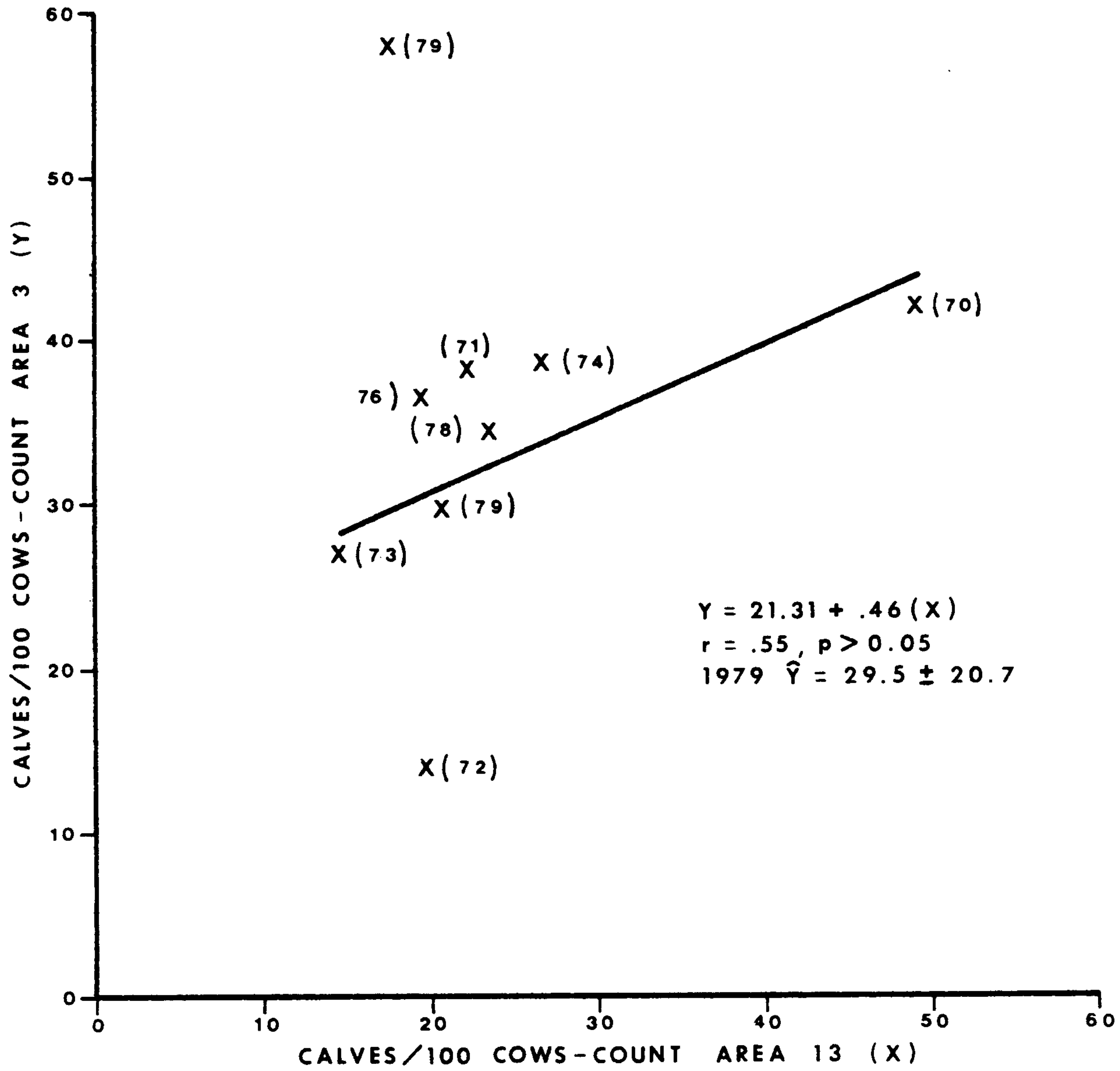

Fig. 5. Relationship between fall calf:cow (≥ 2 yr. old) ratios in moose count areas 3 and 13 located in the Upper Susitna and Nelchina River Basins, respectively, from 1977-1978 (survey year indicated in parentheses).

Table 1. Analysis of residuals of numbers of calves and cows (≥ 2 yr. old) observed in fall moose sex and age composition surveys conducted in three count areas located in the Nelchina and upper Susitna River Basins of southcentral Alaska from 1970-1979.

	Deviations from expected value 1/			Deviations from expected value 1/		
Year	Area	Calves	Cows	Area	Calves	Cows
1970	CA-3	-1.438	1.046	CA-3	-2.200*	1.707*
	CA-7	1.035	-0.668	CA-13	1.954*	-1.226
1971	CA-3	-0.743	0.485	CA-3	0.487	-0.290
	CA-7	0.651	-0.377	CA-13	-0.403	0.194
1972	CA-3	-1.479	0.665	CA-3	-2.317*	1.160
	CA-7	0.932	-0.372	CA-13	1.560	-0.632
1973	CA-3	0.655	-0.317	CA-3	0.680	-0.329
	CA-7	-0.341	0.147	CA-13	-0.405	0.158
1974	CA-3	0.100	-0.061	CA-3	-0.233	0.147
	CA-7	-0.063	0.034	CA-13	0.128	-0.065
1975	CA-3	-0.853	0.381	CA-3	--	--
	CA-7	0.469	-0.186	CA-13	NO	DATA
1976	CA-3	0.854	-0.466	CA-3	0.746	-0.412
	CA-7	-0.362	0.175	CA-13	-0.312	0.139
1977	CA-3	-1.044	0.625	CA-3	-0.258	0.144
	CA-7	0.622	-0.331	CA-13	0.157	-0.071
1978	CA-3	0.920	-0.498	CA-3	-0.169	0.100
	CA-7	-0.534	0.257	CA-13	0.102	-0.049
1979	CA-3	3.055*	-1.871*	CA-3	3.431*	-2.050*
	CA-7	-2.040*	1.109	CA-13	-2.448*	1.183

1/ Significant deviations (t_s <1.66>, $P<0.05$) denoted by *.

upon the assumption that surveying effort was equal, which it was not. Therefore, numbers of cows observed/hour of survey for CA-3 between 1978 and 1979 were compared. No significant differences (T_s = 0.23, P>0.05) were detected between 1978 (21.7 cows/hour, n = 178) and 1979 (18.6 cows/hour, n = 181). This analysis suggests that in CA-3, the numbers of cows remained stable while number of calves increased in 1979 further suggesting improved calf survival in 1979. Significant deviations (P<0.05) in numbers of cows observed also occurred in 1970 and 1972, but cannot be explained on the basis of available data.

Effects of Snow Depths

Although predation by brown bears has been identified as a significant cause of summer moose calf mortality, other factors continue to influence moose productivity and/or survival. Winter severity, as reflected by snow depth data from Monahan Flats (CA-3), was significantly correlated (P<0.05) with subsequent fall calf:cow ratios from 1970 through 1978 (Fig. 6). Forty-five percent of the variation in calf:cow ratios could be attributed to the severity of the previous winter as reflected by snow depth. This relationship was more significant (P<0.01) when the 1971 data were excluded; for unknown reasons the 1971 data did not fit the pattern. Excluding the 1971 data, 76 percent of the variation in fall calf:cow ratios could be attributed to winter severity as reflected by snow depth. Based upon this relationship the predicted fall 1979 calf:cow ratio in CA-3 should have been 23.9 calves:100 cows instead of the observed ratio of 58.0:100, providing additional evidence that bear removal increased moose calf survival.

Snow depths on Monahan Flats from February to April 1979 were the deepest on record (U.S.S.C.S., snow surveys and water supply outlook for Alaska, 1970-1979), equivalent to those recorded during the 1970-71 winter when large moose die-offs were recorded (Bishop and Rausch 1975). Therefore, it appears probable that had the winter of 1978-79 been less severe, an even greater increase in 1979 fall calf:cow ratios could have occurred as a result of reductions in bear density.

Management Implications

Identification of brown bears as a significant cause of moose calf mortality will create problems for game managers attempting to manage moose. Perhaps the most complex problem will be to determine when bears are a significant cause of moose calf mortality. To our knowledge, only the Kenai Peninsula Study which identified black bear (*Ursus americanus*) predation (Franzmann et al. 1980) and this study which identifies brown bear predation, have quantitatively documented the importance of bear predation on moose popula-

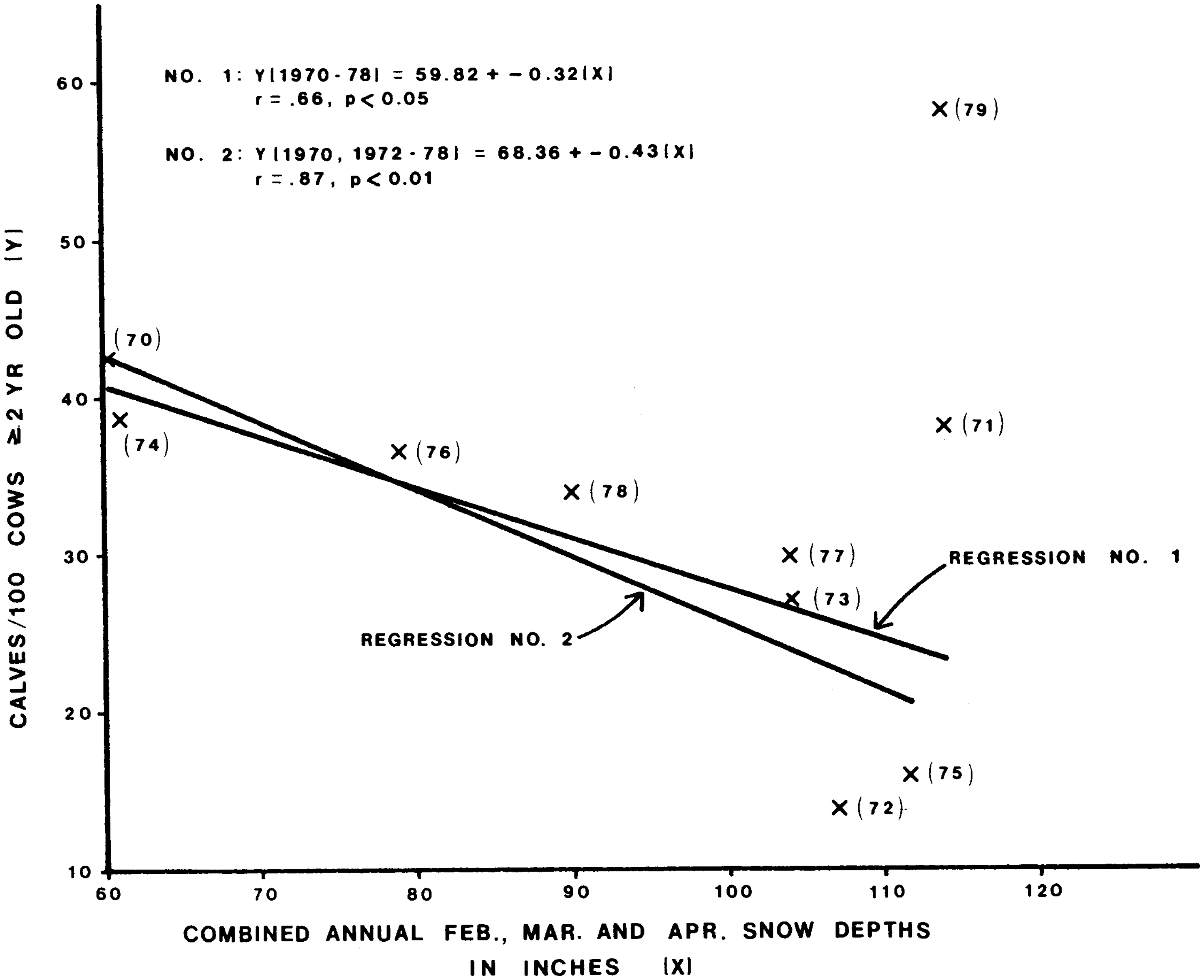

Fig. 6. Relationship of snow depths and following fall calf:cow (_ 2 yr. old) ratios within moose count area 3 located in the Upper Susitna River Basin from 1970-1978 (survey year is indicated in parentheses).

tions. Unfortunately, both studies required funds and manpower of a magnitude which normally are not available to game managers. Even if adequate funds are available, the design of investigative studies is crucial to obtain the types of information needed. Only by radio-collaring newborn calves, or through politically sensitive experimental predator reduction efforts, is it possible to document the types and extent of various mortality factors.

Once brown bears have been identified as a significant mortality factor, the management options available to game managers are limited. Transplanting bears as was done in this study is expensive, impractical and may only influence one calf crop due to the rapid return of transplanted animals. Manipulation of brown bear populations by the Department would be highly unpopular with many segments of the public and might sacrifice one valuable resource (bears) at the expense of another (moose). The only feasible option available is manipulation of bear densities through sport hunting and possibly enhancement of moose calf survival through habitat improvement.

In this study we documented an increase of 24 calves: 100 cows following bear density reduction of at least 58 percent. A permanent reduction in bear density of this magnitude would not be desirable for sound bear management. In fact, it probably would be impossible to attain this level of reduction given the current restrictions on hunting the same day airborne and the protection of sows accompanied by young. Some have speculated that an increase in harvest with these current restrictions in effect may lower the age structure of the bear population (especially for adult males), thereby reducing cub mortality, stimulating productivity and ultimately resulting in bear population increases. Regardless, managers will have to be satisfied with a reduction in bear densities far smaller than that obtained in this study. Whether significantly smaller reductions in bear density would have the desired effects on moose calf survival is unknown. Obviously, bear densities would be an important consideration.

Brown bear density within our bear removal area appeared to be relatively high (approaching 1/16 mi^2) regardless of the procedures utilized to calculate density (Appendix V). It is not known whether these density figures can be applied to the remainder of GMU 13, but the largest bear harvest area, Subunit 13D (S. Eide pers. comm.), has not yet been studied. If our bear density estimates are reasonably accurate, GMU 13 has a relatively dense brown bear population which probably accounts for the low survival of Unit 13 moose calves. Brown bear densities reported in several North American studies were summarized by Pearson (1975) (Table 2). Comparisons with these data indicate that CA-3 bear densities were lower than those reported in other

Table 2. Reported brown bear densities in North America.

mi^2/bear	km^2/bear	Location	Source
0.6	1.6	Kodiak Island, AK	Troyer and Hensel 1964*
6.0	15.5	Alaska Peninsula, AK	Unpublished data (Glenn, pers. comm.)**
8.2	21.2	Glacier Nat. Park, Montana	Martinka 1974*
11.0	28.5	Glacier Nat. Park, B.C.	Mundy and Flook 1973*
9-11	23-27	SW Yukon Territory	Pearson 1975*
16-24	41-62	Upper Susitna R., AK	This study
88(16-300)***	288(42-780)***	Western Brooks Range (NPR-A), AK	Reynolds and Hechtel 1980
100	260	Eastern Brooks Range, AK	Reynolds 1976

* Taken from Pearson 1975.
** Data refer to a 1800 mi^2 intensively studied area of the central Alaska Peninsula.
*** Mean is for the whole of the Nat. Pet. Reserve, Ak, the range represents values for different habitat types in this reserve where the highest density occurred in an intensively studied experimental area.

areas of North America, but were substantially higher than those reported by Reynolds (1976) on the north slope of the Brooks Range in Alaska. Pearson (1975) suggested that his study and the literature indicated that grizzly populations in interior mountain ecosystems stabilize at about 1 bear/ 10 mi^2 (26 km^2). Whether the GMU 13 bear population has stabilized is unknown.

Schwartz and Franzmann (1980) documented higher moose calf survival in areas recently subjected to mechanical crushing. They speculated that black bears found the newly created open habitat less desirable than thickly vegetated areas. This, in addition to the obvious improvements to moose habitat resulting from crushing may have resulted in a decline in predation on moose calves by black bears. Their study suggests an additional management option which should be considered when attempting to lower calf losses from black bear predation. However, this probably does not apply to brown bears, which occupy a wider variety of habitats.

Although calf survival to fall increased as a result of the bear transplants, it remains to be demonstrated whether the 1979 cohort survives through winter and reaches adulthood. Until this is demonstrated, the evidence that reductions in brown bear density will result in moose population increases remains inconclusive.

RECOMMENDATIONS

1. Moose survival in Count Area 3 should be monitored for the next 2 years to determine what proportion of the 1979 age cohort survives to adulthood.

2. Moose calf mortality studies should be conducted on other moose populations where calf survival to the fall of each year appears low.

3. The Department should continue to experimentally manipulate brown bear and wolf population densities in the Susitna River study area to determine interactions between predators and prey and, ultimately, determine the desirable ratios of each species.

4. Long-term studies evaluating the effects of various levels of brown bear harvest on adult and calf moose survival should be investigated.

5. A long-term brown bear study should be initiated in GMU 13. Emphasis should be placed on development of census techniques and on determination of age and sex composition, abundance, movements, mortality factors, productivity and year-round food habits.

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Appendix I. Paper presented at 15th North American Moose Conference Workshop held at Kenai, Alaska during March 1979.

COMPARISON OF TECHNIQUES UTILIZED TO DETERMINE MOOSE CALF MORTALITY IN ALASKA

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Abstract: Studies to assess causes of neonatal moose (*Alces alces gigas*) calf mortality were conducted in two areas (Nelchina Basin and Kenai Peninsula) of Southcentral Alaska during 1977 and 1978. Equipment, techniques and costs associated with conducting the studies were compared. Calf abandonment was influenced by handling method, length of processing time and strength of cow-calf bond. Abandonment rates were lowest when only the calf was captured and no morphometric and physiologic data were obtained, and highest when both cow and calf were captured and all data were obtained.

Radio transmitters utilized in the studies doubled or tripled their pulse rates whenever they remained motionless for either four or one hour periods, indicating that a mortality had occurred. Mortality of radio-collared calves was determined by monitoring from both fixed-wing aircraft and ground stations. A total of 2,092 visual observations of radio-collared calves were made during these studies, while radio signals alone were monitored on 6,617 occasions.

A total of 104 predator-killed moose calves were examined during these studies. Characteristics of calves killed by brown bears (*Ursus arctos*), black

bears (*Ursus americanus*) and wolves (*Canis lupus*) are described. The techniques developed during these studies provided reliable data on causes of mortality which would not have been otherwise obtainable.

In recent years moose populations within several of Alaska's Game Management Units (GMU's) have exhibited downward trends in total numbers (McKnight 1976). Reasons for most of the decline are not known, but low recruitment due to low calf survival prior to November sex and age composition counts has been suggested as the predominant general problem. Specifically, several factors have been suggested which may have contributed to low calf production and survival rates. They included wolf, brown and black bear predation, poor range quality, low bull:cow ratios, and periodic severe winters. The purpose of this paper is to compare various techniques employed to determine causes of moose calf mortality in Alaska.

In an Idaho study (Schlegel 1976), newborn elk (*Cervis canadensis*) calves were radio-collared and monitored to obtain the types of information on calf mortality that we were seeking. Schlegel's technology was adapted for two moose calf mortality studies in Alaska; one in GMU 13 (Nelchina Basin) and one in GMU 15 (Kenai Peninsula). Different techniques were utilized both between and within the studies during the two years (1977 and 1978) in which moose calves were radio-collared and monitored. Ballard and Taylor (1978) described the Nelchina Basin study area while Franzmann and Bailey (1977) described the Kenai Peninsula study area. The Kenai Peninsula Calf Mortality Study was a cooperative effort of the Alaska Department of Fish and Game, Moose Research Center and the U.S. Fish and Wildlife Service, Kenai National Moose Range.

MATERIALS AND METHODS

Transmitters

Two brands of radio transmitters were employed during this study. The Kenai Peninsula study utilized radio transmitters and collars designed by the AVM Instrument Company (Champaign, Illinois) during 1977. These radios transmitted a pulsed signal with frequencies ranging from 164.025 to 164.919 MHz and were designed to triple pulse rate whenever the unit was motionless for 4 hours; a fast pulse rate theoretically indicated a mortality had occurred. Collars were fashioned using the design for expanding goose neck bands and were constructed of vinyl plastic (4 cm wide x 2 mm thick). Each transmitter was encased in acrylic and fastened to the collar by vinyl plastic rings through which the collar freely expanded. A 25-cm insulated wire antenna protruded from the encased transmitter and extended along the side of the collar.

During the second year of the Kenai Peninsula study and for both years of the Nelchina Basin study, transmitters were constructed by Telonics, Inc. (Mesa, Arizona). Collars were designed by Schlegel (1976) for elk calves but were modified to accommodate moose. Expandable calf collars constructed of either international orange (used in 1977) or green (used in both 1978 studies) polyvinyl plastic were 10-cm wide by approximately 0.5 mm thick with an inner circumference ranging from 25 to 69 cm. Collars consisted of two strips sewn together by single stitches of standard number 50 cotton thread. The center of the double strip was folded to form a casing for the radio which was then riveted to the collar through two metal flaps on each side. Nylon elastic 36-cm long and 1.3-cm wide was sewn to the base of the collar between the polyvinyl strips. One side was sewn so the elastic would remain permanently attached and the other side was loosely stitched so the elastic would break away as the collar expanded. Each side of the collar was overlapped at the top and loosely stitched together to permit the collar to break away as the calf grew. On the finished collar, 10 cm above the rivet, a 5-mm wide piece of nylon elastic 9 cm long was sewn to the inner portion of the collar to facilitate a better fit on newborn calves. This elastic was designed to break away in approximately one month, allowing the calf to grow into the collar. The entire collar with transmitter weighed 296 grams.

Each Telonics transmitter (without collar) weighed 170 grams. Transmitters emitted a pulsed signal on frequencies ranging from 148.487 through 148.975 MHz for the Nelchina study and 165.025 to 165.170 MHz for the Kenai study. Transmitters were equipped with a mercury switch "mortality sensor" which doubled or tripled the pulse rate of the signal when the transmitter remained motionless for either a 4-hour period (1977 collars) or a 1-hour period (1978 collars). Power was provided by a lithium battery measuring 24.1 mm by 50.8 mm with an operating voltage of 2.8 VDC providing a theoretical operating life span of 12 to 15 months. Polyvinyl ribbon antennas (1.9-cm wide X 0.09-cm thick X 42-cm long) were between the two polyvinyl strips of the collar, and each transmitter was hermetically sealed in a waterproof metal housing containing internal magnetic switching for storage after use.

Capture and Radio-Collaring of Moose Calves

Three variations of both capturing and processing moose calves were used. A Bell Ranger Jet B helicopter was used to aid in capturing all calves. The variations in capture and handling consisted of: Method 1 -Calf captured and collared with no data obtained; Method 2 - Calf captured and collared with both physiologic and morphometric data obtained; and Method 3 - Both calf and cow captured and collared with both physiologic and morphometric data obtained.

Newborn moose calves were first located from fixed-wing aircraft; then their exact location was relayed by radio to a nearby helicopter. Each helicopter was equipped with a steel-rimmed box on each side measuring approximately 0.6 x 1.2 m which served as a platform from which to jump.

When either capture method 1 or 2 was used, the calf was captured by lowering the helicopter toward the cow and calf until the cow fled from the calf. The calf would then either lie down or run before lying down, and the tagging crew would jump to the ground and capture it. The helicopter remained airborne to keep the cow away from the tagging crew.

When capture method 3 was utilized, the cow was first immobilized by administering a combination of 7 mg. etorphine (M-99, D-M Pharmaceuticals, Inc., Rockville, MD), 300 mg. xylazine hydrochloride (Rompun, Cemagro, Kansas City, MO), and 250 units hyaluronidase (Wydase, Wyth Laboratories, Inc., Philadelphia, PA), with a dart fired from a Cap-chur gun (Nasco-west, Modesto, CA). Once the cow was immobilized, the helicopter was lowered to the ground and the tagging crew then captured the calf which may or may not have been close to the immobilized cow.

Captured cow moose were marked with colored, numbered visual collars (Franzmann et al. 1974) which permitted individual recognition from fixed-wing aircraft. Each cow was ear-tagged with numbered metal tags accompanied by a 5 cm x 13 cm piece of colored polyvinyl plastic. Tags were affixed to the base of the ear. A lower incisor tooth was extracted from each cow for aging purposes according to the methods described by Sergeant and Pimlott (1959).

Each calf was first collared and its sex determined. Under method 1 no further data were obtained except that usually a hair sample was plucked from the back between the shoulder blades to aid in assessing the animal's mineral status using techniques described by Franzmann et al. (1975). When methods 2 and 3 were utilized, several body measurements were recorded. Calves were weighed by placing them in a nylon net with 5-cm stretch mesh and affixing a scale (Overland Nandy Scale #241) to the net. Measurements included total length, heart girth, neck circumference and length of hind foot. The dentition of many calves was photographed.

Samples of blood were taken from the radial vein of each calf and from the jugular vein of adult cows using sterile evacuated containers. Upon returning from the field, the blood was centrifuged and serum separated and placed into 5 ml plastic vials and immediately frozen. One ml samples were later sent to Alaska Medical Laboratories, Anchorage, Alaska or Pathologists Central Laboratory, Seattle, WA for blood chemistry analysis (Technical Autonalysis SMA-12) and protein electrophoresis (Franzmann and Arneson 1973). Generally, one or two 10 ml vials were filled 1/3 to 1/2 full for calves while three to four vials were filled from adult cows. One of the vials contained heparin which provided whole blood for determination of the percent hemoglobin (Hb) with an Hb-meter (American Optical Corporation, Buffalo, NY) and packed cell volume (PCV) with a micro-hematocrit centrifuge (Readocrit-Clay Adam Company, Parsippany, NJ). Remaining sera are being stored for possible future analysis.

Rectal swabs to culture for pathogenic bacteria were taken in the Nelchina study when method 2 was utilized. Swabs were placed in sterile, screw-capped tubes and refrigerated until transferred to the Alaska State-Federal Laboratory, Palmer, Alaska. All samples were cultured on the following media: Blood agar, Eosin Methylene Blue, S S Agar, Brilliant Green Agar, and MacConkey. Enterobacteria were identified by the Enterotube method (R. Barret, pers. comm.).

After tagging and processing the field crews left the calf and/or the cow and calf and met the helicopter away from the site. When the cow was immobilized, an antagonist of diprenorphine (M-50-50, D-M Pharmaceuticals, Inc., Rockville, MD) was administered through the jugular vein. Notes were taken from the helicopter (usually from 0.2 to 0.4 km away), on the cow's reaction to the calf when methods 1 and 2 were utilized.

We began sterilizing the radio collars used in the Nelchina Basin study in 1977 and 1978, after human scent appeared to be partially responsible for calf abandonment. Processing procedures were also modified in the following ways: (1) helicopter was only used to drive the cow away from the field crew when a charge was eminent, (2) the collars were sterilized with detergent and ethyl alcohol, and (3) sterilized latex gloves were worn and calves were held in such a manner as to minimize contact with our torsos.

Monitoring

Radio-collared calves in the Nelchina Basin study were observed from fixed-wing aircraft twice daily for the first two weeks following collaring in 1977. Thereafter, and in 1978, and during both years of the Kenai Peninsula study, calves were observed once daily and the radio signal was monitored one additional time per day to detect mortality. After the first six weeks of study in both 1977 and 1978 calves were monitored less frequently, averaging once per week up to 1 August and then every 6-8 weeks until radio contact was lost or the collar fell off.

Radio-collared calves were located in the Nelchina Basin study using twin three-element antennas mounted on the struts of either a Piper Super Cub or a STOL equipped Cessna 180 aircraft, and in the Kenai Peninsula study using twin 4-element antennas mounted on a Piper Super Cub. Tracking techniques were similar to those described by Mech (1974). Both studies used a portable radio-telemetry receiver (A.V.M. Instrument Company, Champaign, IL).

As a supplement to aerially monitoring moose calves on the Kenai Peninsula, a stationary tracking system was established in 1977 at the Kenai Moose Research Center. A Falcon Five receiver (Wildlife Materials, Inc., Carbondale, IL) and a memory unit (W. W. Cochran design) were used with a 30-m high tower equipped with two yagi antennas. The system was designed to relay a signal to the Kenai National Moose Range whenever a fast mode was detected.

When calves were either observed dead or the mortality unit was activated, an aerial search within approximately 1.0 km of the suspected kill site was made, when practical, in an attempt to sight predators. The presence or absence of radio-collared wolves, brown bears, or black bears was checked. Methods utilized for predator studies were described in Ballard and Taylor (1978), Franzmann and Schwartz (1978), Ballard and Spraker (1979), and Spraker and Ballard, (in prep.). Following the aerial search, a helicopter was used to return to the observed or suspected calf mortality, usually within two hours during the first several weeks of the study. Afterwards, many of the kills were examined using float planes.

A two-element, hand held antenna (Telonics Co., Mesa, AR) attached to the portable AVM Instrument Co. (Champaign, IL) receiver was utilized to locate suspected kills. The antenna was held outside the helicopter window, allowing us to pinpoint and often observe the carcass. When kills were not observable from the helicopter, the same antenna was used to locate the carcass on the ground.

Upon reaching the suspected mortality site, a thorough study of the calf and the surrounding area was made to determine cause of mortality. If predation was suspected, the area was searched for presence of tracks and scats. Observations were recorded on a mortality form adapted from Schlegel (1976). In predator related deaths vegetation within a 15-m radius of the kill was thoroughly searched for the presence of hair for use in predator species identification. Hair samples were later independently verified as to species by Mr. Jack Jordan, Investigative Unit of the Division of Fish and Wildlife Protection, Alaska Department of Public Safety, Palmer, Alaska, using a modification of the methods described by Adorjan and Kolenosky (1969).

All of the dead radio-collared calves in 1977 not killed by predators, and initially, a few of those killed by predators, were retrieved and transferred to permanent facilities for necropsy. Necropsies in the Nelchina study were performed by Richard Barrett, Alaska State-Federal Laboratory, Palmer, Alaska and those in the Kenai study were performed by the second author.

RESULTS AND DISCUSSION

Capturing and Processing

A total of 197 moose calves were captured and radio-collared for the two studies during 1977 and 1978; 68 in the Kenai Peninsula study and 129 in the Nelchina Basin study (Table 1). Of this total, 171 calves subsequently retained the calf:cow bond. The highest abandonment rate was experienced under method 3, where both the cow and calf were captured and processed. Substantially fewer abandonments occurred when either methods 1 or 2 were utilized.

We suspected that the higher abandonment rate experienced under capture method 3 was the result of a combination of factors. Many of the immobilized cows wandered away from their calves shortly after the antagonist had been administered. Therefore, the drugged condition of the animal probably had some impact. Cows which wandered away from calves nearly always resulted in abandonment. Apparently newborn moose calves could not keep up with a cow under stress, and for unknown reasons, some of the cows did not come back to search for the calves.

We believed that some of the abandonments were partially due to a poorly established cow:calf bond. This appeared to be particularly true for calves which were only a few hours old. We noted that when cows with "newborn" calves were pushed away with the helicopter, they sometimes fled and never made any attempt to return to their calves even when ground time was less than 3 minutes. Conversely, when calves were more than several hours old the cow was persistent in her attempts to return to the calf.

For capture methods 1 and 2 we measured the time it took to successfully collar and process calves. We did this with a stop watch and measured time from departure to return to the helicopter. Ground time for capture methods 1 and 2 averaged 5.7 minutes (S.D. = 3.3 min.) and 9.6 minutes (S.D. = 3.02), respectively. Ground time for methods 1 and 2 appeared to be partially a function of vegetation density and experience of participants. Ground time for method 3 in the Kenai study averaged 37.4 minutes (S.D. = 12.2 min.).

Table 1. Comparison of methods used to capture and process neonatal moose calves on the Kenai Peninsula and the Nelchina River Basin of Southcentral Alaska during 1977 and 1978.

Study Area	Study Year	Method 1[a/]			Method 2[b/]			Method 3[c/]			Totals		
		# Collared	# Abandonments	Percent	# Collared	# Abandonments	Percent	# Collared	# Abandonments	Percent	# Collared	# Abandonments	Percent
Kenai Peninsula*	1977	0			9	2	22.2	16	4	25.0	25	6	24.0
	1978	31	2	6.5	0			12	5	41.7	43	7	16.3
Nelchina Basin	1977	24	0	0.0	30	6	20.0	0			54	6	11.1
	1978	36	5	13.9	39	2	5.1	0			75	7	9.3
Totals or Weighted Mean		91	7	7.7	78	10	12.8	28	9	32.1	197	26	13.2

a/ Calf only captured--no condition data obtained.

b/ Calf only captured--condition data obtained.

c/ Cow and calf captured--condition data on both obtained.

* Percent abandonment excludes calves of unknown fate (n = 4).

In the Nelchina study the abandonment rate under method 2, when the calf was captured and full processing occurred, declined from 20.0 percent in 1977 to 5.1 percent in 1978. Although we have no data to statistically prove our assertion, we believe the changes we instituted in handling collared calves were responsible for the lower abandonment rate. During 1977 we observed at least two cases in which the cow returning to her calf lowered her head and slowed her approach when about 10 m from the calf. The cow then appeared to sniff the calf, bolt backwards and run away never returning. We surmised that we had, by altering the calf's scent, reduced its acceptability to the cow. At this time we modified handling procedures as outlined earlier. Following these changes we only experienced one abandonment out of 15 captures in 1977 and, of course, experienced the lower abandonment rate in 1978.

Annual costs of capturing each calf in the Nelchina study were $155.00 and $175.00 for 1977 and 1978, respectively. Increased costs in 1978 reflected increases in the charter rates for both helicopter and fixed-wing aircraft. Comparative costs per calf in the Kenai study averaged $197.00. An additional $58.50 (includes drugs) was required when the cow was also captured and processed. We were unable to do a cost comparison between methods 1 and 2, but since helicopter air time per calf was 68 percent more with method 2, collaring these calves cost approximately 25 percent more than those processed using method 1.

We believe, based upon our comparison of capture and processing methods to abandonment rates, that collection of physiologic and morphometric data on both cows and newborn calves definitely increased the likelihood that the cow would subsequently abandon the calf. Some abandonments also occurred when only the calf was processed, but we believe an abandonment rate approaching 10 percent was acceptable for both studies.

Obviously the abandonment rate of 32 percent under method 3 would be unacceptable for most mortality studies. However, the advantages gained from collection of other types of data may make such a high rate of abandonment justifiable. To our knowledge few data exist on the relative health of either cow moose immediately following parturition, or more importantly, newborn moose calves. Aside from determining proximate causes of moose calf mortality, it seems of equal importance to be able to determine the health of the animals at birth, thereby gaining insight as to whether the animal would have lived had the identifiable sources of mortality not been present.

A total of 928 samples or measurements was obtained for both studies by fully processing captured cows and calves (Table 2). Although these data have only been superficially

Table 2. Types and numbers of biological samples obtained from neonatal moose calves when either both the cow and calf were fully processed or the calf alone was fully processed.

Study area	Year	Weights	Tooth for age determination	Physical measurements	Hair samples	Blood samples	Rectal swabs	
Kenai Peninsula	1977	23	10	154	41	41	0	
	1978	9	13	80	21	21	0	
Nelchina Basin	1977	30	0	117	31	27	15	
	1978	32	0	159	48	36	20	
Totals		94	23	510	141	125	35	928

analyzed to date, we believe they will provide important baseline parameters to aid in assessing moose calf condition at birth. The criteria established by Franzmann and LeResche (1978) for adult moose blood parameters, and Franzmann et al. (1975) for hair mineral analysis as an indicator of mineral deficiencies, all have potential to aid in this assessment. Undoubtedly weight-age correlations will also aid in the interpretation of a calf's health in relation to other regional moose populations. These condition characteristics will also be of value for determining relative health of individual cows in relation to their calves. Consequently we believe that the advantages of the morphometric and physiologic data obtained from processing both cow and calf outweigh the disadvantages of high abandonment at least until an adequate sample is obtained. Once a sufficient sample is obtained, or if high initial calf abandonment is deemed unacceptable, then method 2 should be used whenever practical. The abandonment rate obtained when only the calf was captured and fully processed was relatively low in comparison to other methods, yet it allowed collection of several types of baseline information. Additionally, calves which were abandoned in the Kenai Study in 1978 were recaptured and used in captive moose studies.

Evaluation of Equipment and Methods of Monitoring

Calf monitoring and subsequent examination of dead calves in the Nelchina study required approximately 250 hours of fixed-wing and 25 hours of helicopter flying time during each year of study. For the Kenai study approximately 140 hours of fixed-wing and 13 hours of helicopter flying time were required for each year of study.

Nelchina Basin calves were visually monitored on 1,308 occasions (Table 3) and the signal alone was monitored an additional 2,304 occasions to determine if the mortality sensor had been activated. Kenai Peninsula calves were monitored more intensively than those in the Nelchina study because of the stationary monitoring system. With this system, signals were monitored on 1,379 and 1,110 occasions (Table 3) in 1977 and 1978, respectively. Additionally, Kenai calves were visually monitored on 784 occasions, while signals only were monitored from fixed-wing aircraft a total of 1,824 occasions for both years of the study.

During the Nelchina study, a total of five false alarms were recorded; one in 1977 when the mortality mode was set for 4 hours and four in 1978 when the mode was set for 1 hour. All of these "false alarms" were the result of calf inactivity. Four radios malfunctioned during the Nelchina study when the mortality pulse locked on for unknown reasons and did not return to it's normal pulse rate. This required visual observation of those calves to determine if mortality

Table 3. Summary of radio failures and intensity at which radio signals were monitored during moose calf mortality studies conducted on the Kenai Peninsula and Nelchina Basin of Alaska during 1977 and 1978.

Study area	Year	Number of visual observations from aircraft	Number times signal monitored from ground station	Number of times signal monitored w/o visual from aircraft	Number of false alarms	Number of faulty transmitters and/or collars
Kenai Peninsula	1977	455	1,379	675	1	5
	1978	329	1,110	1,149	6	1
Subtotal		784	2,489	1,824	7	6
Nelchina Basin	1977	1,003	0	776	1	1
	1978	305	0	1,528	4	3
Subtotal		1,308	0	2,304	5	4
Totals		2,092	2,489	4,128	12	10

had occurred. The Kenai study also experienced similar "false alarms" and malfunctions of transmitters; a total of seven false alarms and seven faulty transmitters or collars for both years of study. Although both studies had a slight increase in false alarms when the mortality activator was reduced from four to one hour, we recommend its use for moose. The reduction in time between when mortality occurred and when the unit was activated in all probability aided us in examining dead calves more quickly.

We maintained radio contact with collared calves for as long as possible. For the Nelchina study we maintained contact through November of each year. Following that period, the attrition rate due to premature battery failure, or loss of radio antennas which resulted from the collar splitting in half and exposing the antenna to brush, etc. became pronounced. For the Kenai study radio contact was concluded in August 1977 in response to a combination of mortality, premature failure of AVM radios and from collars falling off. Collars fell off prematurely due to the plastic collar cracking and breaking. During 1978 radio contact was similar to that in the Nelchina study.

Equipment utilized during these studies was so reliable we felt that once a cow:calf bond was verified, visual observation of calves was not necessary. However, calves were tracked periodically to prevent loss of radio contact due to calf:cow movements. Also, visually observing calves on a regular basis increases the probability of observing a predator at the kill site.

During 1977 in the Nelchina study we experienced some problems with the collar designed by Schlegel (1976). It became apparent that the collars, originally designed for elk, were not falling off moose. We were able to examine two calves in late fall 1977 and found that collars were splitting apart at the top as intended, but the continuous elastic strip was not parting. The elastic was holding the collar on the calf and when fully expanded was causing lacerations on the neck. No mortality was observed as a result of this problem. We did modify collar design for 1978 by cutting the elastic on the top and sewing it with cotton thread directly to each flap of the collar. This modification solved the problem and the collars were in the process of falling off at the time this paper was prepared.

We utilized three collar colors during the study: both orange and clear plastic in 1977 and green in 1978. Orange-colored collars proved most beneficial in aiding us to visually observe the animals from fixed-wing aircraft. Both the clear and green collars, however, were very difficult to observe from the air, but may have reduced the visibility of the collar to predators.

Our radio transmissions were spaced at 5 MHz intervals. This spacing created problems with separating individual calf frequencies because the AVM LA-12 receiver lacked crystal control and consequently did not have the refinement required to separate signals spaced only 5 MHz apart. This problem was partially alleviated in the Nelchina study by dispersing the radios over large geographic areas. Collar spacing was not possible in the Kenai study because moose calving was concentrated and serious overlap of calf frequencies was encountered. As a result, a crystal controlled receiver with a programable scanner (TR-2 receiver with digital processor, Telonics, Mesa, AZ) was purchased. This new receiver system eliminated frequency overlap reduced fixed-wing flying time when only signals were monitored by at least 60 percent.

We also experienced operational problems with the automated monitoring system (Falcon five receiver and memory unit) on the Kenai and were subsequently unable to rely upon it as much as we had hoped. We should point out, however, that the system does have tremendous potential to reduce costs of monitoring radio-collared moose, particularly in areas where calving is relatively concentrated.

Determination and Characteristics of Calf Mortality

During our 2 years of study we examined a total of 139 (includes five uncollared calves) moose calf mortalities. We were able to determine cause of the mortality as either being due to predation, accidents or miscellaneous factors in 135 of these. Of the 135 mortalities, 26 (19.3%) were attributed to project induced abandonments, five of which subsequently were killed by predators, while the remainder were the result of natural causes. Of our identified natural causes of mortality on bonded radio-collared calves, brown bear predation was the largest factor (n = 61, 56.0%) for both studies combined, followed by black bear predation (n = 23, 21.1%), miscellaneous (accidents, disease--n = 10, 9.2%), wolf predation (n = 9, 8.3%), and unknown predation (n = 6, 5.5%). We actually observed the predators in 48 (46.2%) of the 104 (includes five uncollared calves) mortalities attributed to predation.

Ground examinations of predator-killed moose calves allowed general characterization of kills made by both brown and black bears and to a limited extent wolves. For moose calves which we determined to have been killed by brown bears, we actually observed the predator at the site on 26 occasions. Brown bear kills differed in their characteristics based upon the length of time it took for us to reach the site. Frequently when we reached the site within 2 hours, the brain contents and viscera were all that had been consumed and most of the edible flesh was still intact. When this was the case often the ears, eyes and tongue were also missing. Puncture wounds in the neck and skull were readily evident. On occasion claw marks across the body cavity were also present. When we visited bear kills several hours after the mortality, we often found that the entire carcass along with bones and hoof sheaths had been consumed, except for the lower jaw and cranial bones. On about half of the kills scats usually containing the flesh, hair, bone and hooves of calf moose were located close to the site. Tracks were often present but their occurrence was largely dependent on soil and vegetation conditions at the site. We found that the hide was inverted on approximately 25 percent of the kills, and 25 percent were buried. Brown bear hair was found in varying quantities, on all of these kills where we searched for the presence of hair on the surrounding brush.

Brown bear densities were high and black bear densities low in the Nelchina study area while the reverse was true in the Kenai study area. This facilitated identification of which species of bear was making the calf kills. Where both species of predators exists in reasonable densities the differences in kill characteristics may not be so obvious.

We observed the predator on 12 of 23 black bear-killed moose calves. At the kill site we noted perhaps two distinct differences from kills made by brown bears. Black bears usually did not break open and consume brain contents, when calves were examined within a short time after the kill; with brown bears it appeared to be the first item sought. Both predator species, however, readily consumed the viscera. Kills by brown and black bears could be differentiated on the basis of hair collected from the kill site, but differentiation was not possible based upon scats.

Although our sample size (n = 9) was small, it appeared that the characteristics of wolf-killed moose calves were somewhat different than bears. Wolves were observed at the kill site on 7 of 9 occasions. At the kill site we found that the brain case had not been broken into and for most, the eyes, ears and tongue were intact. In all cases, we found the viscera unconsumed lying either at, or a short distance from, the carcass. When flesh was consumed many of the bones were intact or scattered at the kill site. Usually ends of the ribs were chewed off and in some cases ends of long bones and their surfaces were chewed. We only found the presence of scats at three kills; however, this may have been the result of forcing the predator away from the kill. Wolf hair was present on the brush surrounding the kill at all of the sites when we searched for it. We never observed any claw marks on the hide but puncture wounds were always found on either the head, neck or rear quarters.

In conclusion, we believe the techniques we utilized to determine causes of moose calf mortality were reliable and provided accurate data not otherwise obtainable. These techniques have widespread application where quantifiable data on predator-prey relationships are needed, and can be modified to suit other ungulate species.

ACKNOWLEDGEMENTS

We wish to extend our appreciation to all of the staff members of the Alaska Department of Fish and Game who participated in various aspects of the project. In particular, we thank Sterling Eide, Thomas Balland, Leon Metz, and Larry Aumiller. We extend special thanks to Mike Schlegel, Idaho Fish and Game, Kamiah, Idaho, for sharing his collar design with us, and to his wife for constructing our collars. Both Donald E. McKnight and Karl Schneider reviewed the manuscript and made helpful suggestions. Both studies were supported in part by Federal Aid in Wildlife Restoration Projects W-17-9, 10.

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Appendix II. Draft of manuscript submitted to Journal of Wildlife Management.

CAUSES OF NEONATAL MOOSE CALF MORTALITY IN SOUTHCENTRAL ALASKA

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ABSTRACT: During spring 1977 and 1978, 136 moose (*Alces alces gigas*) calves were radio-collared in the Nelchina and Susitna River Basins of Southcentral Alaska in an effort to determine causes of mortality. Thirteen calves (9.5%) died as a result of collaring activities. Of 123 remaining calves exhibiting normal cow:calf bonds, contact with 3 calves was lost and 66 (55%) died of natural causes. Brown bear (*Ursus arctos*) predation was the most significant source of mortality, accounting for 79% of the deaths. Timing of radio-collared calf losses was very similar to that of uncollared calves of radio-collared adults, indicating that collaring did not predispose them to predation. Ninety-four percent of the natural mortality occurred prior to 19 July of each year. Lack of scavenging on both abandoned and predator-killed calves was observed. Radio-collared brown bears were observed on 78 kills during 1978, averaging 1 ungulate kill/6.1 observation days. Moose of all age classes comprised 87% of the kills with calf moose being the largest prey item (57%). Identification of brown bears as significant predators of moose will complicate attempts to understand and manage ungulate-carnivore relationships.

J. Wild. Manage.

Key words: Moose calf mortality, *Alces alces gigas*, Brown bear predation, *Ursus arctos*.

The Nelchina and upper Susitna River Basins of Southcentral Alaska have been important areas for moose hunting in recent years, accounting for 18% of the annual statewide harvest. The moose population reached a peak in 1960, and after the severe winter of 1961-62, began declining. Severe winters also occurred in 1965-66 and 1971-72. Severe winters were thought to have precipitated the decline, but factors such as predation, range deterioration, hunting and low bull:cow ratios were also thought to have contributed (Bishop and Rausch 1974).

During this decline, the moose population began exhibiting low calf recruitment, reflected by moose sex and age composition counts (Alaska Department of Fish and Game [ADF&G], unpubl. data). Even after relatively mild winters, calf:cow ratios remained low, reaching a low of 15 calves/ 100 cows in 1975. Predation by gray wolves (Canis lupus), was thought to be preventing the moose population from increasing.

Similar declines occurred in at least two other Alaskan moose populations, but timing and the ecological situations were considerably different. On the Kenai Peninsula, the moose populations remained high or increased prior to 1970, then declined due to severe winters (Bishop and Rausch 1974) and a decline in browse quality and quantity (Oldemeyer et al. 1977). The resulting moose die-off coincided with a wolf population increase resulting in a wolf density of 1 wolf/ 65 km^2 (Franzmann et al. 1980). On the Tanana Flats, however, the moose population increased, crashed and then recovered between 1950 and 1972 with severe winters thought to be the controlling factor (Bishop and Rausch 1974). In the mid-1970's, the population again declined and wolf predation was suspected of preventing the population from recovering (Gasaway et al. 1977).

A number of studies were initiated in an effort to determine the reasons for the moose population declines. Several approaches were used and these were described by Franzmann and Bailey (1977), Oldemeyer et al. (1977), Gasaway et al. (1977), Stephenson (1978), and Ballard and Spraker (1979). The Tanana Flats and Nelchina Basin studies evaluated the effects of wolf predation on moose calf survival, in part, by reducing wolf densities. All study approaches attempted to enumerate predator and prey densities with the aid of radio-telemetry and aerial survey methods.

In the Nelchina study, food habit studies of the gray wolf indicated moose comprised the bulk of the year-round diet, but rates of calf moose predation were not of sufficient magnitude to cause the low moose calf:cow ratios in the basin (Ballard and Spraker 1979). A preliminary analysis of moose composition data indicated either small or no increases in calf:100 cow ratios following reduction in wolf densities. Evaluation of several blood parameters, used by Franzmann and LeResche (1978) to assess the physical condition of Alaskan moose populations, revealed that Nelchina basin moose rated high in comparison to other populations and indicated deteriorating range conditions were probably not the cause. Moose pregnancy rates determined by rectal palpation were normal (88%) and, thus, low initial calf production due to low bull:cow ratios was ruled out (Ballard and Taylor 1978). As a result of these studies, it became apparent that a more direct method of determining causes of moose calf mortality was needed.

In Idaho (Schlegel 1976), newborn elk (Cervis canadensis) calves were fitted with radio-collars and monitored to determine the causes of mortality. Schlegel's technology was adapted to newborn moose calves concurrently for this study and a study on the Kenai Peninsula (Franzmann et al. 1980). The objectives were to identify specific causes of moose calf mortality between parturition and November when fall sex and age counts are conducted. This paper reports results of the Nelchina calf mortality study and brown bear predation studies, and discusses some of their management implications. These studies and the Kenai Peninsula moose calf mortality study (Franzmann et al. 1980) were conducted concurrently during 1977 and 1978.

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STUDY AREAS

The study was conducted in portions of the Nelchina and upper Sustina River Basins in southcentral Alaska (Fig. 1). The area, referred to as Game Management Unit 13, consists of approximately 61,595 km^2 of which 18,798 km^2 is above 1,200 m in elevation.

Moose calf mortality was studied in three study areas (Fig. 1). Area 1, the Susitna River study area, was selected because of its low gray wolf density (averaging 1 wolf/567 km^2) which resulted from wolf removal by Department personnel in 1976 and 1977 (Ballard and Spraker 1979). Areas 2 and 3, the Mendeltna and Hogan Hill study areas, respectively, were studied for comparative purposes. Gray wolf densities in these 2 areas averaged approximately 1 wolf/277 km^2.

Three study areas were inhabited by alternate prey species including caribou (Rangifer tarandus), snowshoe hares, (Lepus americanus), beavers (Castor candensis) and muskrats (Ondatra zibethica). They also supported populations of brown bears and black bears (Ursus americanus), the latter in low densities. Topography, vegetation and climate of these areas have been thoroughly described elsewhere (Skoog 1968, Rausch 1969, Bishop and Rausch 1974).

METHODS

Design and materials utilized during this study were described by Ballard et al. (1980) and utilized by Franzmann et al. (1980). However, a number of differences did exist between the methods utilized in the two studies. Schlegel's (1976) collar design was utilized during both years of this study (orange collars in 1977 and green collars in 1978). Newborn moose calves were first located from fixed-wing aircraft and their location was relayed via radio to a nearby helicopter and calves were captured according to methods described by Ballard et al. (1980). No attempt, however, was made to capture accompanying cows as described by Franzmann et al. (1980).

Radio-collared moose calves were monitored from fixed-wing aircraft similar to methods described by Mech (1974). Calves were observed twice daily during the first 2 weeks of the study; then once daily for 4 weeks and less frequently until their collars fell off or radio contact was lost. Fixed-wing aircraft monitoring was not supplemented with a ground station as was done in the Kenai Study (Ballard et al. 1980).

For comparison of mortality rates, survival of un-collared moose calves of radio-collared cows within the study areas was monitored. These cows and calves were visually observed from fixed-wing aircraft at 3- to 5-day intervals beginning on 24 May of each year. Repeated low passes were made until the observer was satisfied that a calf was present or absent. After 1 July, cows were monitored every 2 weeks until November, then at least once per month until spring. Causes of death were not determined for these calves.

When radio-collared moose calves were observed dead or the mortality unit was activated, an aerial search within approximately 0.8 km of the kill site was made from fixed-wing aircraft in an attempt to sight predators. The presence or absence of radio-collared gray wolves and brown bears in the vicinity was checked. Twenty-three brown bears and all wolf packs in the study areas were radio-collared. Wolf summer food habits were described in Ballard and Spraker (1979) and Ballard (1981).

As a result of our 1977 calf mortality studies, 23 adult (3 years old or older) brown bears were captured and radio-collared in the 3 study areas during 1978 utilizing helicopter capture techniques (Spraker and Ballard 1979). Ages of captured bears were ascertained using methods described by Mundy and Fuller (1964). Bears were classified as sexually mature if at least 6 years old (Hensel et al. 1969). Radio-collared brown bears and wolves were visually observed on the same flights moose calves were monitored.

Species and age (adult or calf) of prey killed by brown bears were identified from fixed-wing aircraft on the basis of size, coloration, and antler growth (Ballard In Press).

Radio-collared calf mortalities were examined on the ground, usually within 2 hours of detection. Identities of predators killing calves were established on the basis of observations of predators at the kill site or by the presence of sign as described by Ballard et al. (1980) and Franzmann et al. (1980). When the cause of death was not predation or abandonment, calves were necropsied within 24-36 hours following death. Calves which died due to project-induced abandonment were not visited on the ground for at least 1 day and, on most, up to 2-3 days. On both abandoned and predator-killed moose calves the area was revisited regularly from fixed-wing aircraft to observe subsequent scavenging activity.

RESULTS AND DISCUSSION

Between 25 May and 10 June, 136 moose calves (55 in 1977 and 81 in 1978) were radio-collared in the three study areas (Table 1). We determined the fate of 96% of all radio-collared calves. Abandonment induced by collaring activities resulted in the deaths of 13 calves (9.5%):6 in 1977 and 7 in 1978. Normal cow:calf bonds were observed for the remaining 123 calves. The fate of 3 of these calves was unknown since radio-contact was lost prior to November. Contact was lost after 94% of the observed mortality had occurred, so these calves probably survived; however, they were not included in survival calculations.

Of the 120 remaining calves, 66 (55%) died of natural causes during their first 6 months of life (Table 1). Predation was the greatest cause of mortality, accounting for at least 86% (57 of 66) of the natural deaths. Brown bears were the most significant predators in all 3 study areas, accounting for 78.8% of the natural mortality during the months studied. Approximately 9% of the mortality resulted from miscellaneous factors such as injury inflicted by the cow, drowning, or pneumonia. Causes of mortality for 3 (4.5%) calves were not determined because the site could not be reached or was reached too long after the calf's death to adequately determine the cause.

Ratios of identified causes of natural mortality for radio-collared calves were pooled for both years of study and compared between study areas and tested (Chi-Square). No differences in causes of mortality ($P>0.05$) were detected among the 3 study areas. Thus, the differences in gray wolf density among the study areas did not appear to be an important factor affecting calf mortality.

Table 1. Numbers of moose calves collared (includes uncollared siblings) and subsequent causes of mortality for 1977 and 1978 in the Nelchina and upper Susitna River Basins of southcentral Alaska.

	Area 1		Area 2		Area 3	All 3 areas		Total	
Calves	1977	1978	1977	1978	1978	1977	1978	N	%
Radio-collared:	25	31	30	26	24	55	81	136	
Abandoned[a]	2	4	4	2	1	6	7	13	
Lost radio contact	1			2		1	2	3	
Remaining	22	27	26	22	23	48	72	120	100.0
Deaths from:									
brown bear predation	8	11	16	10	7	24	28	52	78.8
gray wolf predation			1		1	1	1	2	3.0
Unk. predation			1	1	1	1	2	3	4.5
Misc. factors[b]	1	1	2	1	1	3	3	6	9.1
Unknown		1	1		1	1	2	3	4.5

Table 1 (cont.)

	Area 1		Area 2		Area 3	All 3 areas		Total	
Calves	1977	1978	1977	1978	1978	1977	1978	N	%
Total mortality	9	13	21	12	11	30	36	66	55.0
Surviving to 1 Nov.	9	13	5	10	12	18	36	54	45.0

a Abandoned due to tagging activities.

b Includes injuries inflicted by cow, drownings, and pneumonia.

Abandoned calves (N = 13) died within 4 days and remained unmolested from 30 hours to several days. Only one instance of scavenging by birds was observed within a 30-hour period following death. Predator-killed calves examined on the ground were also observed to receive little use by scavengers. In all cases following ground examination, at least 2 days passed before any use by scavengers was observed. Where less than 50% of the carcass had been consumed, the carcass laid unmolested for several days before being consumed by unknown scavengers. Neither brown bears nor gray wolves were observed returning to a kill site after the disturbance of our ground examination.

We were confident that our assessments of the causes of death were accurate. Eighty-seven percent of the carcasses were examined within 48 hours and 68% within 24 hours of death. Due to the short time between death and examination of the carcass we were able to accurately determine the cause of death on 91% of the natural mortalities. Evidence of the cause of death remained unmolested for a considerable length of time due to lack of scavenging. Nonuse of dead calves by scavengers was also observed on the Kenai Peninsula (Franzmann et al. 1980).

During summer and fall 1978, radio-collared brown bears were observed on 78 kills (Table 2) 87% of which were moose. Moose calves comprised 57% of the moose kills and 47% of the total kill. Based upon observation-days, radio-collared brown bears made 1 ungulate kill/6.1 days. Kill rates varied by individual bear from 0 kills to 1 kill/2.2 days. We pooled numbers of observation-days and numbers of kills by family class (single boars and sows, sows with 1.5-2.5 yr. olds, and sows with 0.5 yr. olds) to determine if any particular sex or age group was disproportionately represented. Single adult sows had the largest ungulate kill rate (1/5.0 days) while sows with young had the lowest kill rate (1/8.5 days), however, no statistical differences in ratios ($P>0.05$) were detected, indicating that all adult bears were preying upon ungulates in the same proportions regardless of family status. Also, we could detect no differences ($\underline{P}>0.05$) for mean number of kills/bear between sexually mature ($\geq$ 6 yr. old) and immature bears. Brown bears were observed on calf carcasses for as long as 2 days, but averaged 1.1 days. On adult moose however, they stayed with a carcass from 1-6 days, averaging 1.8 days. Some adult moose carcasses were revisited, but no revisiting was observed on moose calf carcasses.

Ninety-four percent of the natural mortality of radio-collared calves occurred before 19 July of each year (Fig. 2). The loss pattern of uncollared calves of radio-collared adult cows was similar to that of radio-collared calves. This suggests mortality of collared calves was essentially the same as that of uncollared calves and the

Table 2. Summary of predation observations for radio-collared brown bear in the Nelchina and upper Susitna River Basins of southcentral Alaska from 26 May to 1 November 1978.

Family-age status	n	Number of observation days	Prey: Moose calves	Prey: Adult moose	Prey: Unidentified moose	Prey: Adult caribou	Misc.[a]
Single adult sows	6	141	17	9	-	2	1
Single adult boars	6	65	4	5	1	-	-
Sows with young	5	110	9	3	1	-	3
Single subadults	6	121	7	11	2	1	2
Totals	23	437	37	28	4	3	6

a Includes beaver, small mammals and unidentified species.

collars did not predispose calves to predation. These findings compared favorably with those obtained from observing radio-collared brown bears. Of the 37 kills of moose calves, all were observed prior to 19 July. Thereafter, adult moose and adult caribou comprised the observed prey.

Only 6% of the total natural mortality of radio-collared calves occurred after 19 July. Most calves which survived to 19 July also survived to 1 November of each year. Thereafter, we began losing contact with radio-collared calves due to collars falling off, radio failure, and migration. We do not know the ultimate fate of the calves in most instances. We did, however, maintain contact with calves of radio-collared adults until at least April of the following year when cows and calves began separating. No additional mortality was observed during this period in 1977-78; whereas in 1978-79, a relatively severe winter, 7 of 17 surviving calves were lost in late winter, probably due to either starvation or predation. The timing of mortality indicates that most losses occurred during the first 7-8 weeks of a moose calf's life.

Several investigators have reported instances of brown bear predation on moose, and some concluded that it may be an important cause of moose mortality. Chatelain (1950) noted that black bears and brown bears took both adult and calf moose according to scat analysis on the Kenai Peninsula Alaska. LeResche (1968) observed 2 instances of brown bear predation during his study of 59 marked calves near Palmer, Alaska. Brown bears also reportedly killed 4 radio-collared moose calves on the Kenai Peninsula (Franzmann et al. 1980). Results of this study and the Kenai Peninsula study (Franzmann et al. 1980) are the first to document predation by both brown and black bears as more than just incidental causes of moose calf mortality.

Brown bears were responsible for 79% of the radio-collared moose calf mortality in this study. No substantial increases in calf survival were observed following reductions in wolf densities (Ballard and Spraker 1979). The hypothesis that wolf predation was the main cause of moose calf mortality in the Nelchina Basin (Bishop and Rausch 1974) is not supported. However, wolf predation has been identified as the major cause of calf mortality on the Tanana Flats (Gasaway et al. 1977), while black bears have been identified as a major cause of calf mortality on the Kenai Peninsula (Franzmann et al. 1980). Identification of 3 predator species being responsible for relatively large calf losses in three different Alaska moose populations presents problems for game managers. Attempts to manipulate one predator species to benefit moose while not manipulating, or at least monitoring, the status of others may produce negligible results on calf survival. These studies emphasize the need for evaluating predator-prey relationships on an individual moose population basis.

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Appendix III. Abstract of paper presented at 16th North American Moose Conference Workshop held at Prince Albert, Saskatchewan from April 1-5, 1980.

NEONATAL ALASKAN MOOSE CALF PHYSIOLOGIC AND MORPHOMETRIC MEASUREMENTS AND VARIABILITY

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Abstract: Blood chemistry and hematologic values and morphometric measurements were obtained from neonatal Alaskan moose (*Alces alces gigas*) calves (1 to 3 days old) during calf mortality studies on the Kenai Peninsula, the Nelchina Basin, and the Sustina Basin. Differences between the populations and between years were assessed in relation to relative condition and/or nutritive status of the calves and their mothers. Comparisons of measurements to other ungulate neonates were made. The physiologic and morphometric measurements provided base-line data for application and assessment of the relative well-being of a population. The implications of the low physiologic status of neonatal calves and post-parturient cows is discussed.

Blood chemical and hematological values have been published for all North American ungulates. Assessment and application of these data were lacking until adequate sampling of a species over time and under various conditions was accomplished. Blood studies of Alaskan moose (*Alces alces gigas*) were the first studies of ungulates to incorporate most classes and ages of moose to allow applying these values to assess condition of moose (Franzmann and LeResche 1978). Nevertheless, certain classifications of moose were lacking in these data, namely neonatal moose calves and post-parturient cows.

Weights and measurements of North American moose (*Alces alces*) have been reported (Blood et al. 1967, Breckenridge 1946, Denniston 1956, Franzmann et al. 1978, Karns 1976, Kellum 1941, Murie 1934, Peek 1962, Peterson 1955, Timmermann 1972). However, substantial data for neonatal moose are lacking in these reports.

Moose calf mortality studies in Alaska (Ballard et al. 1980, Franzmann et al. 1980) were designed to collect physiologic and morphometric data from neonatal calves and their post-parturient mothers. This paper reports the results of these collections from different areas of Alaska from 1977 through 1979. Comparisons and assessment of differences were made primarily using the blood parameters which best reflected condition of moose (Franzmann and LeResche 1978).

METHODS

Moose calves were sampled from the Kenai Peninsula, Nelchina Basin, and Susitna Basin during late May and early June in 1977, 1978, and 1979. The Kenai Peninsula studies were conducted from the Kenai Moose Research Center (MRC) which is on the Kenai National Moose Range in the northwestern Kenai Peninsula lowlands. A detailed description of the study area was presented by Oldemeyer et al. (1977). The Nelchina and Susitna Basin studies were conducted from Glennallen and detailed description of the study areas appears in Ballard and Taylor (1978).

Calf capturing methods were described by Ballard et al. (1979). Blood collecting and analysis were done as outlined by Franzmann and LeResche (1978) and measurements were obtained as defined by Franzmann et al. (1978).

The data were sorted by location and year and means and standard deviations calculated. Comparison and evaluation of data were by t-test program with paired samples. All differences referred to hereafter were at $P<0.01$ unless otherwise indicated. The 1977 Kenai Peninsual sample was again sorted by separating the June from May sampled calves. The June calves were approximately 1 week old at capture. All other calves were from 1 to 3 days old. The parameters selected for primary sorting were those outlined by Franzmann and LeResche (1978) as most useful for condition evaluation. The parameters were; packed cell volume (PCV), hemoglobin (Hb), calcium (Ca), phosphorus (P), glucose, total protein (TP), albumin, and beta globulin. The remaining blood parameters were combined and presented as base-line data and include; cholesterol, triglyceride, lactic dehydrogenase (LDH), glutamic oxalacetic transaminase (GOT), alkaline phosphotase, sodium (Na^+), potassium (K^+), chloride (Cl^-), carbon dioxide (CO_2), iron, blood urea nitrogen (BUN), creatanine, bilirubin, uric acid, globulin, alpha 1 globulin, alpha 2 globulin, and gamma globulin. The calf measurement data were sorted by year and population.

Table 1. Neonatal Alaskan moose calf unsorted blood values and measurements from 1977, 1978, and 1979 on the Kenai Peninsula, Nelchina Basin and Susitna Basin.

Parameters measured	Unit	Sample size	Mean	Standard deviation
Glucose	mg/dL	97	141.7	41.2
Cholesterol	mg/dL	97	96.9	20.8
Triglyceride	mg/dL	84	132.8	102.8
LDH	U/L	96	604.0	172.6
SGOT	U/L	97	90.1	87.0
SGPT	U/L	86	82.6	98.0
Alkaline phosphotase	U/L	97	622.2	201.0
Phosphorus	mg/dL	97	8.5	1.9
Calcium	mg/dL	97	11.6	0.9
Ca/P	ratio	97	1.4	
Sodium	mEg/L	86	136.1	5.5
Potassium	mEg/L	86	5.8	1.0
Chloride	mEg/L	86	92.3	4.7
Carbondioxide	mEg/L	85	14.4	4.9
BUN	mg/dL	97	15.4	5.9
Creatanine	mg/dL	87	1.1	0.4
Bilirubin	mg/dL	95	0.5	0.3
Uric acid	mg/dL	93	0.5	0.3
Total protein	g/dL	97	5.28	0.62
Albumin	g/dL	97	2.54	0.40
Globulin	g/dL	97	2.74	0.32
Alpha 1 globulin	g/dL	97	0.47	0.16
Alpha 2 globulin	g/dL	97	0.46	0.18
Beta globulin	g/dL	97	0.91	0.43
Gamma globulin	g/dL	97	0.90	0.52
A/G	ratio	97	0.93	
Iron	mg/dL	47	199.8	158.0
Menoglobin	g/dL	104	11.4	1.6
Packed cell volume	%	103	30.7	4.6
Total Body Length	Cm	102	99.2	8.3
Hind Foot Length	Cm	106	45.0	2.2
Chest Girth	Cm	106	61.2	5.8
Neck Circumference	Cm	103	29.7	3.0
Weight	kg	109	18.0	4.5

Table 2. Condition related blood parameters from Alaskan neonatal moose calves, post-parturient Kenai cows, and adult moose sampled in late winter (Feb.-May).

Population and year	Blood parameters																							
	PCV			Hb			Ca			P			Glucose			TP			Albumin			Beta Globulin		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Nelchina 1977	35.4	4.5	14	11.6	1.3	14	12.4	0.6	13	7.1	1.6	13	136	40	13	5.58	0.6	13	2.32	0.27	13	1.12	0.35	13
Nelchina 1978	30.0	3.0	25	11.7	1.2	24	11.1	0.5	19	7.9	1.6	19	128	35	19	5.01	0.51	19	2.24	0.39	19	0.69	0.18	19
Susitna 1977	34.0	4.9	8	12.4	1.6	8	12.0	0.8	8	7.3	2.8	8	161	30	8	5.47	0.82	9	2.40	0.36	9	1.2	1.0	9
Susitna 1978	30.1	2.9	8	10.3	1.4	8	11.6	0.7	7	9.7	0.7	7	78	39	7	5.11	0.43	7	2.71	0.24	7	0.75	0.17	7
Susitna 1979	28.2	5.8	13	11.9	2.5	14	11.5	1.0	14	9.8	1.9	14	144	31	14	5.23	0.61	14	2.78	0.39	14	0.69	0.15	14
Kenai 1977 May	29.2	4.2	19	10.6	1.2	19	11.7	0.8	21	8.6	1.4	21	154	42	21	5.17	0.55	21	2.62	0.53	21	0.89	0.29	21
Kenai 1977 June	32.8	3.3	6	11.5	0.8	6	11.4	2.0	6	10.2	3.0	6	207	43	6	5.15	0.87	6	2.91	0.53	6	1.17	0.21	6
Kenai 1978	29.8	4.1	10	10.5	1.7	10	11.6	0.4	10	8.7	1.5	10	154	30	10	5.78	0.74	10	2.76	0.28	10	0.61	0.21	10
Post-parturient 1977-78 cows (Kenai)	38.3	5.6	23	14.2	2.3	23	10.6	0.9	24	4.2	1.5	24	141	31	24	6.60	0.81	23	4.25	0.63	23	0.63	0.16	23
Adult moose 1977-78[a] late winter	45.6	5.7	184	18.2	1.8	187	10.4	0.8	273	4.5	1.2	273	120	29	273	7.01	0.61	277	4.12	0.68	277	0.69	0.27	277

a From Franzmann and LeResche (1978).

Limited data were collected from post-parturient cows due to restrictions imposed by the primary objective of the calf mortality studies (Ballard et al. 1980, Franzmann et al. 1980). Nevertheless, during the 2 years of the Kenai Peninsula study, blood samples were obtained from 24 post-parturient cows, but none were obtained from the Nelchina and Susitna studies.

RESULTS

Table 1 lists the combined data means, standard deviations and sample sizes of all blood and measurement parameters obtained from neonatal calves and are presented as base-line data for neonatal Alaskan moose calves. The calf blood data were sorted by location and year (also month for Kenai 1977) for condition related blood parameters (PCV, HB, Ca, P, glucose, TP, albumin, and beta globulin--Franzmann and LeResche 1978) and are presented in Table 2 with mean condition related blood parameters from post-parturient Kenai cows and late winter adult moose (Franzmann and LeResche 1978).

Some differences ($P<0.01$) were detected between calf populations for condition related parameters. The 1977 Nelchina calves mean PCV (35.4%) was higher than all other calf populations except Susitna 1977 (34.0%) and Kenai 1977 June (32.8%). No other differences were detected. Hemoglobin differences were limited to the Kenai 1977 May mean (10.6 g/dL) being lower than the Nelchina 1978 (11.7 g/dL), and Susitna 1977 (12.4 g/dL) means. No differences were detected among Ca levels, but P differences were detected with the Nelchina 1977 P mean (7.1 gm/dL) being less than the Susitna 1978 (9.7 gm/dL), Sustina 1979 (9.8 gm/dL) and Kenai 1977 May (8.6 gm/dL) means. The Nelchina 1978 P level (7.9 gm/dL) was also significantly lower than the Susitna 1979 mean (9.8 gm/dL). Glucose differences were characterized by the Susitna 1978 mean (78 mg/dL) being lower than all but the Nelchina 1978 mean (128 mg/dL) and Kenai 1977 June mean (207 mg/dL) being higher than all but the Kenai 1978 (154 mg/dL), Susitna 1977 (161 mg/dL) and Kenai 1977 May (154 mg/dL). The only differences among TP means were that the Nelchina 1978 mean (5.01 g/dL) was significantly lower than the Kenai 1978 (5.78 g/dL) and Nelchina 1977 (5.58 g/dL) means. Albumin differences were characterized by Nelchina 1977 (2.32 g/dL) and the Nelchina 1978 (2.24 g/dL) means being lower than most Susitna and Kenai populations except the Kenai 1977 May (2.62 g/dL) and Susitna 1977 (2.40 g/dL) populations. The beta-globulins showed sporadic differences among populations, but there was no pattern. The Kenai 1977 June beta globulin mean (1.17 g/dL) was highest and the Kenai 1978 mean (0.61 g/dL) was lowest.

Of particular interest were the differences noted between the neonatal calves and post-parturient cows (Table 2).

Table 3. Physiologic and morphometric measurements from neonatal moose calves and post-parturient cows, sampled during springs of 1977 and 1978 on the Kenai Peninsula, Alaska.

Parameter measured	Unit	Neonatal calves N	Neonatal calves $\bar{x}$	Neonatal calves SD	Post-parturient cows N	Post-parturient cows $\bar{x}$	Post-parturient cows SD
Glucose	mg/dL	36	163.4	42.3	24	140.6	31.3
Cholesterol	mg/dL	36	101.1*	13.7	24	74.5	16.4
Triglycerides	mg/dL	23	108.6	86.9	--	--	--
LDH	U/L	36	544.1*	143.2	24	319.0	93.3
SGOT	U/L	36	71.8	22.5	24	75.3	29.2
SGPT	U/L	26	45.0	32.9	14	38.7	11.2
Alkaline phosphotase	U/L	36	479.9*	133.8	24	112.0	137.0
Phosphorous	mg/dL	36	8.9*	1.8	24	4.2	1.5
Calcium	mg/dL	36	11.5*	0.9	24	10.6	0.9
Ca/P	ratio	36	1.3		24	2.5	
Sodium	mEq/L	26	135.6	8.4	15	133.5	3.4
Potassium	mEq/L	26	5.3	0.7	15	5.0	0.6
Chloride	mEq/L	25	92.2	6.6	14	95.2	6.4
Carbon dioxide	mEq/L	26	10.3*	4.7	14	18.8	4.3
BUN	mg/dL	36	16.5*	5.2	24	10.3	6.8
Creataine	mg/dL	26	1.03*	0.41	15	1.93	0.46
Bilirubin	mg/dL	36	0.47*	0.29	24	0.26	0.17
Uric acid	mg/dL	34	0.32	0.18	23	0.42	0.22
Total protein	g/dL	36	5.38*	0.67	23	6.60	0.81
Albumin	g/dL	36	2.67*	0.54	23	4.25	0.63
Globulin	g/dL	36	2.71*	0.33	23	2.35	0.60
Alpha 1 globulin	g/dL	36	0.48*	0.17	23	0.27	0.15
Alpha 2 globulin	g/dL	36	0.34	0.16	23	0.45	0.20
Beta globulin	g/dL	36	1.10*	0.26	23	0.63	0.16

Continued

Table 3 (cont.)

Parameter measured	Unit	Neonatal calves			Post-parturient cows		
		N	$\bar{x}$	SD	N	$\bar{x}$	SD
Gamma globulin	g/dL	36	0.79	0.40	23	1.03	0.35
A/G	ratio	36	0.99		23	1.81	
Iron	mg/dL	26	233.8*	212.4	14	131.5	67.3
Hemoglobin	g/dL	35	10.7*	1.3	23	14.2	2.3
Packed cell volume	%	35	29.9*	4.2	23	38.3	5.6
MCHC	%	35	35.8	4.0	23	37.1	3.9

* Significantly (P<0.01) different than mean for post-parturient cows.

Table 4. Comparisons of blood parameter means of neonatal moose, pronghorns, white-tailed deer, and black-tailed deer.

Parameter measured	Unit	Moose[a]	Pronghorn[b]	White-tailed deer[c]	Black-tailed deer
Glucose	mg/dL	141.7(97)	203.5(60)	119.7(5)	90.2(7)[d]
Cholesterol	mg/dL	96.9(97)	67.4(89)		
SGOT	U/dL	90.1(97)	106.5(92)		
Alkaline phosphotase	U/dL	622.2(97)	296.4(74)		
Phosphorus	mg/dL	8.5(97)	10.0(83)		
Calcium	mg/dL	11.6(97)	12.4(85)		
Ca/P	ratio	1.40	1.24		
Sodium	mEq/L	136.1(86)	145.2(85)		
Potassium	mEq/L	5.8(86)	6.2(85)		
BUN	mg/dL	15.4(97)	21.3(63)		
Creatanine	mg/dL	1.1(87)	2.4(11)		
Total protein	g/dL	5.28(97)	4.78(46)		
Albumin	g/dL	2.54(97)	2.36(46)		
Globulin	g/dL	2.74(97)	2.42(46)		
Alpha globulin	g/dL	0.93(97)	0.59(46)		
Beta globulin	g/dL	0.91(97)	0.70(46)		
Gamma globulin	g/dL	0.90(97)	1.13(46)		
A/G	ratio	0.93(97)	1.01(46)		
Hemoglobin	g/dL	11.4(104)	14.6(116)	8.4(5)	10.3(26)[e]
Packed cell volume	%	30.7(103)	39.7(110)	30.9(5)	33.8(26)[e]

a This study
b Barrett and Chalmers (1979)
c Johnson et al. (1978)
d Bandy et al. (1957)
e Cowan and Bandy (1969)

Since the post-parturient cows were all from the Kenai Peninsula, we combined the Kenai neonatal calf samples (Kenai 1977 May, Kenai 1977 June, and Kenai 1978) and compared all condition related and other blood parameters between the cows and their calves (Table 3). Neonatal calves' blood chemistry levels were significantly higher than the cows' for cholesterol, LDH, alkaline phosphotase, P, Ca, BUN, bilirubin, globulin, alpha 1 globulin, and beta globulin. Post-parturient cows had higher CO_2, creatanine, TP, albumin, hemoglobin and PCV valves than their calves.

Comparing the condition related parameters of post-parturient cows with adult moose sampled during late winter (Table 2), we detected significant differences. Late winter adult moose had significantly higher blood levels of PCV, Hb, and TP and lower levels of glucose than post-parturient cows.

Barrett and Chalmers (1979) analyzed blood from neonatal pronghorns (*Antilocapra americana*) and we listed the values with neonatal moose calves (Table 4). Glucose, Hb, and PCV data were available from white-tailed deer (*Odocoileus virginianus*) (Johnson et al. 1978) and black-tailed deer (*Odocoileus hemionus columbianus*) (Bandy et al. 1957, Cowan and Bandy 1969) and were included in Table 4.

Differences in weights and measurements between neonatal moose calves sampled were detected only in comparisons between the Kenai 1977 June population and others. This population (n=6) was 1 week old, and all others were generally 1 to 3 days old. The mean weights and measurements listed in Table 1 exclude the weights and measurements from the Kenai 1977 June group and thereby represent calves 1-to-3 days old.

DISCUSSION

Difference in blood parameters between neonatal moose calf populations lacked a pattern that could be used to quantify relative condition of the populations based on criteria established for adult moose (Franzmann and LeResche 1978). Blood values from the calves generally indicate a uniformity among the populations, particularly when the Kenai 1977 June population which was older is excluded. The differences detected may be a function of differences in excitability and stress associated with collecting the calves (Franzmann and LeResche 1978, Franzmann et al. 1975). We had no valid assessment for the stress influence. The blood parameters obtained from the calves when combined (Table 1) represent base-line data from a diverse cross section of neonatal Alaskan moose calves and may be used to compare against future sampling. As more samples become available, refinement of condition assessment may be accomplished.

The differences between Kenai Peninsula post-parturient cows and their calves (Table 3) do reflect a pattern. The calves' blood chemistry levels were significantly higher or the same as the cows' for all parameters except PCV, HB, TP, albumin, CO_2 and creatanine. Both hematologic values (PCV and Hb) were higher in cows and this reflects their more developed hemopoietic system. Barrett and Chalmers (1979), when comparing neonate and adult pronghorns, reported that Ca, P cholesterol, and alkaline phosphotase, were significantly higher in neonates than adults. This pattern was the same for moose (Table 3). Pronghorn adults had significantly higher PCV, Hb, TP, and albumin levels than neonates, which was the pattern for moose in this study (Table 3). The only differences in comparisons of pronghorn and moose neonates and adults noted was that pronghorn fawns had higher magnesium, sodium and glucose values than adults, and in moose there were no differences between sodium and glucose in neonates and adults. Magnesium values were not determined for moose and CO_2 and creatanine were not determined for pronghorn.

The adult moose sampled in this study had all given birth to calves within 1 to 3 days prior to sampling. The cows were in poor condition as graded at capture (Franzmann et al. 1976). Ten cows graded 6; 7 cows graded 5; 3 cows graded 4; and 4 cows were not graded. The physiological stresses of pregnancy, calving, and lactation were shown in physical condition. The blood values of post-parturient cows reflected their poor condition when compared to adult moose samples reported by Franzmann and LeResche (1978) collected in late winter and early spring (February to May). Blood levels of PCV, Hb, and TP (all condition-related parameters) were significantly higher in adult moose than post-parturient cows. Glucose was higher in post-parturient cows which likely reflected the stress of capture (Franzmann and LeResche 1978, Franzmann et al. 1975). Packed cell volume, Hb, and TP were determined not to be influenced by excitability (Franzmann and LeResche 1978). Franzmann and LeResche (1978) listed condition related blood levels that represented adult moose in average or better condition and the post-parturient moose were lower for all (PCV, Hb, P, TP, and albumin) except Ca and glucose. Calcium appears to be least influenced of the parameters, and glucose has limited value due to its response to excitability and stress. In this study, sampling the post-parturient cows created greater than usual excitement and stress (Franzmann et al. 1980). The post-parturient cows condition related parameters were lower than, or equal to, the MRC (Feb., Mar., Apr.) samples (Franzmann and LeResche 1978) which were the lowest levels for a population in the report.

It is apparent that the Kenai Peninsula post-parturient cows are at a definite physiological low. There were no other moose data from post-parturient cows to use for comparison, and the values determined may be normal for moose that have experienced the stress of pregnancy, parturition, and lactation at a critical time of year. What is of equal concern and interest is the low status of some critical neonatal blood values in relation to the already depressed post-parturient cows (PCV, Hb, TP, and albumin). The pattern of low blood values in neonates was also detected in pronghorn fawns (Barrett and Chalmers 1979) and in general, closely resembles moose neonates (Table 4). Moose neonates have lower PCV, Hb, Ca, and P levels, but higher protein fractions except gamma globulin. The mean alkaline phosphotase for moose (622.2 U/L) was considerably higher than for pronghorns (296.4 U/L). Alkaline phosphotase levels are associated with active skeletal development (Coles 1974), and perhaps the larger skeletal structure of the moose calf results in higher levels. Values from other neonate ungulates are limited, but glucose, Hb, and PCV values from white-tailed deer and black-tailed deer (Table 4) are also relatively low and generally similar to pronghorns and moose.

Managers should be aware of the low physiologic state of neonatal moose calves and post-parturient cows as reflected by blood parameters. This period in the life history of moose is most critical and disturbance of the cow and calf should be avoided. Traditional calving areas were likely selected because they provided the quality and quantity of nutrients and protection needed through the parturition period. Protection of these areas should retain a high priority in the manager's program.

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Appendix IV. Paper presented at 16th North American Moose Conference Workshop held at Prince Albert, Saskatchewan from 1-5 April 1980.

INFLUENCE OF PREDATORS ON SUMMER MOVEMENTS OF MOOSE IN SOUTHCENTRAL ALASKA

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Abstract: During late spring and early summer from 1977 through 1979, 168 moose (*Alces alces gigas*) calves were radio-collared for mortality studies in the Nelchina and upper Susitna River Basins. These studies provided an opportunity to monitor cow-calf movements during summer and to evaluate some factors influencing these movements. Moose movements during summer in areas of differing brown bear (*Ursus arctos*) densities were compared. Moose calf movements were correlated with age and brown bear densities. Cow-calf home ranges and linear movements during the 6 weeks following parturition were greater in areas of high bear densities and decreased following removal of bears from one area. Larger cow-calf home ranges resulted, at least partially, from attempts by moose to avoid predators. Observations of brown bear-moose interactions are reported. We believe that once calves attain an age of 6-8 weeks, their ability to evade bears is considerably greater than before.

Movements of moose have long been a subject of interest and study by North American naturalists and scientists; and relationships between moose movements and snow, rainfall, food quantity and food quality have been recognized for a number of years (LeResche 1975); undoubtedly other types of relationships exist.

Summer movements of cows and calves are one aspect of moose movements which has not been thoroughly studied. From 1977 through 1979 168 newborn moose calves were radio-collared in the Nelchina and upper Susitna River Basins of southcentral Alaska in an effort to determine causes of mortality. Background for this study was provided by Ballard and Taylor 1978a, b, Ballard and Spraker 1979, Ballard et al. 1980a, and Ballard et al., in review. These studies provided an opportunity to intensively study cow-calf movements during late spring and summer.

Calf mortality studies in 1977 and 1978 indicated that approximately 80 percent of the natural mortality resulted from predation by brown bears (Ballard et al. In Press). These findings were further substantiated in 1978 by the results of our observations of 23 adult, radio-collared brown bears (Spraker and Ballard 1979) which preyed upon ungulate species an average of once every 6.1 days (Ballard et al. In Press). In 1979 we initiated studies to determine whether compensatory mortality factors would replace bear predation if bear densities were substantially reduced (Ballard et al. 1980b). Consequently, in late spring and early summer 1979 we reduced bear densities within one of the areas where we had studied causes of calf mortality in 1977 and 1978. This reduction program also allowed us to compare cow-calf movements in areas of low and high bear densities. This paper presents information on summer cow-calf moose movements in relation to brown bear densities.

STUDY AREA

Causes of moose calf mortality were studied in three areas of Game Management Unit (GMU) 13, located in the upper Susitna and Nelchina River Basins of Southcentral Alaska (Fig. 1). The areas included: Area 1 - the Susitna River study area, Area 2 - the Mendeltna Creek study area, and Area 3 - the Hogan Hill study area. This report concerns only Areas 1 and 2 where movements were intensively studied. Topography, vegetation, elevation, weather and range conditions in these areas have been thoroughly described (Skoog 1968, Rausch 1969, Bishop and Rausch 1975, Ballard and Taylor 1978a, b, Ballard and Spraker 1979, and Ballard In Press).

Initially, Area 1 was selected for study because of its low wolf (*Canis lupus*) densities (averaging approximately 1/567 km^2) resulting from experimental wolf reductions by the Alaska Department of Fish and Game but in Areas 2 and 3, wolf populations averaged 1 wolf/277 km^2. All areas supported populations of alternate prey species and brown and black bears (*Ursus americanus*), the latter in low densities.

Brown bear densities in 1979 were reduced by capturing and transplanting all bears which could be found within a 3397 km^2 portion of Area 1 (Fig. 1). Causes of moose calf mortality in 1979 were studied in that portion of Area 1 from which bears had been transplanted. Causes of calf mortality had been studied in this area in 1977 and 1978. Calf mortality studies were not conducted in Areas 2 and 3 during 1979 but were in 1977 and 1978.

MATERIALS AND METHODS

Procedures and equipment utilized in the moose calf mortality study were described by Ballard et al. (1980). Briefly, newborn moose calves were captured on foot with the aid of helicopter. Calves were fitted with expandable collars similar to those designed for elk (*Cervis canadensis*) calves by Schlegel (1976). Each radio collar was equipped with a mortality sensor which doubled or tripled the radio pulse rate when the animal remained motionless for either a 4- (1977) or 1-hour (1978 and 1979) period.

Radio-collared calves were observed from fixed-wing aircraft twice daily for 2 weeks following capture and then once daily until they were approximately 7 weeks of age. Thereafter they were monitored less frequently, averaging once per week to 1 August and then every 6-8 weeks until collars fell off or radio contact was lost. Locations of calves were recorded on standard USGS topographic maps (scale 1:63,360). Habitat type at each moose sighting was classified into 1 of 8 aerial classifications and moose activity was classified as either bedded, standing, feeding, or traveling (Ballard et al. 1980c). Causes of mortality were determined by procedures described by Ballard et al. (1980a).

During late May and early June 1979, 48 brown bears were transplanted from a 3397 km^2 portion of Area 1. Bears were captured by darting from helicopter and then transported by pickup truck and/or aircraft (Cessna 206) to release sites 159-254 km distant. Details of the capture and fate of transplanted bears will be presented elsewhere (Miller and Ballard in prep.).

For the purposes of this report, we utilized the home range definition provided by LeResche (1975): "the area in which the individual accomplishes its normal activities during a given time period of time." According to this definition "local movements occur within a home range, home range may shift seasonally, and individuals may occupy more than one home range in a year." In this study home ranges were computed by connecting outer location sightings of each radio-collared calf and then tracing this area with a compensating polar planimeter. Weekly linear movements were defined as the sum of the distance moved between daily observations for a given week. Means for each week were calculated using all calves. All references to a calf or calves from this point also include the cow unless otherwise stated.

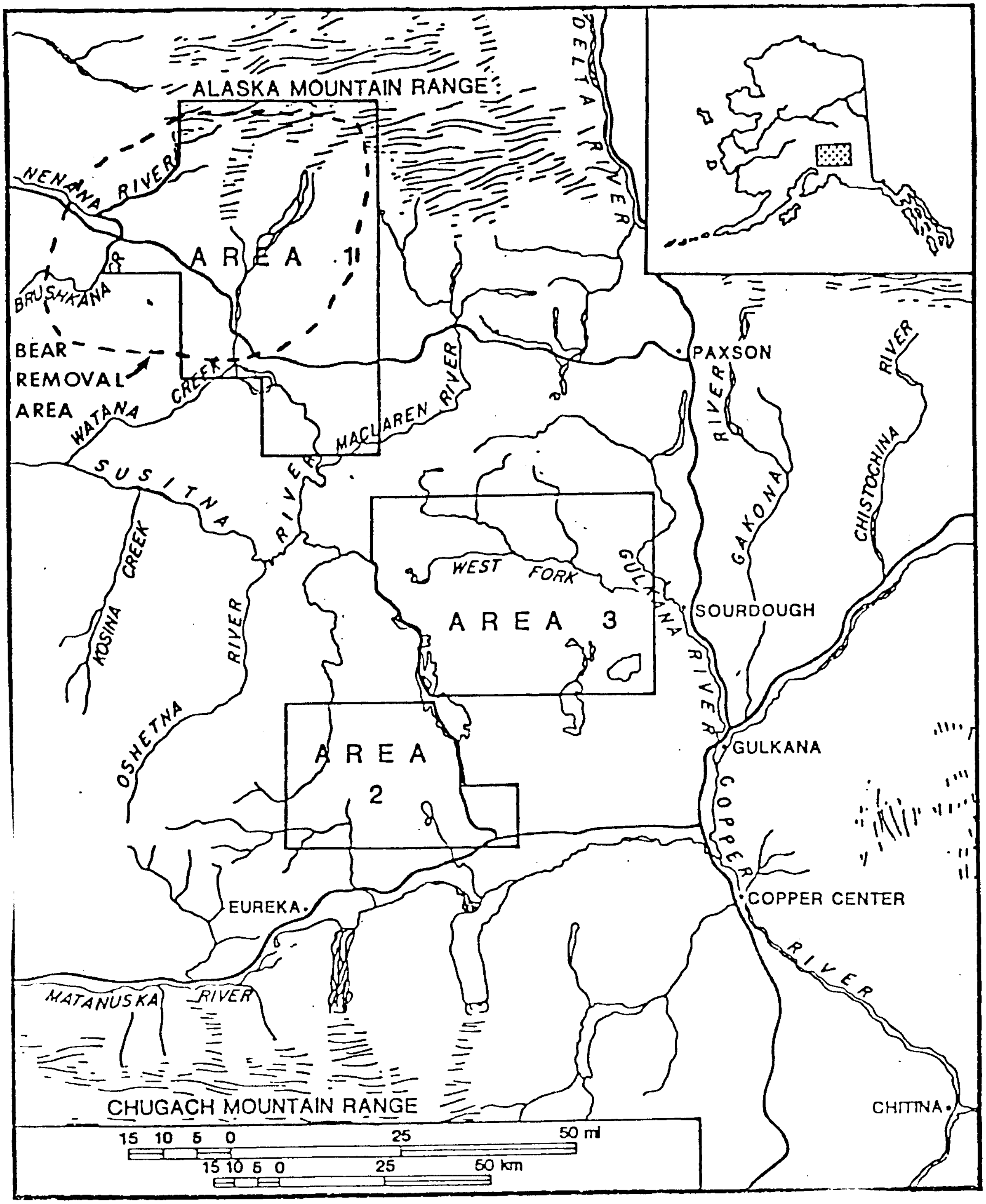

Fig. 1. Locations of study areas where causes of moose calf mortality were studied from 1977-1979 and where brown bear densities were manipulated in 1979 in the Nelchina and upper Susitna River Basins of Southcentral Alaska.

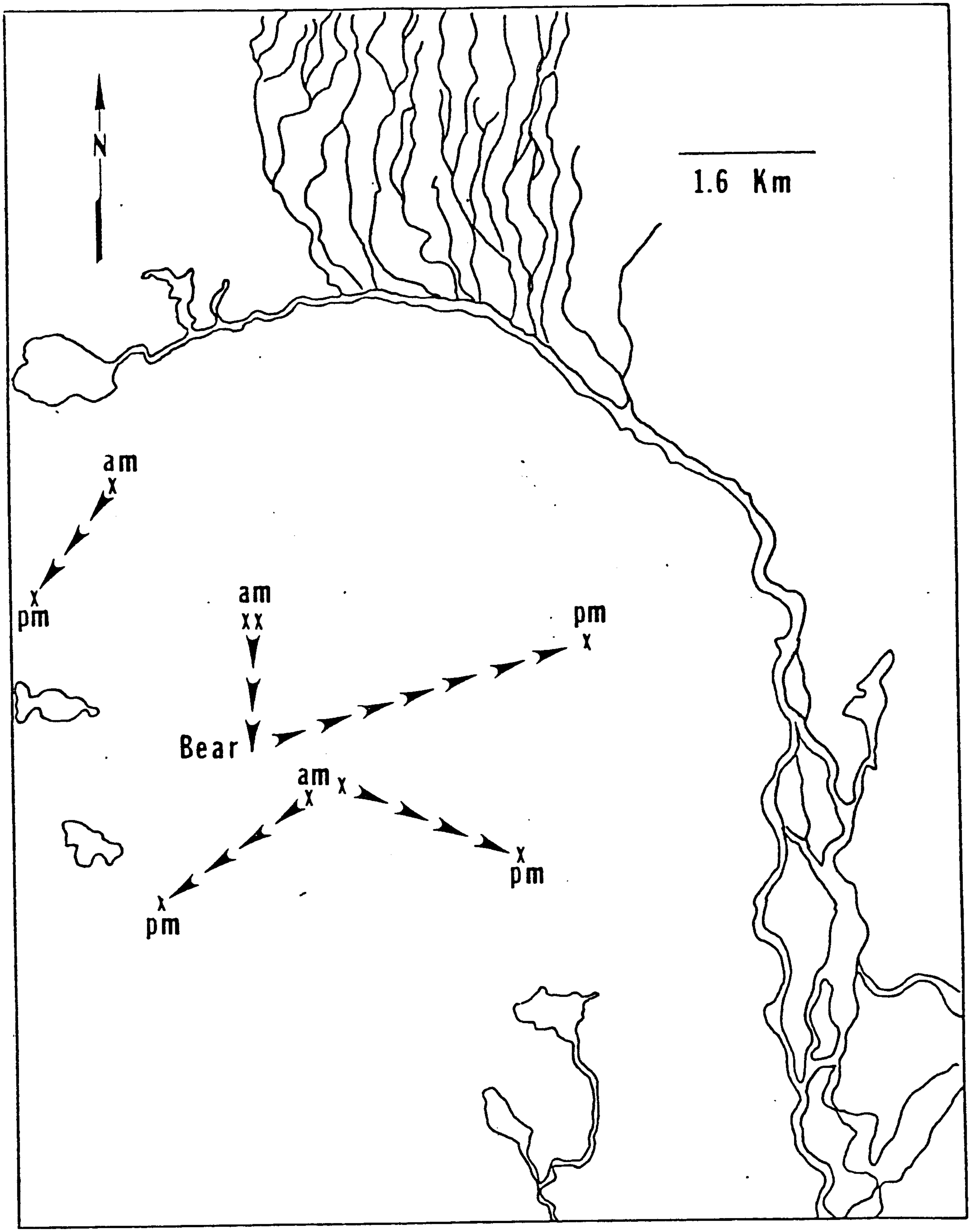

Fig. 2. Movements of Mohahan Lake moose calves in Study Area 1 from AM to PM hours on 8 June 1979 in relation to brown bear observation during AM hours.

RESULTS

While conducting the 1977 calf mortality studies we noticed a number of cow-calf movements which occurred for no apparent reason other than the presence of a bear in the area. At that time we suspected that either the cow-calf pair was being pursued by bears or that they were attempting to avoid bears. For example, calf 036 was observed at essentially the same location from 26 May to 7 June 1977. On 8, June, however, the pair was 4.8 km from this site. On 7 June a female brown bear with a yearling cub had been observed about 2 km from calf 036. On the basis of this and similar observations, we began analyzing movements data to determine if relationships existed between the presence of bears and moose movements.

During their first 6 weeks of life in 1977, Area 1 calves occupied an average area encompassing 37.8 km^2 (n=7) while Area 2 calves occupied an average area of 15.9 km^2 (n=8). Both areas were larger than those LeResche (1975) reported used by for cow-calves during similar time periods. We were unable to explain the differences in moose movements between Area 1 and Area 2, but they appeared to be at least partially related to habitat differences. Brown bear densities in Areas 1 and 2 appeared similar, but there were substantial differences in wolf densities between these areas.

Difference in calf home range sizes also appeared to exist in 1978; however, our emphasis in 1978 was on monitoring radio signals rather than on visual observations. As a result home range size data for 1978 were not directly comparable with those from 1977. Data on home range and movements of calves, after bears had been transplanted in 1979 were, however, comparable with 1977 data.

Thirty-two moose calves were captured and collared within Area 1 during 1979, 12 of these were killed by brown bears. Following bear reduction in a portion of Area 1, two adult brown bears were individually identified on the basis of color, pelage, and size within the bear removal area. These two bears, both in the vicinity of Monahan Lake, were responsible for killing at least 50% (6) of the moose calves.

Observations of cow-calf movements in relation to these two bears provided an excellent opportunity to appraise the relationship between moose movements and bear activities. For example:

1. Monahan Lake calves were observed and their locations plotted on the morning of 8 June. By 5 p.m. one member of a set of twins had been killed by a brown bear and the other twin and 3 other cow-calf pairs had moved

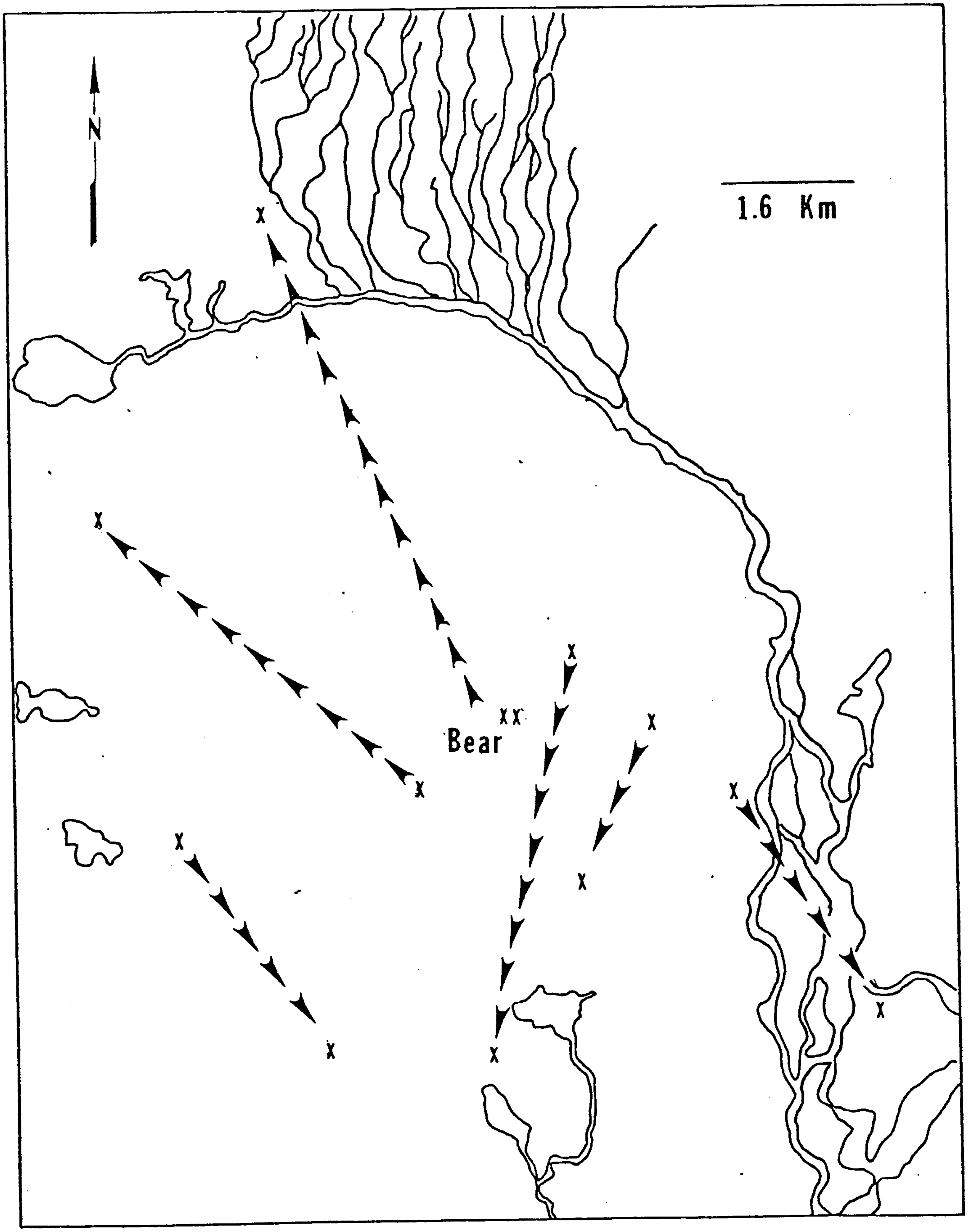

Fig. 3. Movements of Monahan Lake moose calves in Study Area 1 from AM hours on 14 June to AM hours on 16 June 1979 in relation to brown bear observations on 14 June 1979.

from 1.6 to 4.4 km away from the bear's kill site (Fig. 2). Previously each calf had moved less than 0.8 km.

2. Between 6:14 p.m. 14 June and 6:16 a.m. 16 June, one member of a set of twins was killed by a brown bear. Five adjacent cow-calf pairs and the remaining twin moved away from the kill site. Prior to the bear observation they had remained within a 0.8 km^2 area. Distances moved by the pairs ranged from 2.0 km to 6.6 km (Fig. 3).

These examples strongly suggest that some cow-calf pairs moved to avoid bears.

In 1979, average linear movements per week during the first 6 weeks of life were significantly greater ($P<0.05$) for the Monahan Lake calves than for those calves in the remainder of Area 1 (Fig. 4). Since all calves were observed at the same frequency and no bears were observed except at Monahan Lake, we believe this difference reflects differential disturbance by bears. Supporting this premise, was the greater prevalence of bear predation upon calves at Monahan Lake (80%) than in the remainder of Area 1 (20%) during the first 6 weeks of study in 1979.

As expected, home ranges of Monahan Lake calves in 1979 were also significantly larger ($P<0.05$) than those of the Area 1 calves believed to be in areas with fewer bears. Home ranges of Monahan Lake calves averaged 47.1 km^2 (n=5, S.D. = 9.0) while in the remainder of Area 1, calves had an average home range of 20.67 km^2 (n=9, S.D. = 15.6).

Mean linear movements per week and home range sizes for all Area 1 calves were compared between 1977 and 1979. Overall, calves in 1979 had greater weekly movements during weeks 2, 3 and 4 than did 1977 calves (Fig. 5). However, when 1979 data from Monahan Lake calves, were excluded from this analysis, the 1977 calves moved greater distances overall (Fig. 6).

These differences, as expected, also were reflected in 1977 and 1979 home range sizes. Home ranges of calves in 1977 averaged 37.8 km^2 in comparison to 1979 calves (Monahan Lake calves included) which averaged 29.5 km^2. When the Monahan Lake calves were excluded, home range sizes in 1979 averaged 20.7 km^2, a significant difference ($P<0.05$) from the 1977 home range sizes. Cow-calf pairs in 1977, prior to bear removal, used almost twice as large a home range as calves within the area of bear removal.

As expected, moose calves became more mobile and their average linear movements per week increased (Fig. 7) as they got older. A similar relationship ($r = 0.98$, $P<0.05$) existed for 1979 Area 1 calves.

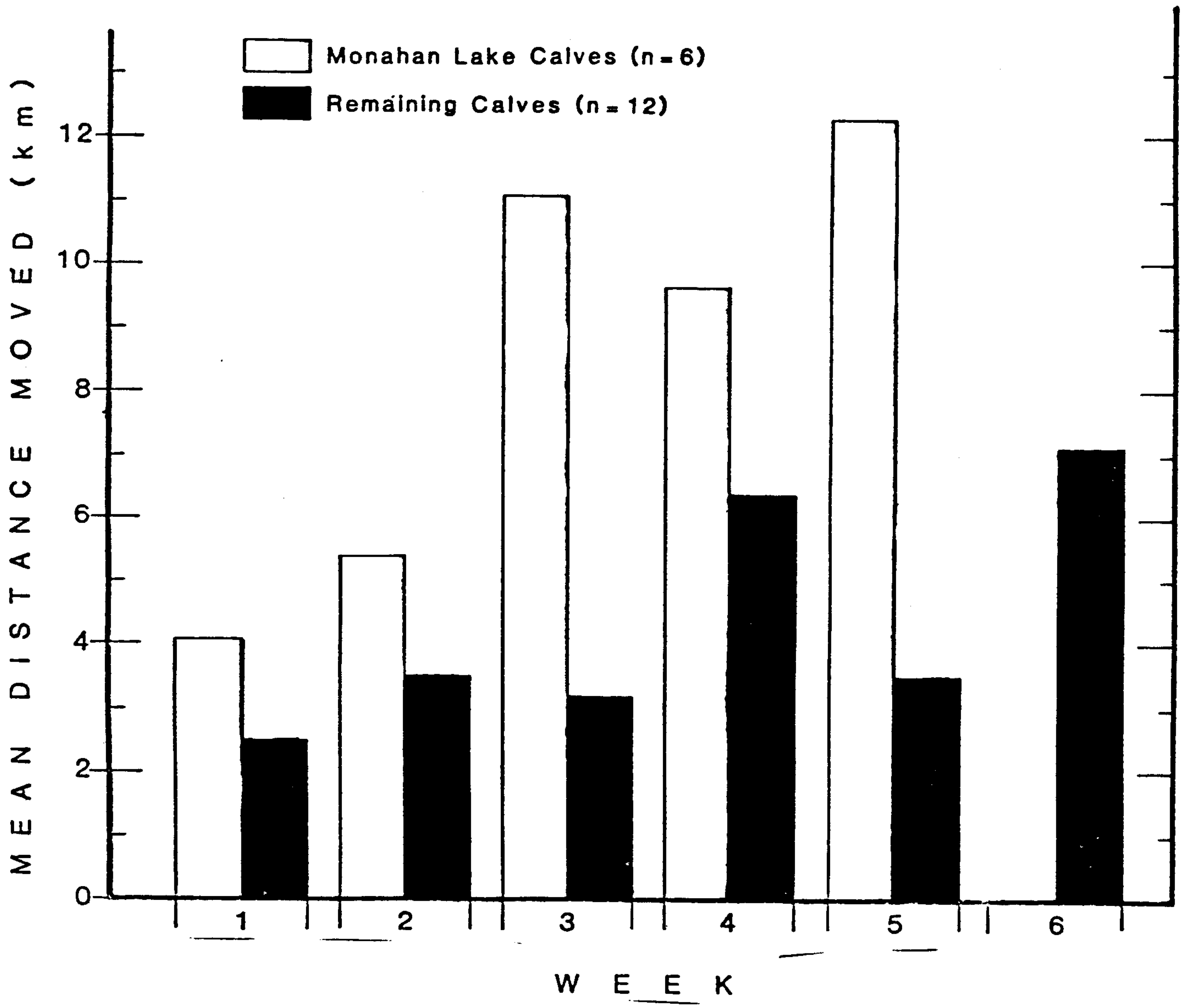

Fig. 4. Comparison of weekly linear movements of Monahan Lake radio-collared moose calves in relation to movements of other Area 1 calves for the first 6 weeks following parturition in 1979.

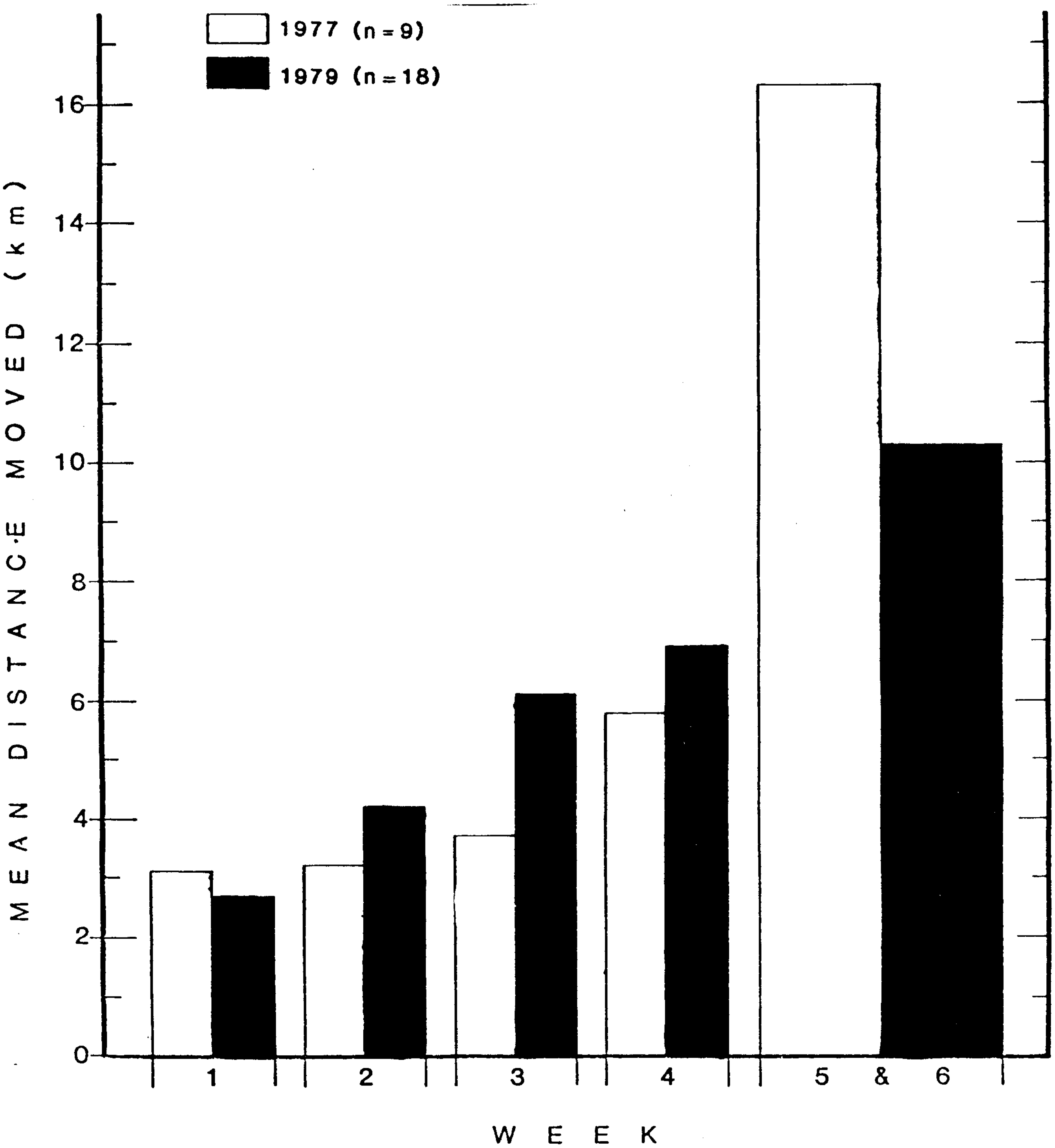

Fig. 5. Comparison of weekly linear movements of Area 1 radio-collared moose calves in 1977 to those in 1979 for the first 6 weeks following parturition.

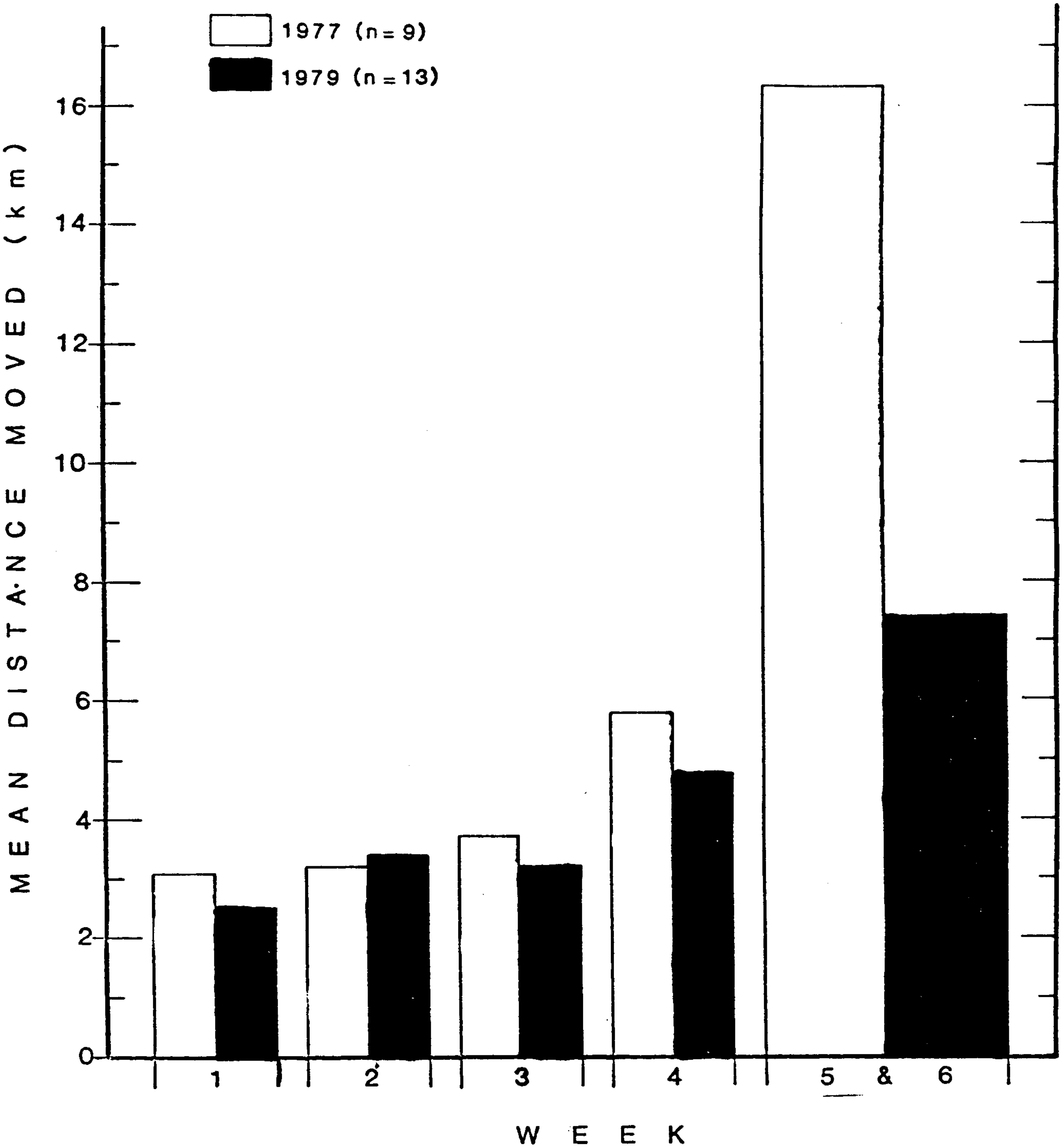

Fig. 6. Comparison of weekly linear movements of 1979 Area 1 radio-collared moose (excluding Monahan Lake calves) to those in in 1977.

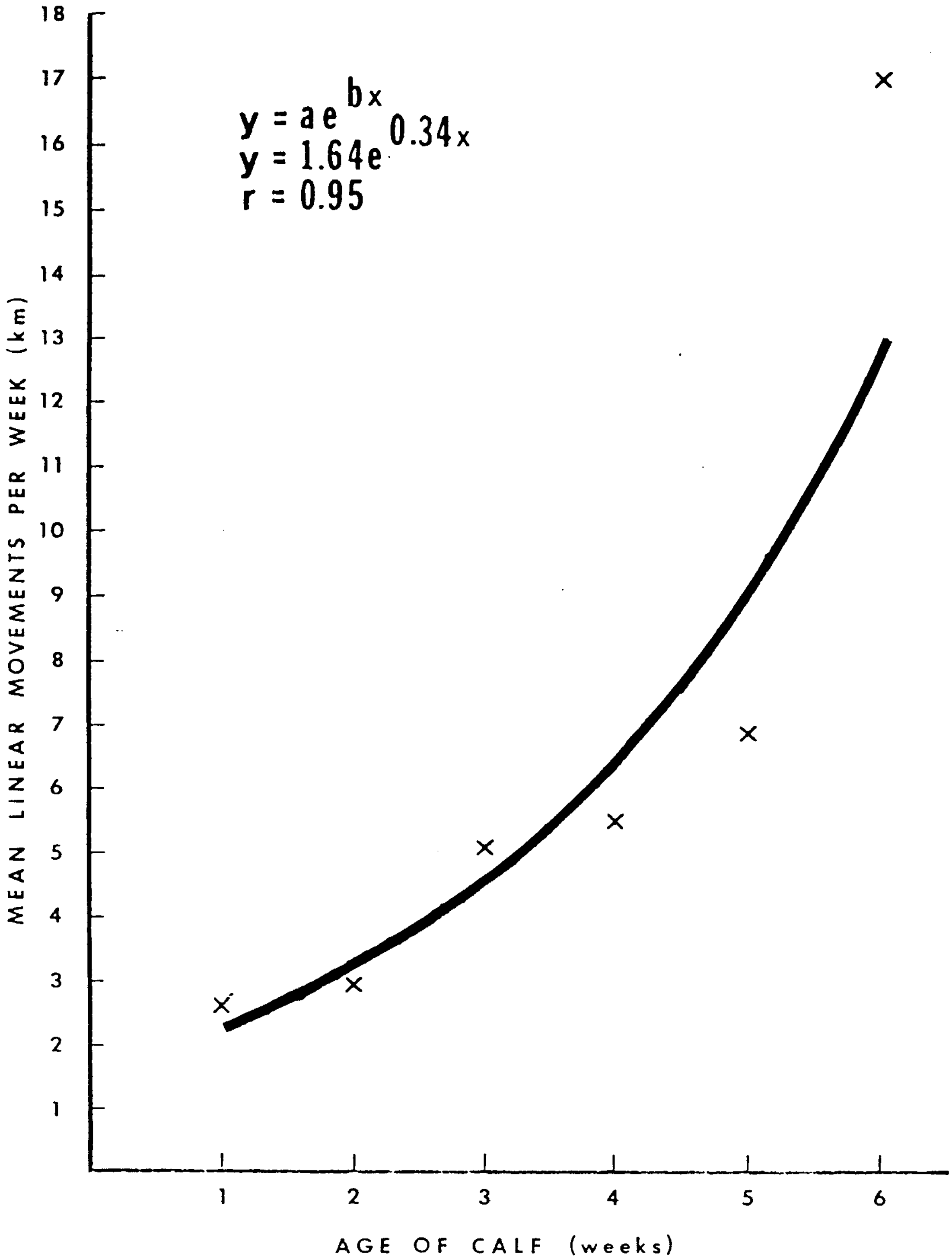

Fig. 7. Relationship of age to weekly linear movements of Area 1 and area 2 radio-collared moose calves during 1977.

To our knowledge there are only a few references in the literature concerning predators, particularly brown bears, influencing movements of cow-calf moose. Franzmann and Peterson (1978) reported that certain movements of radio-collared moose calves on the Kenai Peninsula, Alaska may have been associated with predation or predation attempts. Calves killed by black bears moved 3.2, 4.8, 14.4 and 20.0 km 1 to 2 days prior to predation, whereas calves killed by wolves or brown bears all died within 1.6 km of their capture site. This sort of relationship was not evident in this study, except possibly for wolf predation; however, our sample of wolf-killed calves was too small (n = 2) to draw conclusions. Moose calves killed by brown bears moved a wide range of distances before being killed. It was apparent that a number of these movements were directly related to predation and predator avoidance.

Our comparison of cow-calf movement data, before and after bear removal, indicates that density and movement of bears were at least partially responsible for the observed values. Calf movements and home range sizes became smaller after bear densities were reduced.

Eighty percent of the bear-related calf mortalities occurred within 6 weeks following moose parturition. It was apparent that a calf's ability to evade brown bears was a function of its age and related mobility.

From this study we conclude that moose calf movements and home range sizes are altered by density and movement of brown bears. Whether calf-cow movements and home range sizes are influenced by other species of predators is unknown, but appears likely for black bears (Franzmann and Peterson 1978). We do not maintain that predator density is the primary factor governing moose movements and home range size, but merely that it is an additional factor which has not previously received adequate consideration. We recommend that future references to movements and home range sizes of moose should include mention of the species of predators present and, preferably, provide some measurement of relative density.

ACKNOWLEDGEMENTS

K. P. Taylor, T. H. Spraker, S. H. Eide and L. H. Metz, of the Alaska Department of Fish and Game (ADF&G), assisted with data collection. K. Schneider, D. McKnight, and R. Kramer (ADF&G) reviewed the manuscript and made a number of suggestions for improvements. A. Cunning and D. Cornelius (ADF&G) constructed the graphs for the final manuscript. All of the above mentioned individuals made significant contributions to our analyses and interpretation of data. The study was supported in part by Alaska Federal Aid in Wildlife Restoration Project W-17-R.

There was a significant relationship ($P<0.05$) between mean linear movements per week and percent weekly mortality due to predation for 1977 Area 1 and Area 2 calves (Fig. 8). As moose calves became older and more mobile their apparent ability to evade predators increased. This relationship was not evident ($r = 0.22$, $P>0.01$) for 1979 Area 1 calves after bears had been transplanted away from the area. In spite of increasing mobility associated with age these cow-calf pairs were relatively sedentary; we believe this reflected reduced disturbance by bears. However, return of adult bears probably influenced the relationship between age and mortality.

Bear removal efforts were concentrated from 22 May to 7 June. Following transplant, a number of bears returned to the area within 3-4 weeks (Miller and Ballard in prep.). We suspect that the bear removal program reduced mortality of calves from 1-3 weeks of age, but that as bears returned, mortality increased for 4 to 6-week-old calves. However, overall, total calf mortality was reduced as a result of the removal experiment (Ballard et al. 1980b).

DISCUSSION

Casual observations and formal studies in many areas of North America indicate that during any given season a moose's home range rarely exceeds 5-10 km^2 (LeResche 1975). Studies of adult cow movements in the Nelchina and upper Susitna River Basins resulted in summer home range estimates of from 8 to 210 km^2 while winter home ranges varied from 21 to 389 km^2 (Ballard et al 1980c). The large home ranges observed in this part of southcentral Alaska probably reflect poorer quality habitat and more severe climatic conditions than those found in the more southerly latitudes discussed by LeResche (1975).

Summer home ranges of cow-calf pairs in this study were compared with those presented by LeResche (1975) in Table 1. However, our home range sizes were calculated by connecting outermost locations while those reported by LeResche were computed by multiplying maximum length by width. Therefore, the home range sizes are not directly comparable but do serve to demonstrate the magnitude of the differences. The average summer home range sizes reported in this study exceed those previously reported. Our reported mean value of 25.7 km^2 (average range of 15.9 to 47.1 km^2) was based upon 43 calves that survived for 6 weeks following parturition and over 500 visual observations. All other reported home range sizes have been based on considerably fewer calves and relatively few location sightings. We do not intend to infer that there are not true differences between the home range sizes listed for the different studies; however, perhaps a greater range of values exists in those areas than what has been reported.

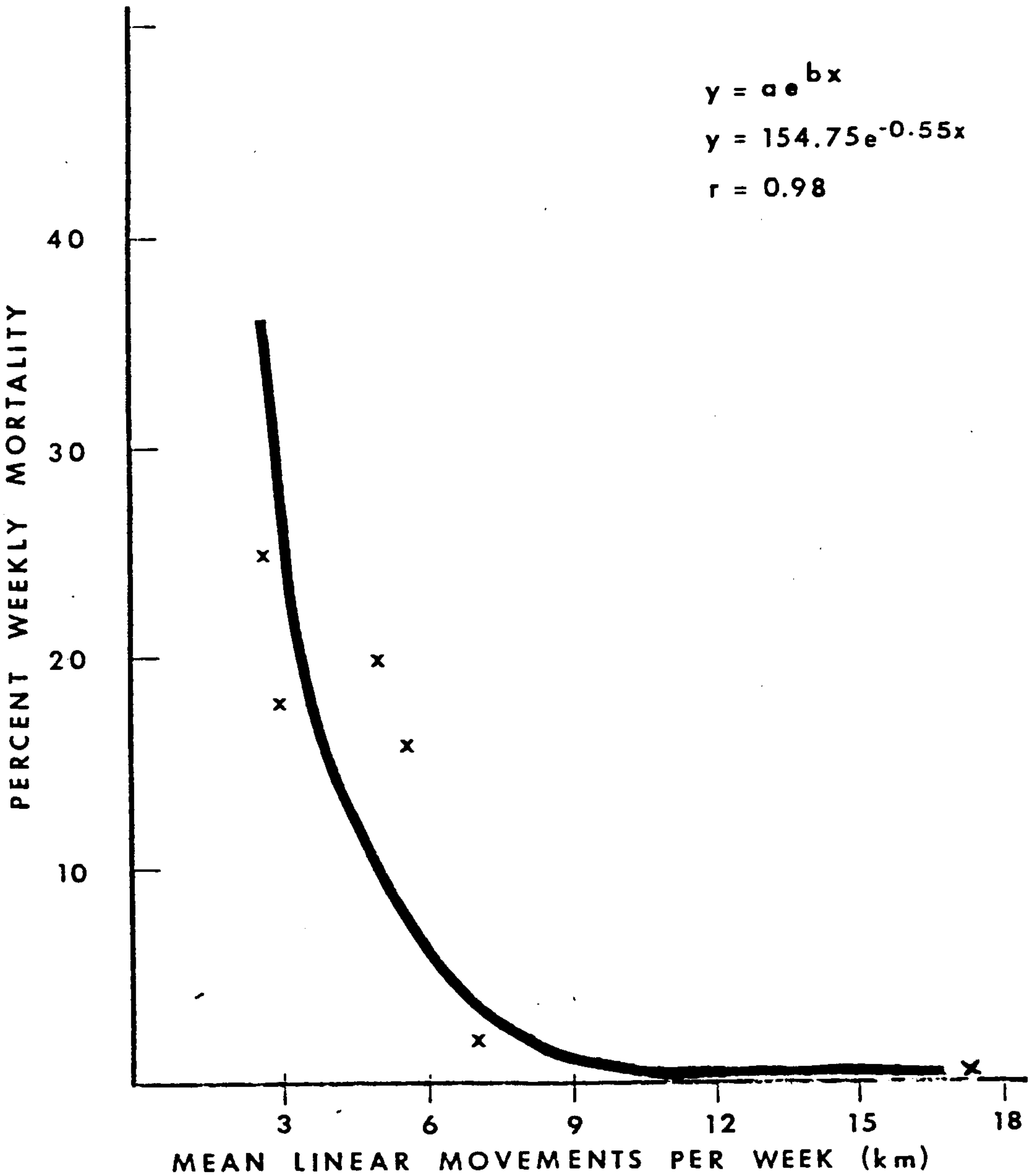

Fig. 8. Relationship of weekly linear movements to percent weekly mortality of radio-collared moose calves of Areas 1 and 2 during 1977.

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Appendix V. Estimates of the density, structure and biomass of an Interior Alaskan brown bear population.

By
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Alaska Department of Fish and Game

Forty-eight brown bears (*Ursus arctos*) were captured and transplanted from a 1,327 mi^2 (3,436 km^2) area of the upper Susitna River Basin of southcentral Alaska in May and June 1979. The purpose of the experimental removal was to determine the response of moose calves (*Alces alces*) to relief from brown bear predation.

This intensive removal effort provided a unique opportunity to estimate brown bear density, biomass, population structure in this region, and to compare various methods of estimating bear density. Density calculations were based upon total number of captures (minimum density estimate), mark-recapture data, and home range data. Estimates from the latter two procedures were based on bears marked and monitored in earlier studies (Spraker and Ballard 1979, and in prep.). Corrections were offered to compensate for known or suspected biases in each of the density estimates.

No evidence of immigration into the study area was evident in the sex and age structure of bears when related to time or location of capture. Therefore, immigration was assumed to be negligible and density estimates were based on the actual area searched.

Apparent capture biases against female bears with newborn cubs were identified.

Of the three techniques for estimating density, the "corrected" mark-recapture estimate of one bear/16 mi^2 was thought to be the most accurate. A corrected minimum estimate of one bear/24 mi^2 was also derived, based on the number of bears actually captured plus those known to have been present. The home range estimate was found to be unreasonably low unless corrected by an estimate of the proportion of the population which had been radio-collared; once corrected this estimate of density was only slightly higher than the "corrected" mark-capture estimate.

The above estimates of density were converted to biomass estimates using sex and age-specific weight data collected in 1978 and 1979. The minimum biomass estimate was 201 kg/100 km^2 (1,150 lbs/100 mi^2) and the "corrected" mark-recapture biomass estimate was 267 kg/100 km^2 (1,514 lbs/100 mi^2).

Compared to a lightly harvested brown bear population in the National Petroleum Reserve-Alaska (NPR-A) (Reynolds and Hechtel 1980), the upper Susitna population was younger, more productive, and had a higher percentage of males; the bear density in the upper Susitna was equivalent to that estimated in the most densely populated portion of the NPR-A.

The age and sex structure of the bears (1.5 years old or older) captured was compared to 10 years of harvest data from Alaska's Game Management (GMU) Unit 13 and the tentative conclusion was drawn that hunters are relatively non-selective in GMU 13. Based on tentative extrapolations from the available data, it was thought that the GMU 13 brown bear population was currently being relatively heavily exploited (4-6%/year) and that substantial or prolonged increases in brown bear harvests, intended to benefit moose calf populations, could reduce bear populations below sustainable levels (12-15% total annual mortalities from all causes/year). Additional data are needed to definitively calculate sustainable mortality levels and unit-wide bear densities.

INTRODUCTION

Brown bear predation has been identified as a significant cause of calf moose mortality in studies recently conducted in GMU 13 from 1975 through 1979 (Ballard et al. 1980). Subsequently, an attempt was made to drastically reduce brown bear densities in a portion of GMU 13 during spring 1979 and to evaluate whether this reduction resulted in an increase in moose calf survival (Ballard et al. 1980). Reduction of brown bear densities was accomplished by capturing and transplanting as many brown bears as could be found in late May and early June, the period of moose calf parturition.

This reduction effort provided a unique opportunity to estimate the population structure, density, and biomass of brown bears in a region of Alaska where such estimates have not previously been made. Previous studies in this area have concentrated on home range determinations and food habits (Spraker and Ballard 1979 and Spraker and Ballard in prep.). Because bears were marked during these earlier studies, mark-recapture population estimates were possible based on the capture of marked and unmarked bears in 1979. An additional population estimate was based on home range data collected in these earlier studies. In this report, results of various population estimation procedures are compared and those thought to be most accurate were converted to biomass estimates.

Because derivation of unbiased determinations of bear density and population structure was not the primary objective of the bear removal effort,results reveal evident biases of various sorts and some assumptions of population estimation procedures are inadequately met. Corrections for these biases and unfulfilled assumptions are offered, but the results should be interpreted cautiously.

MATERIALS AND METHODS

Bears were located from fixed-wing aircraft (Piper Super Cub PA-18). Search efforts were concentrated in the early morning and late afternoon hours and two aircraft, each with a pilot and an observer, were utilized. Once located, bears were darted from a helicopter (Bell 206B) following procedures described by Spraker and Ballard (1979). Immobilized bears were slung by helicopter to the Denali Highway base station at the Susitna Lodge where they were processed. Each bear was weighed and measured, had a premolar extracted for age determination, had identifying marks or radio-collars applied, and was transported by pickup truck and aircraft (Cessna 206) to release sites 100-160 miles distant (159-254 km). The fate of transplanted bears will be reported elsewhere (Miller and Ballard in prep.).

Ages of bears were based on sections of the first premolar by methods described by Mundy and Fuller (1964). Ages were recorded to the nearest decimal, 0.5 for spring-captured bears and 0.8 for fall, sport-harvested bears. Ages assigned to some bears originally captured in 1978 (Spraker and Ballard 1979) were reassigned based on new sections of teeth collected in 1979.

Weights were obtained using a hand-held spring scale with a capacity of 200 lbs (Hanson Model 8920, Northbrook, Ill.) or with a spring scale mounted on a boom affixed to the front of a pickup truck (Senator Scale, Martin-Decker Corp., Santa Ana, Calif.) with a capacity of 1,500 lbs.

Blood samples were taken from the femoral artery using evacuated vials, one of which contained heparin for determination of percent hemoglobin with a Hb-meter (American Optical Corporation, Buffalo, NY) and packed cell volume (PCV) with a microhematocrit centrifuge (Readocrit-Clay-Adams Co., Parsippany, NJ). The non-heparinized samples were centrifuged and the sera were separated, frozen, and sent to Pathologists Central Laboratory (1100 East Union, Seattle, WA) for blood chemistry analysis and protein electrophoresis. Remaining sera were frozen and stored for possible future analyses.

Hair samples were taken from the center of each bear's back. These samples are currently being analyzed by Dr. Arthur Flynn (Case Western Reserve Univ., Cleveland, Ohio).

Forty-seven bears were captured from 22 May to 7 June 1979. Additional efforts on 21-22 June resulted in the removal of one more bear and the recapture of one radio-collared bear (#237) which had returned to the experimental area. The second removal period was terminated because the rapidly growing vegetation made animals difficult to find. All observed bears were captured, except an unmarked female accompanied by male #237 which escaped during the second capture period.

Search efforts were neither uniform nor random throughout the experimental area of 1,327 mi^2 (3,436 km^2). Efforts were concentrated in the central portion of the area. Search efforts were probably less effective at lower elevations in spruce-forested habitats where spotting was difficult. Some bears were also located at moose kill sites, including kills of radio-collared moose calves equipped with mortality-sensor radio collars (Ballard et al. 1980). Of the seven adult bears in the experimental area originally captured in 1978, only two retained functioning radio collars; both of these animals were recaptured on the first day of the removal effort.

Bear population estimates were obtained by three methods: total captures, proportions of marked and unmarked captures (Peterson Index), and home range data collected in 1978. For each of these methods, corrections for known or suspected biases are offered.

Home range estimates were based on data collected in 1978 by Spraker and Ballard (1979 and in prep.) in the experimental area and in two nearby sites, Hogan Hill and Mendeltna. Twenty-two bears, including seven from the experimental area, were radio-located on 8 or more separate days. These data were utilized in determining average home range sizes by connecting peripheral points of observed locations, the "minimum home range" (Mohr 1947). The two-dimensional area of the resulting polygon was determined utilizing a Numonics Model 1224 electronic digitizer provided by the US Fish and Wildlife Service. For the purpose of determining the average home range radius, the area was assumed to be circular.

Twelve of 38 bears marked in 1978 were in the experimental area; these served as the basis for adjusted mark-recapture (Peterson Index) estimates of population size (Richer 1975). In this estimate it was assumed that all 12 of the marked bears were still alive and present in the experimental area in 1979. Mark-recapture calculations were made separately for each sex and included all bears older than 3 years in 1979. This procedure was followed because no yearlings were marked in the experimental area in 1978, so no marked 2.5-year-old bears were present in 1979.

Data on sex and age of grizzly bears harvested in Alaska were obtained from sealing documents maintained by the Alaska Department of Fish and Game (ADF&G) since 1961. These documents were examined to determine the population structure of harvested bears in Unit 13. These data were compared with the population structure of captured bears.

THE STUDY AREA

The bear removal area was located in southcentral Alaska in the northernmost portion of GMU 13. This area included the drainages of the Upper Susitna River (Fig. 1) and roughly encompassed 1,327 mi^2 (3,436 km^2). Monahan Flats (2,700 feet [823 meters] elevation) is in the center of this area.

Descriptions of the topography, vegetation, geology, and climate of this area were provided by Skoog (1968), Ballard and Taylor (1978a, b), and Ballard et al. (1980).

The bear removal area was included within a much larger area described by Spraker and Ballard (1979) where the impacts of bear and wolf (*Canis lupus*) predation on moose populations have been intensively studied since spring 1975. Wolf populations were reduced in this larger area by ADF&G personnel from an estimated density (on available habitat) of 1 wolf/98 sq. miles to 1 wolf/232 sq. miles (Ballard and Spraker 1979). The wolf reduction program was terminated in spring 1979, and wolf densities remained low during this study. Ballard and Spraker (1979) were unable to document significant increases in moose calf survival as a result of the wolf reduction effort. It is considered unlikely that the bear population in the experimental area was altered as a result of changes in either moose or wolf populations caused by the wolf removal efforts.

RESULTS AND DISCUSSION

Forty-eight brown bears were captured in May and June 1979. One bear was captured twice yielding a total of 49 captures. All bears were successfully transported and released except for one (#250) which drowned during initial capture efforts and another (#254) which died of unknown causes within 2 days following release.

Tagging statistics and morphometric measurements of the bears captured are presented in Tables 1 and 2, respectively. Base-line spring blood values obtained from the captured bears are given in Table 3, without discussion. Analysis of this blood data awaits additional data from ongoing studies.

Of 12 bears which were marked in the study area in spring 1978, 8 were recaptured and removed in the spring of

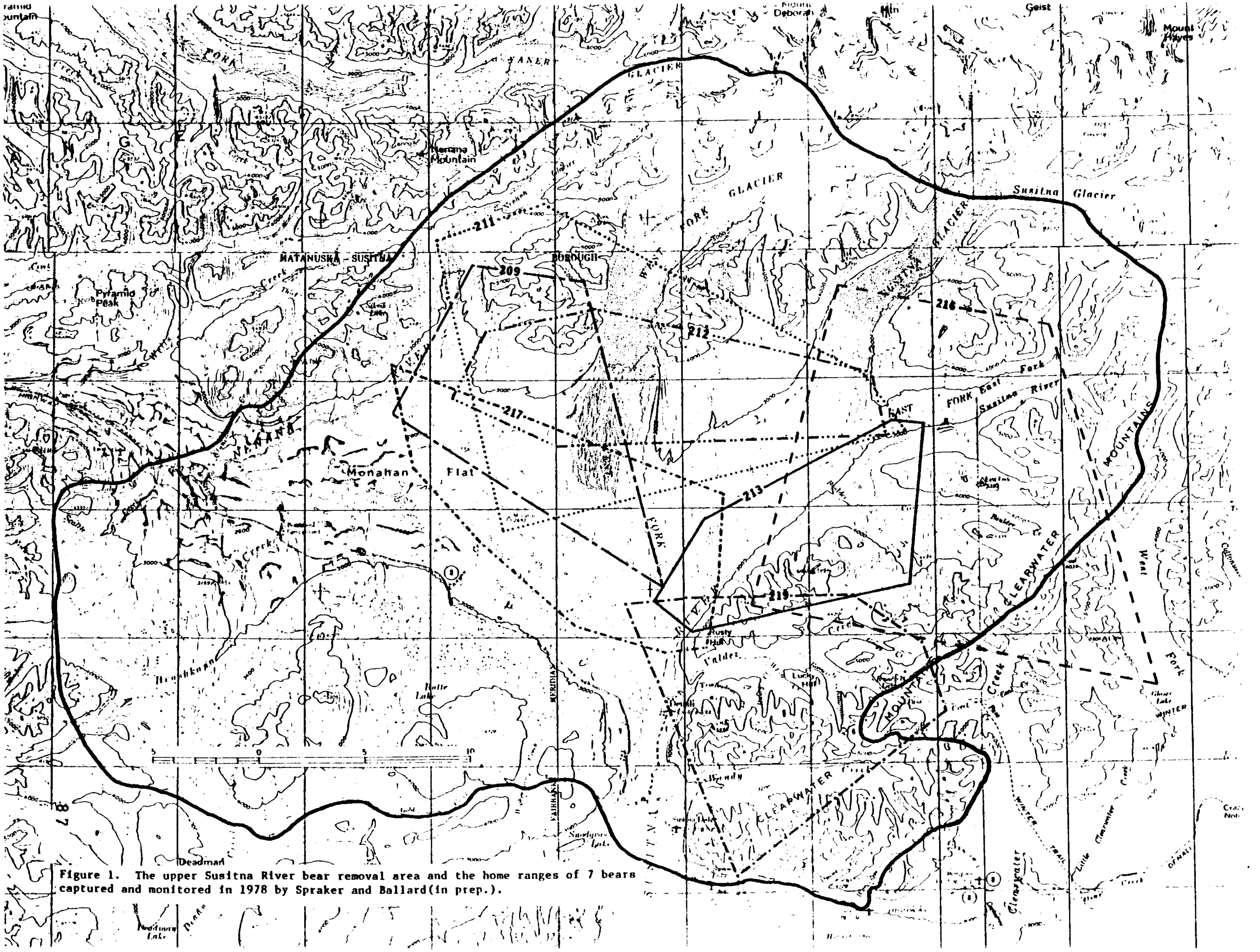

Figure 1. The upper Susitna River bear removal area and the home ranges of 7 bears captured and monitored in 1978 by Spraker and Ballard(in prep.).

Table 1. Tagging data on grizzly bears captured in the upper Susitna River experimental area from 22 May through 22 June, 1979.

TATOO #	CAPTURE DATE	SEX	AGE	WEIGHT (lbs.)	RADIO COLLAR #	EAR TAG # L.	EAR TAG # R.	CAPTURE SITE	RELEASE SITE	COMMENTS
216*	5/22/79	M	11.5	541	6	833	834	East Fork	Mentasta Pass	
213*	5/22/79	F	11.5	234	3406	827	828	Boulder Ck.	Klutina L. Rd.	With #1 and #2
1	5/22/79	M	0.5**	10	--	607	608	Boulder Ck.	Klutina L. Rd.	With 213
2	5/22/79	M	0.5**	10	--	609	610	Boulder Ck.	Klutina L. Rd.	With 213
236	5/22/79	F***	5.5	324	2410	611	612	Mile 68 Denali	Mile 40 Tok	
237	5/22&6/22	M	10.5	594	2408	613	614	Clearwater	Tok cutoff/ Lower Kotsina	Quick return
240	5/23/79	F	5.5	234	3407	615	616	West Fork	Willow Ck.	With 238 & 239
238	5/23/79	M	1.5	95	--	699	694	West Fork	Willow Ck.	With 240
239	5/23/79	F	1.5	65	--	691	692	West Fork	Willow Ck.	With 240
210/242*	5/24/79	M	3.5	205	--	822	821	West Fork	Peter's Ck. Rd.	#210 in '78, now 242
241	5/24/79	M	3.5	209	--	618	617	West Fork	Peter's Ck. Rd.	
215*	5/24/79	F	3.5	167	3982	832	831	East Fork	Mentasta Pass	
243	5/24/79	M	2.5	308	--	619	620	West Fork	Mentasta Pass	
244	5/24/79	F	6.5	189	3991	621	622	West Fork	Klutina Lk. Rd.	With 245
245	5/24/79	F	1.5	46	--	695	696	West Fork	Klutina Lk. Rd.	With 244
246	5/25/79	M	3.5	264	--	624	623	Mile 93 Denali	Edgerton Hwy.	Killed 9/2/78
218*	5/25/79	M	5.5	254	--	625	626	West Fork	L. Tonsina	
247	5/26/79	M	8.5	523	1981	628	627	Brushkana Ck.	L. Tonsina	
248	5/26/79	F***	4.5	214	3990	693	700	Brushkana Ck.	L. Tonsina	
249	5/27/79	M	4.5	284	--	631	632	Brushkana Ck.	Montana Ck.	
250	5/27/79	M	8.5	499	--	--	--	Butte Lake	--	Drowned during capture
251	5/27/79	F	10.5	254	3409	630	629	Boulder Ck.	L. Tonsina	With 252 & 253
252	5/27/79	M	1.5	134	--	633	634	Boulder Ck.	L. Tonsina	With 251
253	5/27/79	M	1.5	139	--	636	635	Boulder Ck.	L. Tonsina	With 251
254	5/27/79	F	9.5	239	--	637	638	Boulder Ck.	Willow Ck.	Post-release mortality
256	5/27/79	M	1.5	47	--	641	642	Boulder	Willow Ck.	With 254
257	5/27/79	M	1.5	52	--	639	640	Boulder Ck.	Willow Ck.	With 254
258	5/29/79	M	21.5	599	3992	650	649	Nenana R.	Strelna	
211*	5/30/79	M	5.5	424	3989	823	824	West Fork	Strelna	
259	5/31/79	M	2.5	129	--	644	643	East Fork	Sanford R.	
230*	6/01/79	M	10.5	580	3981	651	652	Monahan L.	Lower Kotsina	
260	6/02/79	M	4.5	256	--	648	647	Middle Fork	Sanford R.	
261	6/02/79	F	7.5	224	3986	656	655	West Fork	Upper Kotsina	With 262 & 263
262	6/02/79	M	1.5**	90	--	645	646	West Fork	Upper Kotsina	With 261
263	6/02/79	M	1.5**	87	--	653	654	West Fork	Upper Kotsina	With 261

Table 1. Continued.

TATOO #	CAPTURE DATE	SEX	AGE	WEIGHT (lbs.)	RADIO COLLAR #	EAR TAG # L.	EAR TAG # R.	CAPTURE SITE	RELEASE SITE	COMMENTS
264	6/03/79	F***	4.5	160	--	663	664	Nenana R.	Chalet L.	
209*	6/04/79	F***	5.5	250	3987	817	818	Flats	Lower Kotsina	
265	6/04/79	M	4.5	399	3988	658	657	Nenana R.	Lower Kotsina	
267	6/05/79	F***	4.5	170	--	697	698	Middle Fork	Skwentna Strip	
268	6/05/79	M	4.5	324	--	665	666	Middle Fork	Skwentna Strip	
269	6/06/79	F	16.5	255	3983	667	668	Nenana R.	Upper Kotsina	With 270 & 271
270	6/06/79	F	1.5**	100	--	699	670	Nenana R.	Upper Kotsina	With 269
271	6/06/79	F	1.5**	95	--	671	672	Nenana R.	Upper Kotsina	With 269
272	6/06/79	M	9.5	570	3984	673	674	Brushkana	Sanford R.	
273	6/07/79	F***	3.5	214	3985	675	676	West Fork	Upper Kotsina	
274	6/07/79	F	11.5	219	--	679	680	West Fork	Kahiltna R.	With 275
275	6/07/79	M	1.5**	68	--	678	677	West Fork	Kahiltna R.	With 274
276	6/22/79	M	4.5	295	--	681	682	Monahan Lake	Yenlo Hills	

* Recapture, originally captured in 1978 (see Spraker and Ballard, 1979).
** Not aged by cementum lines
*** In estrus.

Table 2a. Morphological measurements in relation to age of male brown bears captured in Game Management Unit 13 from May 22 through June 22, 1979.

Age (yrs.)	Bear I.D. number	Weight (kg)	Total length (cm)	Shoulder height (cm)	Length of hind foot (cm)	Neck circum-frence (cm)	Girth (cm)	Body length (cm)	Head width (cm)	Head length (cm)	Head width and length (cm)	Anterior-posterior width upper L. canine (mm)	Lingual labial width upper L. canine (mm)	Anterior-posterior width lower L. canine (mm)	Lingual labial width lower L. canine (mm)
0.5	1	5	-	-	-	-	-	-	-	-	-				
0.5	2	5	-	-	-	-	-	-	-	-	-				
1.5	256	21.3	95.9	59.9	20.3	33.7	54.0	50.4	12.3	21.6	33.9				
1.5	257	23.6	104.8	60.3	20.3	35.6	56.2	51.4	12.3	21.2	33.5				
1.5	275	30.9	122.6	72.4	23.2	28.1	73.7	63.5	12.9	23.9	36.8				
1.5	263	39.5	121.9	68.9	23.8	42.2	78.1	72.4	13.6	24.8	38.4				
1.5	262	40.9	118.7	66.3	24.1	40.6	78.3	65.0	14.2	24.8	39.0				
1.5	238	43.1	130.2	74.3	26.3	40.9	80.6	68.6	13.5	24.5	38.0				
1.5	252	60.8	144.1	84.1	26.0	48.3	83.4	83.8	16.0	28.6	44.6	14.3	12.3	16.0	14.8
1.5	253	63.1	155.9	82.6	28.2	47.6	80.6	83.8	16.2	27.9	44.1	12.7	11.2	12.9	10.6
2.5	259	58.6	152.4	85.3	28.9	47.0	88.9	79.0	14.2	27.3	41.5	13.3	9.4	17.0	15.3
2.5	243	139.8	195.6	100.0	34.5	62.5	120.9		20.1	35.2	55.3	24.3*	18.4*	26.8*	18.6*
3.5	210/242	93.1	170.2	103.5	28.6	58.4	98.4	99.1	17.5	30.8	48.3	15.8	15.4	21.6	14.6
3.5	241	94.9	193.0	96.5	28.6	55.9	97.8	88.9	18.1	30.5	48.6	17.0	15.2	21.1	15.8
3.5	246	119.9	191.8	108.2	31.1	63.8	118.1	107.3	20.1	35.6	55.7	21.0*	16.3*	20.9*	14.9*
4.5	260	116.2	181.0	115.6	32.4	67.3	108.6	102.2	18.8	33.9	52.7	19.8	14.7	22.6	15.0
4.5	249	129.9	194.3	92.1	33.0	72.4	128.9	103.5	19.5	33.3	52.8	18.5	17.0	22.7	15.9
4.5	276	133.9	190.5	113.0	37.5	67.3	115.6	108.6	18.5	35.0	53.5	20.2	14.6	23.0	16.0
4.5	268	147.1	175.3	106.7	33.0	74.9	116.8	97.8	19.3	37.1	56.4	20.0	15.3	24.6	13.4
4.5	265	181.1	217.2	116.4	38.1	77.5	142.2	114.3	21.1	34.9	56.0	21.9*	17.6*	24.4*	15.1*
5.5	218	115.3	180.3	102.9	32.4	68.6	111.1	101.6	19.7	33.3	53.0	19.9*	15.1*	22.1*	16.5*
5.5	211	192.5	206.0	106.7	34.3	78.1	130.8	123.4	22.3	38.1	60.4	22.7*	11.5*	22.0*	15.7*
8.5	250	226.5	204.7	116.2	26.7	81.3	138.4	125.7	22.9	35.7	58.6	17.5*	11.5*	16.5*	13.2*
8.5	247	237.4	196.9	123.8	38.1	91.4	138.4	134.6	23.2	37.8	61.0	23.5*	17.8*	23.1*	16.0*
9.5	272	258.8	218.4	124.5	40.6	86.7	154.9	127.0	24.2	40.0	64.2	22.5	17.0	19.0	15.5
10.5	230	263.3	212.3	122.2	35.6	98.5	157.5	155.6	24.4	35.6	60.0	25.0	16.5	22.8	16.8
10.5	237	269.7	226.7	126.0	37.7	92.1	151.8	144.8				23.1	18.4	23.0	16.2
11.5	216	245.6	225.4	125.1	36.2	83.8	137.2	120.7				25.2	18.3	22.1	17.3
21.5	258	271.9	222.9	127.6	40.6	94.0	161.9	121.9	26.5	38.6	65.1	26.4		23.8	

* Right canine.

Table 2b. Morphological measurements in relation to age of female brown bears captured in Game Management Unit 13 from May 22 through June 22, 1979.

Age (yrs.)	Bear I.D. number	Weight (kg)	Total length (cm)	Shoulder height (cm)	Length of hind foot (cm)	Neck circum-frence (cm)	Girth (cm)	Body length (cm)	Head width (cm)	Head length (cm)	Head width and length (cm)	Anterior-posterior width upper L. canine (mm)	Lingual labial width upper L. canine (mm)	Anterior-posterior width lower L. canine (mm)	Lingual labial width lower L. canine (mm)
1.5	245	20.9	111.4	59.3	21.2	32.0	57.8	54.3	12.1	21.8	33.9				
1.5	239	29.5	117.5	69.2	15.5	40.0	75.6	66.7	13.2	23.9	37.1				
1.5	271	43.1	138.4	70.5	24.1	43.2	52.2	85.7	14.6	25.4	40.0				
1.5	270	45.4	138.4	81.9	25.4	40.9	72.4	77.1							
3.5	215	75.8	170.2	91.4	27.3	53.3	104.1	88.9	18.1	30.5	48.6	16.1	13.0	16.8	12.5
3.5	273	97.2	226.7	93.3	32.0	58.4	105.7	105.4	17.1	30.1	47.2	17.6*	13.6*	18.5*	13.4*
4.5	264	72.6	163.2	90.8	28.6	55.9	95.9	92.1	17.4	29.6	47.0	17.1*	12.8*		13.6*
4.5	267	77.2	157.5	91.4	26.0	57.2	94.0	83.2	17.9	30.6	48.5	17.2	13.1	18.4	13.4
4.5	248	97.2	169.2	92.1	28.9	59.7	110.5	104.1	19.2	31.8	51.0	17.2	12.8	18.2	14.8
5.5	240	106.2	187.3	101.6	29.8	56.5	108.6	101.0	19.2	33.0	52.2	17.5*	12.8*	19.2*	13.1*
5.5	209	113.5	181.0	97.4	31.1	61.0	102.2	113.7	18.8	32.8	51.6	16.7*	15.3*	18.5*	13.2*
5.5	236	147.1	190.5	106.7	33.0	74.9	114.9	106.7				18.3	13.0	17.2	
6.5	244	85.8	175.3	100.3	31.1	54.0	94.0	96.5	17.8	32.5	50.3	13.5	9.0	15.0	9.5
7.5	261	101.7	179.7	103.7	28.2	65.6	104.1	103.5	19.5	33.0	52.5	17.2	14.0	18.4	13.6
9.5	254	108.5	197.1	99.4	31.4	57.8	100.3	104.4	21.0	35.2	56.2	20.5	14.8	20.0	14.7
10.5	251	115.3	182.9	96.5	29.8	62.5	108.0	92.1	21.2	32.2	53.4	17.0	13.5	20.2	14.4
11.5	274	99.4	177.8	91.4	29.2	54.6	115.6	110.5	19.3	32.0	51.3	17.75*	13.0*	16.5*	12.0*
11.5	213	106.2	181.6	101.0	33.9	53.3	104.1	99.7				17.9	14.2	18.7	13.3
16.5	269	115.3	184.8	95.9	30.1	59.7	134.6	111.8	19.3	32.6	51.9	20.0	15.0	18.0	13.0

* Right canine.

Table 3a. Results of chemical analyses of blood serum from brown bears captured in Alaska's GMU 13, May 22 through June 22, 1979.

ID Number	216	213	1&2	236	** 237	** 237	240	238	239	210/ 242	241	215
Sex	M#	F#	No	F#	M#	M#	F#	M#	F*#	M#	M*#	F#
Age	11.5	11.5	Data	5.5	10.5	10.5	5.5	1.5	1.5	3.5	3.5	3.5
Glucose (1)	222	190		114	151	97	111	112	133	119	118	93
BUN (1)	74	7		9	12	33	32	21	24	32	38	18
Creatinine (1)	1.2	2.0		1.5	1.4	1.5	2.0	0.7	0.8	1.1	0.9	1.2
Na^+ (2)	139	125		142	136	144	136	137	147	147	141	129
K^+ (2)	5.0	4.6		3.8	3.9	4.1	3.2	4.3	4.3	3.9	3.7	3.4
Cl^- (2)	102	88		104	102	100	85	90	98	102	97	98
CO_2 (2)	18	16		13	18	10	23	28	29	18	18	14
Uric Acid (1)	1.2	1.9		2.7	1.6	5.9	8.9	1.4	2.1	2.9	2.0	1.2
Total Bilirubin (1)	0.1	0.1		0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Direct Bilirubin (1)	0.0	0.1		0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Electrolyte Balance (3)	9.0	11.0		15.0	6.0	24.0	18.0	9.0	10.0	17.0	16.0	7.0
Ionized Calcium (1)	3.8	3.6		4.0	3.8	4.1	4.9	5.8	6.0	4.5	4.7	4.3
Calcium (1)	8.5	7.3		8.8	8.6	9.8	10.4	12.0	12.7	10.3	10.1	8.6
Phosphorus (1)	3.7	4.2		3.7	2.6	6.4	2.0	3.5	5.9	5.6	6.2	3.7
Alkaline Phosphatase (4)	44	12		53	65	72	46	145	204	88	62	73
LDH (4)	790G	300		707C	542	639G	667G	756G	926G	812G	634G	612G
SGOT (4)	546G	31		149	95	178	121	38	82	113	69	92
SGPT (4)	115	13		64	34	68	54	6	14	72	13	33
Cholesterol (1)	181	259		223	201	276	221	303&	272&	310&	238	253
Triglycerides(1)	189	205		146	155	194	246	252	244	253&	273&	224
Total Protein (5)	6.9	5.5		6.6	7.0	7.6	6.2	6.0	6.4	7.2	6.5	5.5
Albumin (5)	3.9	3.0		3.7	4.4	4.3	3.8	3.7	4.0	4.0	3.6	3.6
Globulin (5)	3.0	2.5		2.9	2.6	3.3	2.4	2.3	2.4	3.2	2.9	1.9
A/G Ratio	1.3	1.2		1.3	1.7	1.3	1.6	1.6	1.7	1.3	1.2	1.9

* Sample Cloudy # Sample Hemolyzed
(1)=mg/dl (2)=mEq/L (3)=N/A (4)=U/L (5)=Gm/100ml
B=Specimen too cloudy or accurate result, G=Result exceeds maximum range of accuracy,
T=Specimen too turbid or lipemic to measure, D=Specimen rechecked on dilution,
&=Indicates result has been checked by operator.
** Bear 237 was captured twice, uncertain which of these values relate to the first and which to the second capture.

Table 3a. (cont.)

ID Number	243*#	244#	245	246*#	218#	247#	248*	249#	250	251*#	252#	253*#
Sex	M	F	F	M	M	M	F	M	M	F	M	M
Age	2.5	6.5	1.5	3.5	5.5	8.5	4.5	4.5	8.5	10.5	1.5	1.5
Glucose (1)	119	101	No	93	99	84	88	73	No	168	90	229
BUN (1)	23	30	Data	22	30	43	49	25	Data	66	37	28
Creatinine (1)	0.8	1.1		1.1	1.0	1.2	1.1	0.7		1.4	0.7	0.6
Na^+ (2)	135	146		137	133	131	145	138		158	145	141
K^+ (2)	3.9	4.9		3.1	4.7	3.8	4.9	5.3		51	5.8	5.0
Cl^- (2)	100	105		94	95	94	105	101		104	95	99
CO_2 (2)	18	19		18	15	13	13	12		25	21	23
Uric Acid (1)	1.2	1.1		1.4	1.4	4.7	3.4	1.6		1.8	2.0	1.0L
Total Bilirubin (1)	0.1	0.1		0.1	0.1	0.1	0.1	0.1		0.2	0.2	0.1
Direct Bilirubin (1)	0.0	0.0		0.1	0.1	0.0	0.0	0.0		0.1	0.1	0.1
Electrolyte Balance (3)	7.0	12.0		15.0	13.0	14.0	17.0	15.0		19.0	19.0	9.0
Ionized Calcium (1)	4.1	3.9		4.3	3.8	4.0	3.6	3.4		4.0	4.3	4.0
Calcium (1)	9.3	8.6		9.2	8.1	8.9	8.2	7.6		9.1	9.4	7.9
Phosphorus (1)	3.9	3.4		6.4	5.9	3.6	4.6	5.5		8.3	8.9	6.1
Alkaline Phosphatase (4)	85	22		59	51	79	66	69		34	83	69
LDH (4)	681G	780G		593	612G	499	697G	755G		876G	1029G	791G
SGOT (4)	80	327		46	87	152	96	87		197	152	70
SGPT (4)	48	54		19	23	54	33	53		133	82	12
Cholesterol (1)	277	290*		300*	248	262	276	270&		255	321	273
Triglycerides(1)	299	193		213	253*	154	312	180		209	236	263
Total Protein (5)	7.0	6.8		6.4	6.3	6.7	6.9	6.9		7.2	6.7	5.4
Albumin (5)	4.1	4.0		3.8	3.7	4.2	4.0	3.9		4.4	4.1	3.4
Globulin (5)	2.9	2.8		2.6	2.6	2.5	2.9	3.0		2.8	2.6	2.0
A/G Ratio	1.4	1.4		1.5	1.4	1.7	1.4	1.3		1.6	1.6	1.7

* Sample Cloudy # Sample Hemolyzed
(1)=mg/dl (2)=mEq/L (3)=N/A (4)=U/L (5)=Gm/100ml
B=Specimen too cloudy or accurate result, G=Result exceeds maximum range of accuracy, T=Specimen too turbid or lipemic to measure, D=Specimen rechecked on dilution, &=Indicates result has been checked by operator.

Table 3a. (cont.)

ID Number	254*#	256*#	257*#	258*#	211#	259#	230*#	260#	261#	262#	263#	264$
Sex	F	M	M	M	M	M	M	M	F	M	M	F
Age	9.5	1.5	1.5	21.5	5.5	2.5	10.5	4.5	7.5	1.5	1.5	4.5
Glucose (1)	230	2.2	130	148	93	63	35	112	120	84	97	78
BUN (1)	78	40	43	14	73	27	88	27	34	19	26	23
Creatinine (1)	1.4	0.6	0.6	1.2	1.0	1.0	1.2	0.7	0.6	0.5	0.6	0.7
Na^+ (2)	158	138	135	143	134	138	141	134	146	127	147	130
K^+ (2)	4.7	5.5	5.0	4.0	3.7	4.2	4.9	4.5	4.1	5.0	4.7	4.9
Cl^- (2)	107	97	93	110	96	94	96	99	106	88	102	94
CO_2 (2)	22	20	18	13	20	8	15	20	22	19	24	14
Uric Acid (1)	1.7	1.4	1.3	1.2	1.8	4.7	1.8	2.4	0.6L	1.2	1.0L	1.4
Total Bilirubin (1)	0.2	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Direct Bilirubin (1)	0.1	0.0	0.0	0.0	0.1	0.0&	0.0	0.0	0.1	0.1	0.0	0.1
Electrolyte Balance (3)	19.0	11.0	14.0	10.0	8.0	26.0	20.0	5.0	8.0	10.0	11.0	12.0
Ionized Calcium (1)	3.3	4.2	3.8	4.0	4.6	3.9	3.7	3.9	4.5	4.6	5.0	2.7
Calcium (1)	7.8	8.1	7.4	9.2	9.8	8.5	8.8	8.5	9.5	9.2	10.4	6.1
Phosphorus (1)	6.6	7.0	6.9	2.7	4.7	8.2	5.5	5.6&	3.3	5.2	7.2	4.3
Alkaline Phosphatase (4)	23	72	80	51	78	100	155	109	31	107	123	54
LDH (4)	582	594	613G	703G	666G	787G	959G	891G	559	660G	741G	776G
SGOT (4)	99	79	81	140	212	138	413	97	63	70	69	167
SGPT (4)	27	19	16	23	131	62	113	32	9	9	10	122
Cholesterol (1)	253	309	&B	188	260	347	251	228	260	277	329	239
Triglycerides(1)	222	195	217	89	114	250	243	156	200	240	233	153
Total Protein (5)	7.6	5.2	5.1	7.1	6.3	6.5	7.7	6.4	6.3	5.7	6.1	6.6
Albumin (5)	4.5	3.2	3.3	4.1	4.0	4.0	4.9	3.8	3.9	3.4	3.8	4.0
Globulin (5)	3.1	2.0	1.8	3.0	2.3	2.5	2.8	2.6	2.4	2.3	2.3	2.6
A/G Ratio	1.5	1.6	1.8	1.4	1.7	1.6	1.8	1.5	1.6	1.5	1.7	1.5

* Sample Cloudy # Sample Hemolyzed
(1)=mg/dl (2)=mEq/L (3)=N/A (4)=U/L (5)=Gm/100ml
B=Specimen too cloudy or accurate result, G=Result exceeds maximum range of accuracy,
T=Specimen too turbid or lipemic to measure, D=Specimen rechecked on dilution,
&=Indicates result has been checked by operator.

Table 3a. (cont.)

ID Number	209#	265#	267*#	268*#	269*#	270*	271*#	272#	273*#	274#	275#	276*#
Sex	F	M	F	M	F	F	F	M	F	F	M	M
Age	5.5	4.5	4.5	4.5	16.5	1.5	1.5	9.5	3.5	11.5	1.5	4.5
Glucose (1)	84	87	110	121	146	105	113	44	118	127	132	96
BUN (1)	79	25	35	45	59	63	77	23	61	56	48	75
Creatinine (1)	1.0	0.9	0.5	0.5	1.2	0.6	0.7	1.0	0.7	0.9	0.6	0.6
Na^+ (2)	153	134	135	138	140	139	143	135	133	132	126	138
K^+ (2)	4.5	4.5	4.1	4.1	3.4	4.8	4.1	4.1	3.8	2.9	3.3	5.3
Cl^- (2)	114	101	104	101	100	101	102	98	91	88	89	101
CO_2 (2)	12	13	13	16	19	19	20	13	16	23	14	11
Uric Acid (1)	2.2	1.5	0.8L	0.3L	1.7	1.3	1.2	1.3	2.7	1.3	1.5	2.5
Total Bilirubin (1)	0.1	0.1	0.0	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Direct Bilirubin (1)	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Electrolyte Balance (3)	17.0	10.0	8.0	11.0	11.0	9.0	11.0	14.0	16.0	11.0	13.0	16.0
Ionized Calcium (1)	4.4	4.3	3.9	3.7	4.4	4.6	4.9	3.7	4.3	4.7	4.8	3.4
Calcium (1)	10.7	9.1	8.3	8.9	9.2	9.0	9.5	8.2	9.1	9.9	9.0	7.3
Phosphorus (1)	4.7	5.1	4.0	4.9	3.5	5.9	6.6G	2.9	4.8	3.0	5.3	7.1
Alkaline Phosphatase (4)	51	131	32	174	33	118	105	52	47	15	77	85
LDH (4)	652G	590	711G	778G	737G	774G	937G	558	652G	475	652G	792G
SGOT (4)	175	73	198	549G	210	189	388	109	219	155	61	94
SGPT (4)	49	36	35	165	42	232	136	34	151	35	35	30
Cholesterol (1)	256	319	224	241	213	330&	280	262	276&	228	250	292
Triglycerides(1)	262	197	214	158	222	305	261	240	230	180	215	170
Total Protein (5)	8.0	6.3	6.2	7.6	6.2	5.4	5.3	6.8	6.3	6.2	4.9	6.2
Albumin (5)	4.7	3.8	3.7	4.1	3.9	3.4	3.4	4.0	3.8	3.6	3.3	3.5
Globulin (5)	3.3	2.5	2.5	3.5	2.3	2.0	1.9	2.8	2.5	2.6	1.6	2.7
A/G Ratio	1.4	1.5	1.5	1.2	1.7	1.7	1.8	1.4	1.5	1.4	2.1	1.3

* Sample Cloudy # Sample Hemolyzed
(1)=mg/dl (2)=mEq/L (3)=N/A (4)=U/L (5)=Gm/100ml
B=Specimen too cloudy or accurate result, G=Result exceeds maximum range of accuracy,
T=Specimen too turbid or lipemic to measure, D=Specimen rechecked on dilution,
&=Indicates result has been checked by operator.

Table 3b. Results of protein electrophoresis analyses of blood serum from brown bears captured in Alaska's GMU 13, May 22 through June 22, 1979.

ID Number	216	213	1&2	236	** 237A	** 237B	240	238	239	210/ 242	241	215
Sex	M	F	No	F	M	M	F	M	F	M	M	F
Age	11.5	11.5	Data	5.5	10.5	10.5	5.5	1.5	1.5	3.5	3.5	3.5
Total Protein (1)	6.9	5.5		6.6	7.0	7.6	6.2	6.0	6.4	7.2	6.5	5.5
Albumin (1)	4.2	2.9		4.1	4.7	4.6	4.1	3.9	4.4	4.5	3.9	3.6
Albumin % Globulin (1)	61	52		62	67	60	66	64	68	62	61	66
Alpha 1 Globulin (1)	0.4	0.5		0.4	0.4	0.5	0.4	0.5	0.6	0.5	0.6	0.4
% Alpha 1	6	9		7	6	6	7	8	9	7	9	8
Alpha 2 Globulin (1)	0.6	0.6		0.5	0.5	0.7	0.6	0.5	0.5	0.2	0.5	0.4
% Alpha 2	9	10		8	8	10	10	9	8	3	8	8
Beta Globulin (1)	0.8	0.5		0.6	0.6	0.7	0.5	0.7	0.6	1.1	0.8	0.6
% Beta	11	10		9	8	9	8	12	9	15	12	11
Gamma Globulin (1)	0.9	1.1		1.0	0.9	1.1	0.6	0.4	0.4	1.0	0.7	0.4
% Gamma	13	19		15	12	14	10	7	5	13	11	7
A/G Ratio	1.6	1.1		1.6	2.0	1.5	1.9	1.8	2.1	1.6	1.6	2.0

(1)=Gm/100ml

Table 3b. (cont.)

ID Number	243	244	245	246	218	247	248	249	250	251	252	253
Sex	M	F	F	M	M	M	F	M	M	F	M	M
Age	2.5	6.5	1.5	3.5	5.5	8.5	4.5	4.5	8.5	10.5	1.5	1.5
Total Protein (1)	7.0	6.8		6.4	6.3	6.7	6.9	6.9	NO	7.2	6.7	5.4
Albumin (1)	4.2	4.5		3.9	3.5	4.4	4.2	4.2	Data	4.3	4.4	3.2
Albumin % Globulin (1)	60	65		60	56	66	62	61		60	66	59
Alpha 1 Globulin (1)	0.5	0.5		0.5	0.5	0.3	0.5	0.4		0.5	0.5	0.5
% Alpha 1	8	7		7	8	5	7	6		7	7	9
Alpha 2 Globulin (1)	0.7	0.5		0.7	0.6	0.5	0.9	0.7		0.7	0.6	0.6
% Alpha 2	10	7		11	9	7	13	10		9	9	11
Beta Globulin (1)	0.6	0.6		0.7	0.8	0.6	0.7	0.8		1.2	1.0	0.8
% Beta	9	9		11	13	10	10	12		17	14	15
Gamma Globulin (1)	0.9	0.8		0.7	0.9	0.8	0.7	0.7		0.5	0.2	0.2
% Gamma	13	12		11	14	12	9	10		7	3	3
A/G Ratio	1.6	1.9		1.5	1.3	2.0	1.6	2.5		1.5	1.9	1.5

(1)=Gm/100ml

Table 3b. (cont.)

ID Number	254	256	257	258	211	259	230	260	261	262	263	264
Sex	F	M	M	M	M	M	M	M	F	M	M	F
Age	9.5	1.5	1.5	21.5	5.5	2.5	10.5	4.5	7.5	1.5	1.5	4.5
Total Protein (1)	7.6	5.2	5.1	7.1	6.3	6.5	7.7	6.4	6.3	5.7	6.1	6.6
Albumin (1)	5.0	3.4	3.4	4.3	3.9	4.1	5.1	4.0	4.0	3.3	3.8	4.0
Albumin % Globulin (1)	66	65	65	61	62	62	67	62	63	58	64	60
Alpha 1 Globulin (1)	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.6	0.6	0.6
% Alpha 1	6	10	10	6	8	9	6	7	7	10	9	8
Alpha 2 Globulin (1)	0.5	0.5	0.4	0.5	0.4	0.7	0.6	0.5	0.6	0.7	0.6	0.4
% Alpha 2	6	9	8	8	7	11	8	8	8	12	10	6
Beta Globulin (1)	0.8	0.4	0.5	1.0	1.0	0.9	0.8	0.6	0.8	0.7	0.6	1.2
% Beta	10	8	9	14	15	13	11	10	13	12	9	18
Gamma Globulin (1)	0.9	0.4	0.4	0.8	0.5	0.4	0.7	0.8	0.4	0.5	0.6	0.5
% Gamma	12	8	8	12	9	6	9	12	8	9	9	7
A/G Ratio	2.0	1.8	1.9	1.5	1.6	1.7	2.0	1.7	2.5	1.4	1.9	1.5

(1)=Gm/100ml

Table 3b. (cont.)

ID Number	209	265	267	268	269	270	271	272	273	274	275	276
Sex	F	M	F	M	F	F	F	M	F	F	M	M
Age	5.5	4.5	4.5	4.5	16.5	1.5	1.5	9.5	3.5	11.5	1.5	4.5
Total Protein (1)	8.0	6.3	6.2	7.6	6.2	5.4	5.3	6.8	6.3	6.2	4.9	6.2
Albumin (1)	4.9	3.9	3.8	4.1	4.1	3.5	3.6	3.6	3.9	3.8	3.3	3.8
Albumin % Globulin (1)	62	62	61	55	66	65	67	53	62	62	68	62
Alpha 1 Globulin (1)	0.6	0.4	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.4	0.4
% Alpha 1	7	6	8	7	8	9	10	8	9	8	9	7
Alpha 2 Globulin (1)	0.7	0.9	0.7	0.9	0.3	0.5	0.4	0.2	0.6	0.5	0.4	0.4
% Alpha 2	9	14	11	12	5	9	8	17	10	8	9	7
Beta Globulin (1)	0.8	0.7	0.8	0.9	0.8	0.6	0.4	0.8	0.7	0.8	0.4	0.8
% Beta	10	12	12	12	13	11	8	12	11	13	9	12
Gamma Globulin (1)	0.9	0.4	0.5	1.1	0.6	0.3	0.3	0.7	0.5	0.6	0.3	0.8
% Gamma	12	7	8	13	9	6	6	10	9	9	6	13
A/G Ratio	1.6	1.6	1.5	1.2	1.9	1.8	2.1	1.1	1.6	1.7	2.1	1.6

(1)=Gm/100ml

1979. Only two of these bears (#213 and #216) retained functioning radio collars when recaptured.

The removal effort had not removed all bears present in the experimental area when initial efforts were terminated on 7 June. Bears were encountered with essentially unchanged frequency from 22 May through 7 June including 3 removed on 7 June and 4 the preceding day (Table 1). In June and July, two unmarked bears were seen in the experimental area incidental to moose calf monitoring flights and two additional bears were seen in the experimental area on 15 August. Twelve of 32 radio-collared moose calves in the experimental area were killed by bears (Ballard et al. 1980). All radio-collared moose calves were located in the center of the experimental area, none in peripheral areas. In addition, 4 bears marked the previous year were not recaptured, 3 of these were well documented experimental area residents in 1978 (Spraker and Ballard, in prep).

POPULATION STRUCTURE AND REPRODUCTIVE STATUS

The 48 bears captured in 1979 included 17 males and 15 females aged 3.0 years or older, and 12 males and 4 females aged less than 3.0 years (Table 2).

Eight females were accompanied by offspring. The only female with newborn cubs captured in 1979 was #213; she retained a functioning radio collar from 1978. Five females were accompanied by twin yearling cubs and two females were accompanied by a single yearling cub each. Neither bear aged at 2.5 years was accompanied by a female indicating that separation of the maternal bond had already occurred.

The average age for 17 males older than 3.0 years was 7.4 years (3.5-21.5). The average age for 15 females older than 3.0 years was also 7.4 years (3.5-16.5). The eight females accompanied by offspring averaged 9.9 years old (5.5-16.5) while the seven females not accompanied by offspring were an average age of 4.5 years (3.5-5.5). Six of the 7 females not accompanied by cubs, had swollen vulvas and were noticeably in estrus; these females had an average age of 4.7 years (3.5-5.5 years). The non-parous female (#215) was 3.5 years old.

IMMIGRATION

A key assumption of the population estimates derived from the bear removal effort is that immigration did not occur. These estimates would be inflated if bears were moving into the experimental area in response to vacancies created by removal of resident bears. Had immigration occurred we would have anticipated shifts in sex or age composition of animals captured late in the capture period relative to earlier, or different sex and age compositions of animals captured in the periphery relative to the center of the search area. For example, immigration would be indicated if later in the removal period, or in the periphery of the search area, younger animals which are naturally dispersing were more prevalent than older animals with well established home ranges, or if males wandering in search of females were more prevalent than females. For the purposes of these determinations a periphery zone was defined as the area within one average home range radius inside the border of the search area, 9.7 miles for males and 7.1 miles for females (Table 4).

In comparisons of sex ratios relative to time of capture, these differences were not evident. Chi square tests run on the sex ratios of captured bears in three different groupings of consecutive time periods (Table 5) (six 3 day intervals, three 6 day intervals, and two 9 day intervals) reveal no significant differences in sex ratios (X^2=3.48, p=0.37; X^2=2.86, p=.76; and X^2=0.33, p=.43, respectively). Also, the sex ratio in the center of the area was 8:7 in favor of males throughout the removal period, and the sex ratio in the periphery during the last half of the removal period was 3:2 (Table 6). These ratios are not significantly different (X^2=0.07, p=.21). These data indicate that no evidence of immigration exists in the sex ratios of the bears captured.

A similar lack of evidence for immigration existed in the age ratio data. The seven males captured in the last half of the capture period were younger (5.8 years) than the 12 males captured in the first half (7.6 years), however, excluding one exceptionally old bear (21.5 years) no differences in age were apparent (6.2 years and 5.8 years, respectively) (Table 5). No difference was apparent in the average ages of 8 females captured early (7.1 years) relative to 7 captured late (7.6 years) (Table 5).

Although sample size was small, the average age of males captured in the periphery during the last half of the removal period (6.2 years, n=3) was greater than the average age of all males captured in the center (5.0 years, n=8) (Table 6). This could be interpreted as indicating movement of older males into the area late in the capture period, however, the males captured in the periphery in the first half of the capture period were older (9.0 years, n=8) than in the last half (6.2 years, n=3) (Table 6). Excluding the 21.5-year-old male the same relationship exists (7.3 years, n=7). This suggests that immigration by older males did not occur.

Only two females were captured in the periphery during the last half of the removal period so comparisons of female average ages were not meaningful. Overall, females captured in the periphery were older (8.5 years, n=8) than females captured in the center (6.1 years, n=7) (Table 6).

Table 4. Brown bear home range sizes as determines from visual relocations*, 1978-1979, Nelchina Basin studies (Spraker and Ballard, in prep.).

Bear No.	Location	Sex/ Age	Reproductive Status	No. of Days Observed (78/79)	Home Range $Miles^2$	Home Range Radius (mi)**
209	Susitna	F/4	w/1 (2.5)	22/1	93.19	
212	Susitna	F/10	turgid	17/0	85.81	
213	Susitna	F/10	w/1 (1.5)	16/1	74.67	
219	Susitna	F/4	turgid	12/0	117.81	
				SUSITNA FEMALE AVERAGE =	92.87	5.4
206	Hogan Hill	F/13	w/male 205	27/3	86.15	
207	Hogan Hill	F/11	w/3 (0.5)	22/5	118.73	
208	Hogan Hill	F/12	--	33/0	283.22	
220	Hogan Hill	F/5	w/1 (1.5)	29/8	224.22	
202	Mendeltna	F/8	turgid, w/ male #203	26/0	169.53	
204	Mendeltna	F/8	w/2 (2.5)	25/0	202.14	
221	Mendeltna	F/8	w/2 (1.5)	28/2	331.99	
231	Mendeltna	F/12	turgid, w/ male #208	19/11	101.53	
				HOGAN HILL AND MENDELTNA FEMALE AVERAGE =	189.69	7.8
				ALL FEMALES AVERAGE =	157.42	7.1
216	Susitna	M/10	--	10/1	226.31	
217	Susitna	M/3	--	17/0	108.72	
211	Susitna	M/4	w/sow 212	16/1	182.31	
				SUSITNA MALE AVERAGE =	172.45	7.4
200	Hogan Hill	M/7	--	5/4	120.84	
205	Hogan Hill	M/4	w/sow 206	29/0	308.05	
222	Hogan Hill	M/11	--	11/0	413.02	
227	Hogan Hill	M/9	w/sow	8/0	191.29	
201	Mendeltna	M/10	w/sow 202	20/0	533.37	
225	Mendeltna	M/4	--	25/4	400.80	
228	Mendeltna	M/7	w/sow 231	11/0	483.43	
				HOGAN HILL AND MENDELTNA MALE AVERAGE =	350.11	10.6
				ALL MALES AVERAGE =	296.81	9.7
				ALL BEARS AVERAGE =	220.78	8.4

* Animals observed on fewer than 8 days are not included in the calculations of average home range size.

** Radius calculated by assuming a circular home range of indicated area.

Table 5. Average ages of bears captured by time of capture. Newborn cubs and yearlings are not included.

Date captured	MALES Avg. age	Range	n	FEMALES Avg. age	Range	n	BOTH SEXES Avg. age	Range	n
5/22-5/24	6.3	2.5-11.5	5	6.5	3.5-11.5	5	6.4	2.5-11.5	10
5/25-5/27	6.3	4.5- 8.5	5	8.2	4.5-10.5	3	7.0	4.5-10.5	8
5/28-5/30	14.0	5.5-21.5	2	--	--	0	14.0	5.5-21.5	2
SUBTOTAL 5/22-5/30	7.6*	2.5-21.5	12	7.1	3.5-11.5	8	7.4	2.5-21.5	20
5/31-6/02	5.8	2.5-10.5	3	7.5	--	1	6.3	2.5-10.5	4
6/03-6/05	4.5	4.5- 4.5	2	4.8	4.5- 5.5	3	4.7	4.5- 5.5	5
6/6-6/7&6/22	7.0	4.5- 9.5	2	10.5	3.5-16.5	3	9.1	3.5-16.5	5
SUBTOTAL 5/31-6/22	5.8	2.5-10.5	7	7.6	3.5-16.5	7	6.7	2.5-16.5	14
TOTAL 5/22-6/22	6.9**	2.5-21.5	19	7.3	5.5-16.5	15	7.1	2.5-21.5	34

* Excluding the 21.5 year old male, the average age would be 6.2 years.

** As above, it would be 6.1

Table 6. Average age of bears captured in peripherial and central zones by capture period and sex. Yearlings and newborn cubs are not included.

	Males						Females					
	Periphery			Center			Periphery			Center		
Date	Avg. age	Range	n	Avg. age	Range	n	Avg. age	Range	n	Avg. age	Range	n
5/22-5/24	8.2	2.5-11.5	3	3.5	3.5- 3.5	2	6.8	3.5-11.5	4	5.5	-	1
5/25-5/27	6.5	4.5- 8.5	4	5.5	-	1	10.0	9.5-10.5	2	4.5	-	1
5/28-5/30	21.5	-	1	5.5	-	1	-	-	-	-	-	-
SUBTOTAL 5/22-5/30	9.0*	2.5-21.5	8	4.5	3.5- 5.5	4	7.8	3.5-11.5	6	5.0	4.5- 5.5	2
5/31-6/02	4.5	-	1	6.5	2.5-10.5	2	-	-	-	7.5	-	1
6/03-6/05	4.5	-	1	4.5	-	1	4.5	-	1	5.0	4.5- 5.5	2
6/6-6/7 & 6/22	9.5	-	1	4.5	-	1	16.5	-	1	7.5	3.5-11.5	2
SUBTOTAL 5/31-6/22	6.2	4.5- 9.5	3	5.5	2.5-10.5	4	11.5	4.5-16.5	2	6.5	3.5-11.5	5
TOTALS	8.3**	2.5-21.5	11	5.0	2.5-10.5	8	8.5	3.5-16.5	8	6.1	4.5- 7.5	7

* Excluding the 21.5 year old bear the average age would be 7.3 (2.5-11.5).

** As above, it would be 7.0 (2.5-11.5)

A final method of searching for evidence of immigration was to examine indicated bear density in the periphery compared to the center. Unfortunately, the search intensity was lower in the periphery than in the center so these data are of limited value. Regardless, the data provide no indication of a periphery effect (more captures per unit area in the periphery later relative to earlier, or more captures in the periphery than in the central area) (Table 7).

Because the above analyses indicated that bears were not immigrating into the search area during the capture period, population estimates for bears in this area are based on the assumption that no immigration occurred.

POPULATION ESTIMATES

Data obtained from the transplant operation were used to generate 3 different population estimates: (1) actual numbers removed (minimum population estimate), (2) mark-recapture estimates (for the total adult population and separately for each sex of adults), and (3) estimates based on the 1978 home range size data. Results of these procedures were adjusted to correct for evident or known biases. Together these estimates provide a range within which the true bear population in the search area probably falls.

Minimum Population Estimate

The number of bears actually captured yielded a minimum population estimate of 48. In addition, eight bears were known to have been missed in the removal effort (2 of unknown sex which were observed in June and July, 2 others observed in August, and 4 from 1978 which were not recaptured in 1979, 2 males and 2 females). These bears were individually identified on the basis of pelage, size and the absence of ear flags or other marks applied in 1978. Therefore, the search area population was comprised of at least 56 bears, 86 percent of which were captured. This appears to be a reasonable minimum estimate as some bears which were missed in the capture effort were undoubtedly not observed during subsequent flights with fixed-wing aircraft.

Mark-Recapture Population Estimates

Seven male bears were captured and marked in the removal area in spring 1978 (Spraker and Ballard 1979). Of these, one was 2.5 years old (#210), two were 3.5 (#214 and #217), two were 4.5 (#211 and #218), one was 9.5 (#230), and one was 10.5 years old (#216). All of these males were recaptured in 1979 except for numbers 214 and 217. Bear number 214 was only visually marked, but bear number 217 had a radio collar and was relocated 15 times in the center of the experimental area prior to losing his signal in late June, probably because of a radio malfunction. Either bear may have died or immigrated from the experimental area and would therefore have been unavailable for recapture in 1979, however, three males of younger or equal age in the 1978 sample (#'s 210, 211, and 218) were still present and were recaptured in 1979. For the purpose of this estimate, it was assumed that bear numbers 214 and 217 were alive and present in the experimental area but were missed in the 1979 recapture effort. This assumption is made although number 214 was recaptured in April 1980 some 30 miles south of the experimental area, an indication that he may not have been present in the experimental area during spring 1979. Male number 216 had a functioning radio collar in 1979, was therefore "trap prone," and was correspondingly excluded from the following population calculations.

Five female bears were captured and marked in 1978 (Spraker and Ballard 1979). Of these, one was 2.5 years old (#215), two were 4.5 years old (#209 and #219), and two (#212 and #213) were 10.5 years old. Bear number 213 was accompanied by one apparent yearling bear which was not captured. This yearling was not seen again with number 213 although she was relocated 16 times in the summer of 1978; her collar was still functioning in 1979 when she was recaptured with two newborn cubs. Because of her functioning radio collar, bear number 213 was considered "trap prone" and excluded from the following calculations. Of the remaining females marked in 1978, two were not recaptured in 1979 (#212 and #219). Both were gravid in 1978 and could have had newborn cubs in spring 1979. Female number 212 was observed 17 times and female number 219 was observed 12 times in 1978, all observations were in the center of the experimental area, and in some 1978 observations both bears were in the company of unmarked and presumably male, bears; number 212 was observed mating on 7 June 1978 (Spraker and Ballard in prep.). Although females number 212 and number 219 may have died or emmigrated, it was assumed in the following calculations that both were present in the experimental area in 1979. Female number 209 was also in estrus when captured in 1978; she had no cubs when recaptured in 1979 but was again in estrus.

Excluding the "trap-prone" bears described above, adjusted mark-recapture (Peterson Index) calculations (Richer 1975) were made for each sex on the total number of bears 3.0 years or older captured in 1979 (16 males and 14 females) using the recaptures of bears marked in 1978 (4 of 6 males and 2 of 4 females). This process yielded population estimates of 24 males and 25 females older than 3.0 years (Table 7). By lumping sexes, the index independently provided an estimate of 49 bears older than 3.0 years (Table 7). Because of the low numbers of marked individuals, the numerical confidence intervals (Richer 1975) for these estimates were large (Table 7).

Table 7. Brown bear populations in the Susitna River experimental area as estimated by raw and "corrected" mark-recapture calculations.

	Number captured	Raw Peterson estimate (95% CI)	"Corrected" Peterson estimate
Males older than 3.0 years	17	24(9-96)	24
Females older than 3.0 years	15	25(8-280)	33
Both sexes older than 3.0 years	32	49(23-136)	57
Cubs at 2.5 years	2		2*
Cubs at 1.5 years	12		12
Cubs at 0.5 years	2		12*
TOTALS	48		83

* Probable conservative estimate

These estimates were based on the assumption that the probabilities of capture are equal and remain constant over time. This assumption may be incorrect, but there was no evidence on which to discard it for the male segment estimate. For the female segment estimate, however, there were indications that females with newborn cubs had lower capture probabilities. The only sows with newborn cubs encountered in 1978 and 1979 were number 213, "trap-prone" because of her functioning radio from the previous year, and number 207, an 11-year-old sow from the Hogan Hill study area which was captured with three newborn cubs in 1978. Because the only female captured with newborn cubs in 1979 was "trap-prone," because the two 1978 females which were not recaptured likely had newborn cubs, and because the numbers of females captured with yearling cubs greatly exceeded the number with newborn cubs, we concluded that females with newborn cubs were "trap shy" relative to the capture technique utilized.

The disproportionately low capture rate for females with newborn cubs may be interpreted in at least three ways: 1) these bears have lower capture probabilities because of behavioral patterns which make them more difficult to locate; or 2) capture probabilities were actually equivalent but the parturition rates were lower in 1979 than in 1978 (i.e. the sample was not biased against females with cubs-of-the-year); or 3) sows with newborn cubs dispersed to areas outside the experimental area.

Although available evidence was inadequate to conclusively reject any of these alternatives, number 3 was considered unlikely based upon the 1979 recapture of number 213 inside her 1978 home range. Alternative 2 also appeared unlikely because of the low ratio of females with newborn cubs to females with yearling cubs in 1978, 1979 and 1980. In 1978 only one female (Hogan Hill #207) with newborn cubs was captured compared to five with yearling cubs, an equivalent ratio to that found in the 1979 removal effort (1 female with newborn cubs and 7 with yearlings); females with yearlings were abundant in 1979 even though females with newborn cubs were sparsely represented in 1978 captures. In spring 1980, during brown bear tagging operations on the mid-Susitna River, five females with 1- or 2-year-old cubs were captured but no females with newborn cubs were encountered, further indicating parturition rates were normal in 1979. Therefore, it is most probable that females with newborn cubs were under represented in the 1979 sample relative to their actual occurrence in the population.

Sows with newborn cubs have been reported to remain in the vicinity of their den sites longer than other bears (Glenn and Miller 1980 and Craighead and Craighead 1972). On the Alaska Peninsula, females with newborn cubs were seldom captured in the spring because they tended to remain in mountainous terrain and near protective cover (Glenn and Miller 1980). Observations of female number 207, radio-collared in 1978, accompanied by three newborn cubs indicate that she tended to remain in thickly forested habitats and, consequently, was less frequently observed than other radio-collared bears (Spraker and Ballard in prep.).

In recognition of this capture bias, the aforementioned Peterson estimate for the female segment of the 1979 sample should be adjusted upwards to correct for "trap shyness" of females with newborn cubs. A conservative adjustment was derived by assuming that the number of females with newborn cubs that were actually present was equal to the number of captured females with yearlings (7). This adjustment increased the female segment estimate to 33 bears older than 3.0 years (Table 7). This is probably conservative because it is unlikely that all females with yearlings were captured. However, it should be noted that the Peterson estimate of 25 females was used as the base to which the adjusted number of seven females with newborn cubs was added and that females marked in 1978, but not recaptured in 1979, probably had newborn cubs. The dual usage of probable females with newborn cubs in both the corrected Peterson estimate (25) and in the corrected addition to the Peterson estimate (7), is mathematically questionable.

The number of newborn cubs also required adjustment in a similar manner as the number of females with cubs. Seven females accompanied by 12 yearlings were captured in 1979 yielding an average litter size of 1.7 yearlings/female with yearlings. The assumption that there were at least as many newborn cubs present as yearlings captured, yielded a conservative correction for newborn cubs (Table 7). This was conservative because the highest rate of mortality should occur in a bear's first year of life and because all females with yearlings were probably not captured.

With these adjustments, the "corrected" mark-recapture (Peterson Index) population estimate was 83 bears (Table 7).

<u>Home Range Method Population Estimate</u>

A bear population estimate was also derived from 1978 home range data collected by Spraker and Ballard (in prep.) in the upper Susitna River study area. The home ranges of 7 bears older than 3.0 years which were relocated on 8 or more separate days (Table 4) had substantial overlap (Fig. 1). The total area occupied by these 7 bears was 602 mi^2. Using a simple extrapolation from this figure to the total search area of 1327 mi^2 yielded a population estimate of 15 bears aged 3 or older. This estimate is substantially lower than both the estimate of 57 bears older than 3.0 obtained from the mark-recapture estimate and the 32 bears older than 3.0 actually captured (Table 8).

Table 8. Captures per square mile in peripheral and central portions of the experimental area.*

Date	PERIPHERAL ZONE				CENTRAL ZONE			
	Males (1120 mi^2)		Females (917 mi^2)		Males (207 mi^2)		Females (410 mi^2)	
	No. captures	No. $/mi^2$	No. captures	No. $/mi^2$	No. captures	No. $/mi^2$	No. captures	No. $/mi^3$
5/22-5/30	8	1/140	6	1/153	4	1/52	2	1/205
5/31-6/7&6/22	3	1/373	2	1/459	4	1/52	5	1/82
5/22-6/7&6/22	11	1/102	8	1/115	8	1/26	7	1/59

* Search intensity was lower in the peripheral zone than in the central zone of the removal area. Peripheral zone defined as area within one average home range radius of search area boundary. Cubs-of-the-year and yearlings are not included.

This result was expected since not all of the bears occupying the area illustrated in Fig. 1 were radio-collared. For example, 5 of the bears which were marked in 1978 but were not resighted on 8 or more occasions, were originally captured or were subsequently observed within the 602 mi^2 area illustrated in Fig. 1. In addition to these marked bears, home ranges of unmarked bears doubtless overlapped portions of the 602 mi^2 area inhabited by the 1978 radio-collared bears.

An adjustment can be made on this home range population estimate using the ratio of marked to unmarked bears in the 1979 sample. Of the 32 bears caught, only eight were marked (25%). If the above estimate of 15 bears represents only 25 percent of the actual population older than 3.0 years, then the population would be 60 bears. This corrected estimate was slightly larger than the "corrected" mark-recapture estimate of 57 bears older than 3.0 years.

These calculations demonstrate that density estimates cannot be obtained from home range data unless the proportion of the population for which home range data are available is known.

Population Density Estimates

To arrive at density estimates using the above population estimates, the area occupied by the removed bears must be determined. Some of the bears captured had portions of their home ranges outside of the search area (Fig. 1), suggesting the total area from which bears were removed was larger than the area searched. However, it appeared reasonable to assume that for each such bear captured, another bear which was only partially resident in the search area was not captured. Assuming that bears with home ranges that are not completely included within the search area have a probability (P) of being captured (where [P] is equivalent to the proportion of their home ranges which is within the search area) and a probability of being missed of (1-P), it is reasonable to use just the search area in making density estimates. This assumption was further supported in that search intensity was lower in peripheral portions of the search area than in central portions; consequently bears in peripheral areas had a lower probability of encounter than bears in central locations of the search area. Making this assumption and utilizing the search area (1,327 mi^2) combined with the above estimates of bear populations yielded the bear density estimate shown in Table 9 for each of the above population estimates. The brown bear density estimates for the upper Susitna River are compared with those from other studies in North America in Table 10.

Table 9. Summary of population and density estimates determined by various methods.

	No. actually captured	Captured Plus known to be present	Mark-recapture (uncorrected)	Mark-recapture plus corrections	Home Range (uncorrected)	Home Range (corrected)
Search area population:						
Males (3.0 yr.+)	17	21*	24	24	-	-
Females (3.0 yr.+)	15	19*	25	33	-	-
Both sexes (3.0 yr.+)	32	40	49	57	15	60
Cubs (0.5-2.5 yrs.)	16	16	-	26	-	-
All bears	48	56	-	83	-	-
Search area density - mi^2/bear (km^2/bear):						
Males (3.0 yr+)	78(202)	-	-	55 (143)	-	-
Females (3.0 yr.+)	89(230)	-	-	40 (104)	-	-
Both sexes (3.0 yr.+)	42(108)	33 (86)	27 (70)	23 (60)	85 (220)	22(57)
Cubs (0.5-2.5 yrs.)	83(215)	83 (215)	-	51 (132)	-	-
All bears	28 (72)	24 (62)	-	16 (41)	-	-
Percent of estimate actually captured:						
Bears (3.0 yr.+)	100	80	65	56	213	53
All bears	100	86	-	58	-	-

* The four adult bears of unknown sex were assigned as two males and two females.

Table 10. Reported brown bear densities in North America.

mi^2/bear	km^2/bear	Location	Source
0.6	1.6	Kodiak Island, AK	Troyer and Hensel 1964*
6.0	15.5	Alaska Peninsula, AK	Unpublished data (Glenn, pers. comm.)**
8.2	21.2	Glacier Nat. Park, Montana	Martinka 1974*
11.0	28.5	Glacier Nat. Park, B.C.	Mundy and Flook 1973*
9-11	23-27	SW Yukon Territory	Pearson 1975*
16-24	41-62	Upper Susitna R., AK	This study
88(16-300)***	288(42-780)***	Western Brooks Range (NPR-A), AK	Reynolds and Hechtel 1980
100	260	Eastern Brooks Range, AK	Reynolds 1976

* Taken from Pearson 1975.

** Data refer to a 1800 mi^2 intensively studied area of the central Alaska Peninsula.

*** Mean is for the whole of the Nat. Pet. Reserve, Ak, the range represents values for different habitat types in this reserve where the highest density occurred in an intensively studied experimental area.

Biomass Estimates

The 38 bears captured in 1978 by Spraker and Ballard (1979) combined with the 48 bears captured in this study (8 of which were duplicates, 1 year older) yields 86 bears from the Nelchina basin of known sex, age, and weight (48 males and 38 females) (Table 11). These data, combined with the above estimates of population density, permit a preliminary approximation of bear biomass in this region of interior Alaska.

These biomass estimates are given in Table 12 for the corrected minimum population estimate (201 kg/100 km^2, 1,150 lbs/100 mi^2) and for the "corrected" mark-recapture estimate (267 kg/100 km^2, 1,514 lbs/100 mi^2). Summing the weights of the individual bears removed in 1979 (Table 2) yields a total of 5,286 kg (11,653 lbs). The biomass actually removed from the study area was, correspondingly, 154 kg/100 km^2 (879 lbs/100 mi^2) or 58 percent of the "corrected" mark-recapture biomass estimate.

DISCUSSION

Population and Density Estimates

In the preceding sections, five different brown bear population estimates and corresponding density estimates (Table 9) were derived from data obtained from intensive capture efforts in spring 1979 and from data collected in spring 1978 by Spraker and Ballard (1979 and in prep.). Except for the uncorrected mark-recapture estimate, confidence intervals could not be placed on these estimates, but subjective evaluations of their relative accuracies are possible.

No evidence supporting immigration into the search area was found. The area utilized in making density estimates was the actual area searched for bears which may be an underestimate of the actual area involved (yielding, if true, overestimates of density), however, this procedure was justified on the basis of the search procedure utilized.

The lowest population estimate (15 bears older than 3.0 years) was derived by extrapolation from home range data collected in 1978 (Spraker and Ballard in prep.). This estimate was less than one-half the number of bears actually captured and is, obviously, too low. The highest estimate (60 bears older than 3.0 years) was derived by extrapolation from the home range estimate based on the percentage of the bears captured in 1979 (32) which were marked (8 or 25%). This estimate can be criticized since the 32 bears were from the whole search area but the marked bears were concentrated in the center of the search area. The actual percentage of marked bears in the search area population was probably less than 25 percent, if so, the estimate of 60 would be inflated, correspondingly.

Assuming lack of immigration, data on the number of bears actually captured plus the number known to have been missed in the search area provide a population estimate of 40 bears older than 3.0 years (56 bears of all ages). This estimate is considered a valid minimum population estimate.

Estimates obtained using the mark-recapture (Peterson Index) method are subject to a number of potential sources of error. The include: low numbers of marked animals in the population, probable non-random distribution of marked animals in the population, untestable assumptions about the survival of the 1978 marked animals in this population to the spring of 1979, nonuniform distribution of recapture efforts, and probable unequal probabilities of capture of some sex and age groups (demonstrably unequal for females with newborn cubs). Essentially, none of the assumptions required to apply mark-recapture techniques in a mathematically correct way can be demonstrated to be valid. Regardless, the technique was applied to the data available and the results provide an estimate which is only nine bears (older than 3.0) more than the above minimum estimate, an increase of 23 percent. When this estimate is "corrected" for bears thought to have been missed because of unequal probabilities of capture, the results indicate a population (57 bears older than 3.0) which is 50 percent larger than the corrected minimum estimate.

It is difficult to objectively evaluate the mark-recapture density estimate. An apparent problem with the minimum estimates and with the uncorrected mark-recapture estimate is the unbalanced sex ratio in favor of males (bears older than 3.0). In an exploited population, where hunters tend to selectively harvest males (because males range greater distances and females accompanied by cubs are legally protected), a population with a sex ratio skewed towards females would be expected (Bunnell and Tate, n.d.). Harvest data from GMU 13 reveal that males are more commonly taken than females (Table 13). This lends credence to the "corrected" mark-recapture estimate which has a sex ratio of 73 males to 100 females compared with the actual capture ratio of 113 males to 100 females (includes only bears older than 3.0 years). The sex ratio of the "corrected" mark-recapture estimate seems intuitively reasonable. The "corrected" mark-recapture estimate was conservatively calculated for females with newborn cubs, newborn cubs, yearlings and 2.5 year-old bears.

The corrected minimum population estimate was regarded as a realistic minimum value and the "corrected" mark-recapture population estimate as the best available approximation of the true value. The density estimate calculated

Table 11. Average weights of spring brown bears captured in 1978 (Spraker and Ballard, 1979, n=38) and 1979 (n=48) Susitna River Studies, by sex and age classes.

	MALES			FEMALES		
Age	Avg. Wt. (kg.)	Range	(n)	Avg. Wt. (kg.)	Range	(n)
0.5	5	-	3	5	-	1
1.5	40	21-63	8	38	21-45	6
2.5	87	59-140	5	74	52-95	3
3.5	110	93-139	5	87	76-97	2
4.5	156	100-259	9	89	73-101	5
5.5	181	115-236	3	128	106-148	5
6.0+	255	226-289	15	116	86-170	16

Table 12. Brown bear biomass estimates based on average measured weights for each sex and age class and estimated population numbers.

				Biomass					
				No. actually caught plus No. known to be present			Mark-recapture plus corrections		
		Avg. wt.							
Sex/age class	n	kg	lb	$\hat{N}$	$kg/100km^2$	$lb/100mi^2$	$\hat{N}$	$kg/100km^2$	$lb/100mi^2$
Males (3.0+)	32	198	437	21*	121	692	24	139	790
Females (3.0+)	28	111	245	19*	61	351	33	107	609
Both sexes (2.5 yrs.)	8	82	181	2	5	27	2	5	27
Both sexes (1.5 yrs.)	14	39	86	12	14	78	12	14	78
Both sexes (0.5 yrs.)	4	5	11	2	0.3	2	12	2	10
All bears	86				201	1150		267	1514

* The four adult bears of unknown sex were assigned as two males and two females.

Table 13. Composition of known brown bear harvests in Alaska's Game Management Unit 13, 1970-1979. Only fall seasons have been held in this period.

						Average age		
Year	No. males	(%) males	No. females	No. unknown	Totals	Males	Females	Both sexes
1970	20	(69)	9	1	30	4.9	5.4	5.0
1971	32	(48)	35	6	73	5.0	7.2	6.3
1972	29	(58)	21	0	50	6.9	5.4	6.3
1973	29	(63)	17	2	48	6.8	7.2	6.8
1974	43	(57)	33	1	77	6.3	7.2	6.6
1975	45	(58)	33	6	84	7.6	7.8	7.5
1976	29	(52)	27	6	62	7.0	5.1	6.3
1977*	32	(74)	11	-	43	6.0	7.1	6.2
1978*	39	(61)	25	2	66	6.0	6.8	6.3
1978*	45	(57)	34	-	79	6.3	7.5	6.8
Totals	343	(58)	245	24	612	6.4	6.8	6.6

* $25.00 resident tag fee in effect.

from these population estimates were considered, correspondingly, to be realistic minimums and best available approximations of the actual bear density.

Population Structure, Productivity and Sustainable Harvests

The sex ratios and age structure of the bears captured in the upper Susitna River are compared with equivalent data from the National Petroleum Reserve-Alaska (NPR-A) (Reynolds and Hechtel 1980) in Table 14. Bears captured in the upper Susitna were younger and there were proportionally more males than in the NPR-A. The estimated brown bear densities in these study areas were similar (Table 10).

For both sexes, the age structure of the GMU 13 brown bear harvest (Table 13) is only slightly older than the mean ages of all captured bears older than 1.0 years (Table 14). This suggests that hunters in GMU 13 are not selecting for older bears but tend to take animals as encountered. Relative to the NPR-A study area, characterized as having "very low" hunting pressure by Reynolds and Hechtel (1980), the upper Susitna bears were younger in all sex and lumped age classes (Table 14). This suggests that relative to the NPR-A population, the upper Susitna bears may be heavily exploited. It is also likely, however, that at least some of these age structure differences are attributable to the fact that the Susitna population is presently expanding from a formerly reduced level.

Extrapolating the upper Susitna River minimum and "corrected" mark-recapture density estimates (Table 9) to the whole of GMU 13 (22,857 mi^2) would indicate a GMU 13 population of 940-1,430 bears. The average harvest of 61 bears from GMU 13 (Table 13), correspondingly, represents 4-6 percent of the extrapolated population per year. Assuming an average age at first reproduction of 5 years and an average natality rate of 0.66 (litter size-estimated 2 divided by years between litters-estimated 3), the model presented by Bunnell and Tait (n.d.) suggests that the maximum sustainable mortality (all deaths) of this population is currently between 12 and 15 percent per year. Sustainable mortality levels and productivity parameters are not necessarily constant or density independent, but are useful figures in rough approximations of acceptable harvest intensity.

Yearling bears represented 25 percent of all bears captured and 14 percent of the "corrected" mark-recapture estimate (Table 7). If there is an average mortality in the first year of life of 20 percent, this translates into an overall population mortality of 3-5 percent caused by natural cub mortalities alone. Subtracting this from the maximal sustained mortality as calculated above suggests that all cub mortalities to bears other than newborn cubs in

Table 14. A comparison of the population structure of brown bears captured in the upper Susitna River with the National Petroleum Reserve-Alaska. Data for NPR-A from Reynolds and Hechtel (1980).

	Average age (sample size)							
	Males		Females		Both sexes		% males	
Age	Susitna*	NPA-A	Susitna*	NPR-A	Susitna*	NPR-A	Susitna*	NPR-A
0.5+	4.9(31)	7.3(38)	6.4(21)	9.3(49)	5.5(52)	8.4(87)	--	--
1.0+	5.2(29)	7.8(35)	6.4(21)	9.5(48)	5.7(50)	8.8(83)	58	42
2.0+	6.6(21)	8.2(33)	7.5(17)	10.5(43)	7.0(38)	9.5(76)	55	43
3.0+	7.0(19)	9.4(27)	7.5(17)	12.0(36)	7.3(36)	10.9(63)	53	43
4.0+	7.7(16)	9.9(25)	8.0(15)	12.8(33)	7.9(31)	11.5(58)	52	43
5.0+	10.2(9)	10.5(24)	8.9(12)	13.3(31)	9.5(21)	11.9(55)	43	44
6.0+	11.5(7)	11.4(19)	10.6(8)	13.8(29)	11.0(15)	12.9(48)	47	40
7.0+	11.5(7)	12.7(15)	10.6(7)	14.1(28)	11.0(14)	13.6(43)	50	35
10.0+	13.5(4)	16.2(9)	12.3(5)	17.4(17)	12.8(9)	17.0(26)	44	35

* Data for the Susitna River includes all bears captured in 1979 plus four bears captured in 1978 but not recaptured in 1979; one year was added to the 1978 ages of these four bears in making the above calculations.

this population should not exceed 8-12 percent/year. Since estimated harvest mortalities alone represent 4-6 percent of the population as calculated above, these preliminary calculations suggest that brown bear harvests in GMU 13 cannot be greatly increased without the risk of exceeding sustainable levels of harvest. Certainly, if brown bear harvests were doubled from historical levels over a period of years, managers should remain very alert to evidence of overexploitation. Currently, inadequate data are available to accurately estimate all the parameters in the above model, nevertheless, it is appropriate to illustrate, on the basis of extrapolations from available data, that caution should be exercised in any major expansion of brown bear harvests in GMU 13. Such expansion is exactly what is being proposed by some segments of the public in response to evidence presented by Ballard et al. (1980) that brown bears are significant predators of moose calves. These proposals are being offered regardless of the absence of evidence that any bear reduction brought about by sport hunting would actually result in either increased calf survival or ultimately more adult moose.

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