ALASKA DEPARTMENT OF FISH AND GAME

JUNEAU, ALASKA

STATE OF ALASKA
Bill Sheffield, Governor

DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner

DIVISION OF GAME
W. Lewis Pamplin, Jr., Director
Steven R. Peterson, Research Chief

KENAI PENINSULA MOOSE CALF MORTALITY STUDY

By
Albert W. Franzmann,
Charles C. Schwartz,
and
David C. Johnson

Progress Report
Federal Aid in Wildlife Restoration
Project W-22-2, Job 1.33R

(Printed June 1984)

PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperator: Ted Spraker and David A. Holdermann, ADF&G; and Kenai Air Service

Project No.: W-22-2 Project Title: Big Game Investigations

Job No.: 1.33R Job Title: Kenai Peninsula Moose Calf Mortality Study

Period Covered: 1 July 1982 through 30 June 1983 (includes limited data during May-June 1982 as well as July-November 1983)

SUMMARY

During spring 1982 and 1983, mortality mode expandable radio collars were placed on 37 and 42 moose (Alces alces) calves, respectively. Three calves were abandoned by their cows within 24 hours of capture in 1982; 1 was abandoned in 1983; and 1 transmitter ceased functioning resulting in 74 calves to monitor. Predators killed 33 of 74 (45%) bonded moose calves, mostly within 1 month of age. Black bears (Ursus americanus) killed 26 calves (35%), brown bears (Ursus arctos) killed 2 (3%), a brown or black bear killed 2 (3%), wolves (Canis lupus) killed 1 (1%), and unknown predation accounted for 2 mortalities (3%). Three calves died as result of natural abandonment (4%), 1 calf drowned (1%), and 1 died from causes unknown (1%). Total mortality of bonded calves was 51% (38). These mortality data were compared with calf mortality studies in the 1947 Kenai Peninsula burn and their similarity discussed. Sex ratios of captured calves favored males (47 of 74, 65%). Predators killed 70% male calves (23 of 33), indicating no significant predator selection by sex. Differential sex ratios were discussed relative to nutritional influences. The twinning rate for moose cows was 70% (71 of 102) for all cows observed with calves. The proportion of twins monitored was also 70% (52 of 74). A cow with triplets was excluded from the count. This rate is the highest we have seen reported for North American moose. There was a slightly higher proportion of twin calves killed by black bears (77%) and by all predators (73%) than in the actual and monitored populations. Habitat differences between the 1947 and 1969 burns generated a hypothesis regarding differences in calf predation between the areas prior to the study. The rejection of the hypothesis was discussed.

Key words: black bear, habitat, Kenai Peninsula, moose calves, mortality, 1969 burn, 1947 burn, predation, radio transmitter, sex ratios, twinning rate.

CONTENTS

BACKGROUND

Background information regarding the need to identify causes of moose (Alces alces) calf mortality was outlined (Franzmann and Peterson 1978, Franzmann and Schwartz 1979, Franzmann et al. 1980) Black bears (Ursus americanus) were a major cause of moose calf mortality during the 1st 6 weeks following birth in the Kenai Peninsula, Alaska 1947 burn area where 34% of the radio-collared calves were killed by this predator (Franzmann and Schwartz 1979, Franzmann et al. 1980). Black bear ecology studies in the 1947 Kenai Peninsula burn indicate that the area has a high density (3.9 to 7.5 bears/km^2) of black bears (Schwartz et al. 1983a). Another finding from these studies was that black bears generally avoided nontimbered areas (Schwartz and Franzmann 1983).

From these studies in the 1947 burn, a hypothesis was developed that stated black bear density was keyed to the food resource and this food resource was more abundant in older successional stages of forest. If this hypothesis were true, then bear numbers should be less in recently burned forests. The 1969 burn lies to the west of the 1947 burn separated by an unburned area of forest (Fig. 1). Descriptions of the areas appear in LeResche and Davis (1973), Oldemeyer et al. (1977), and Schwartz and Franzmann (1983). If the hypothesis were true, then stage of plant succession in the 1947 burn (30-year-old forest) should have a high black bear density at the time of these studies (1977, 1978). An important assumption in this study is that bear density is important in the high rate of black bear predation on moose calves. Areas devoid of overstory cover, or in an earlier successional stage (such as the 1969 burn), would not favor black bears to the same degree, and moose calf predation rates from black bears should be significantly reduced. This study was designed to test this hypothesis and provide information on both black bear and moose ecology that should assist managers in decision making on certain management and habitat manipulation programs that may favor 1 species over the other.

OBJECTIVE

To determine the extent and causes of moose calf mortality in the 1969 burn on the Kenai Peninsula.

PROCEDURES

This study was conducted in the 33,500-ha 1969 burn located in the central lowlands of the Kenai Peninsula, Alaska (Fig. 1). Description of the physical aspects, vegetation, soils, and specific habitats of the Kenai Peninsula have been widely published (Spencer and Hakala 1964, Stephens 1967, Rausch and Bishop 1968, LeResche and Davis 1973, Bishop and Rausch 1974, LeResche et al. 1974, Oldemeyer et al. 1977, Sigman 1977, Bailey et al. 1978, Schwartz and Franzmann 1980, Oldemeyer 1981).

Calves were located by visual search from both fixed-wing aircraft (Piper Super Cub) and helicopter (Bell Jet Ranger) during the peak calving period (late May-early June), and captured when less than 72 hours old, generally within 24 hours of birth. Calves were captured by using the helicopter to force the cow away from the calf and landing nearby to allow the crew to disembark and catch the calf. The calf was sexed, and a radio transmitter applied. Initially, a 50-g radio transmitter equipped with a 27-cm antenna (Model S2BSETT, Telonics, Mesa, Ariz.) was attached to the ear. This was replaced with an expandable neck collar made from Ace bandage material in which a similar radio transmitter (Model SZB5, Telonics, Mesa, Ariz.) was sewn in place (Schwartz et al. 1983b). In addition, some recovered expandable neck collars from a previous study were used in 1982 (Franzmann and Schwartz 1978).

The replacement of ear tag transmitters was made due to problems associated with the time delay in attaching the transmitter and the weight of the transmitter pulling on the calf's ear. Previous studies (Ballard et al. 1979, Franzmann and Schwartz 1979) indicated that the time involved to collect physiologic data from the calf contributed to calf abandonment by the cow. Therefore, we did not handle the calf for additional data and discontinued use of the ear tag transmitter. The Ace bandage style expandable neck collar was constructed as outlined by Schwartz et al. (1982b). As soon as the collar was placed on the calf, the crew departed via the helicopter. Prior to leaving the area, we made sure the cow returned to the calf.

The transmitter pulsed at approximately 35 beats/min (slow mode) while the calf moved, and when movement ceased for 4 hours, the pulse doubled (fast on mortality mode). Flights were made daily over the study area (until 20 June in 1982, and 17 June in 1983) with fixed-wing aircraft (Piper Super Cub) equipped with H antennas (Telonics, Mesa, Ariz.) mounted on the struts. Flights were made every other day until 1 July in 1982 and 11 July in 1983, then twice per week until 1 August, both years. Thereafter, weekly flights occurred until early October.

When we detected a fast or mortality signal, the area was searched from the air until we located the calf and marked it on a map. When the monitoring flight was completed, a helicopter (Bell Jet Ranger) was used to go to the site and determine cause of mortality. The criteria used to determine cause of mortality were outlined by Franzmann and Bailey (1977), Franzmann and Schwartz (1978, 1979), and Franzmann and Peterson (1978).

RESULTS AND DISCUSSION

Bonded Calf Mortality

During 1982, mortality mode radio transmitters were placed on 37 calves (19 on 26 May, 16 on 27 May, and 2 on 1 June) (Table 1). During 1983, 42 calves were radio-collared (17 on 23 May, 18 on 25 May, and 7 on 27 May) (Table 2). Three calves were abandoned by their cows within 24 hours of capture in 1982, and 1 calf was abandoned in 1983. One transmitter ceased functioning on 5 June 1983, resulting in 74 bonded calves to monitor. The proportion of abandonment (5%) was a considerable improvement over previous studies when the calf was processed for physiologic data (20%, Ballard et al. 1979) and when the cow was immobilized and the calf then processed (29%, Franzmann and Schwartz 1979) (see Capture and Natural Abandonment section of this report). During this study, the calf was sexed and the collar placed on the calf as quickly as possible.

Predators killed 33 of 74 (45%) bonded, radio-collared moose calves in the 1969 Kenai Peninsula burn. Black bears killed 26 calves (35%), brown bears (_Ursus arctos_) killed 2 (3%), wolves (_Canis lupus_) killed 1 (1%), and unknown predation accounted for 2 (3%). Three calves died as result of natural abandonment (4%), 1 calf drowned (1%), and 1 died from causes unknown (1%). Total mortality of bonded calves was 38 (51%) (Table 3).

During 1982, all mortalities occurred by 24 June. However, due to failure of 4 transmitters as of 19 July, 24 July, 5 August, and 17 August, we have a gap in our data. Two of 3 ear tag transmitters sloughed out of the ear and fell off--1 on 24 July, the other on 23 September (Table 1). Fortunately, the failed transmitters and those lost remained on the calves through the high mortality period. We assumed that calves that lost collars after 1 July lived through the remainder of the study. The calves were monitored until 4 October 1982, and 10 transmitters were still functioning at that time.

During 1983, mortalities were recorded through 18 July. All but 3 mortalities occurred during the 1st month of life. We monitored the calves until 18 October. One transmitter failed on 5 June, and another failure occurred 25 June. The latter calf was assumed to have survived, but the 5 June failure was too early and we did not use that calf in the study for any mortality assessment. By mid-August, 4 transmitters separated from their collars; by 18 October, 8 additional transmitters had dropped. Again, we were fortunate that nearly all transmitter losses occurred after the peak mortality period.

We plotted mortalities for the 1st 30 days from each segment of our calf mortality studies on the Kenai Peninsula (1977 and 1978 in the 1947 burn; 1982 and 1983 in the 1969 burn) (Fig. 2). The patterns are similar in that steady losses occurred for the 1st 30 days and then essentially ceased for the remainder of the summer.

Visual coverage of the study area while monitoring these calves and while monitoring black bears for a concurrent study in the area provided observations of 7 nonradioed calves being eaten by black bears (4 in 1982, 3 in 1983).

Radio signals (2,180) were monitored during this study (1,049 in 1982, 1,131 in 1983), and 453 aerial sighting of calves with radio transmitters were made (303 in 1982, 154 in 1983). We were able to get to the calf mortality sites (N = 38) in less than 24 hours on 24 calves (63%), and on site of 4 calves while bears were still feeding (11%). Of the 10 remaining mortalities, we were at 6 within 48 hours (16%) and the other 4 within 72 hours (11%). We believe getting to the sites this quickly assured us of an accurate method to assess moose calf mortality. This has been concluded from other studies as well (Franzmann and Schwartz 1979; Ballard et al. 1979, 1981; Franzmann et al. 1980).

Mortality assessments were made on a case by case basis. Each mortality had its own characteristics and circumstances. Case histories of calves monitored in reference to the mortality site will demonstrate this and provide a basis for our judgments (Appendix A). Characteristics of moose calf kills by different predators have been described (Franzmann and Schwartz 1979, Ballard et al. 1979). The inverted hide, legs intact and extruding from hide mass, and an intact head is often used to describe the calf kills associated with black bears; it has become known as the "typical" kill scene for black bears (Fig. 3).

Sex Ratios of Calves Captured

Sixty-eight percent of calves captured in 1982 were males (23 of 34), and in 1983 the male percentage was 60 (24 of 40). The mean for both years was 64% (47 of 74). In 1982, predators killed 67% males (10 of 15) and in 1983, 72% (13 of 18). For both years, predators killed 70% males (23 of 33) (Table 4). Calf mortality studies in the 1947 burn during 1977 and 1978 (Franzmann et al. 1980) showed sex ratios in favor of male calves (62%, 29 of 47) (Table 4). The sex ratios from all the calf mortality studies on the Kenai Peninsula have ranged from 60 to 68% males. Combined sex ratios provide a 63% (76 of 121) male component in the calf population (Table 4). The predation rate on sexes of calves was similar (66%, 37 of 56) to their component in the population, so there did not appear to be a sex bias in predation.

Sex ratios have been reported to favor males when white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) are in a poor nutritional state (Verme 1965, 1969; Robinette et al. 1977; McCullough 1979; Verme and Ozoga 1981). Other reports contradict these findings (Mansell 1974, Woolf and Harder 1979). Verme (1983:581) reviewed these and other reports on sex ratios for the genus *Odocoileus* and concluded the following: "an excess of male fawns would be expected (1) where the bulk of the breeding stock consisted of pubertal doe fawns and yearlings, (2) in herds of low density or scattered distribution, (3) among animals nutritionally deprived during the rut, or (4) in instances of extreme density leading to intraspecific strife. Conversely, more female births would prevail (1) in stable or increasing populations on good range, or alternatively, (2) where seasonal food restrictions caused infertility or heavy neonatal mortality leading to compensatory fecundity in the ensuing breeding season." These conclusions are based on deer data, but it would seem reasonable that similar responses would be expected from another cervid when the basis for the discussion is related to population dynamics.

In another section of this report (Habitat Differences and Calf Mortality), we have outlined the differences between the 1947 and 1969 burn habitats. It is apparent that the 1969 burn is highly productive for moose and this habitat has been available and utilized annually for the last 4 years (mild snowfall each winter). The population is on excellent range and is stable or growing. There have been no seasonal food restrictions, and there is no indication of a low density or an extremely high density population. Using Verme's criteria, we should expect a higher proportion of females in the population, yet we have found the opposite (males 64%) (Table 4).

Sex ratios in the 1947 burn also favored male calves (62%), and in this situation, we believe the criteria outlined by Verme (1983) are appropriate. The herd was at low density and on poor range (Oldemeyer et al. 1977).

Perhaps we should not attempt to extrapolate from deer to moose on sex ratios, but since we have, we can only conclude either that the criteria for deer do not apply to moose, or the criteria are incomplete.

Capture and Natural Abandonment

The 3 calves (2 males and 1 female) that were abandoned during capture in 1982 were each from a set of twins, but the 1 calf abandoned in 1983 was a single male calf. These calves did not rebond with their mothers, 3 died in 3 days and 1 in 4 days. The calves were undisturbed for several days thereafter as was reported in other studies (Franzmann and Schwartz 1979; Ballard et al. 1979, 1981; Franzmann et al. 1980). The undisturbed carcasses of abandoned calves were useful to mortality information, since they helped negate the idea that the calves we monitored died from other causes and then predators fed on them. This certainly was possible, but when we arrived at the mortality scene as soon as we have reported, it does not seem probable that it occurs very often, if at all.

Capture-related abandonment was 8% (3 of 39) in 1982 and 2% in 1983 (1 of 41). During the 1947 burn studies, we experienced 38% abandonment when we processed (blood, hair, measurements, and weight) of the cow and calf, and 11% when we processed only the calf. When the calf was not processed, (except sexing), the abandonment dropped to 7% (Franzmann and Schwartz 1979). The data from the 1947 Kenai Peninsula burn was combined with abandonment data from calf mortality studies in the Nelchina Basin; this information indicates abandonment was 8% when the calf was just captured and sexed verses 13% when the calf was captured and additional condition data obtained (Ballard et al. 1979).

It is obvious that immobilizing the cow while capturing the calf should not be recommended, but the differences in abandonment between capturing the calf and just obtaining the sex or also getting weight, measurements, and blood may require a judgment based upon study objectives. The 4-5% increase in abandonment may be acceptable in some instances.

During the calf mortality study in 1977 when we placed visual collars on the cow processed with the calf, we witnessed an adoption of a radio-collared calf that was abandoned by another cow (Franzmann and Bailey 1977). No natural abandonment was detected. During the 1969 burn studies, 3 of 74 (4%) of bonded calves monitored died as a result of natural abandonment (Table 3). Natural abandonment mortality was higher than any other non-predator cause of mortality. In 1982, 2 female calves that rebonded after capture were later abandoned by the cow. One was abandoned on 3 June and the other on 7 June, 7 and 11 days after capture, respectively. Both calves were visually located several times after it was determined that they rebonded with their mothers. In 1983, we witnessed an additional natural abandonment of a bonded male calf 7 days after capture. We do not believe that capture was a contributing factor in these 3 cases and concluded that we had witnessed natural abandonment. We can only speculate as to cause but believe abandonment was associated with predation attempts that forced the movement of the cow and calf and subsequently separated them.

Twinning Rates

Findings relative to twinning rates and their implication between the 1947 and 1969 burns on the Kenai Peninsula were reported elsewhere (Appendix B). One aspect of twinning, which has not been discussed and which relates to predation, is the concept of disparity in predation rates between single and twin births. We were able to radio-collar calves in proportion to their classification as single or twin in the population (69% in population, 70% of captured calves were twins [Table 5]).

The twinning rate in the population during 1982 was 66% (35 of 53 cows had twins) (Table 5). Of the 11 calves killed by black bears, 8 were twins (73%); of 15 calves killed by all predators, 10 were twins (67%); and of the total 18 calf mortalities, 13 were twins (72%) (Table 6). We monitored 34 calves in 1982 and 24 were twins (71%) (Table 6). The twinning rate in the population in 1983 was 72% (36 of 50 cows had twins) (Table 5). Of the 15 calves killed by black bears, 12 were twins (80%); of 18 calves killed by all predators, 14 were twins (78%); and of the total 20 calf mortalities, 14 were twins (70%) (Table 6). We monitored 40 calves in 1983 and 28 (70%) were twins (Table 6). Combined years' mortality for twins was 77% by black bears (20 of 26), 73% by all predators (24 of 33), and 71% for all causes of mortality (27 of 38) (Table 6). Total mortality for twins (71%) and proportion of twins monitored (70%) were nearly the same.

However, there was a slightly higher proportion of twin calves killed by black bears (77%) and by all predators (73%) than in the monitored population. This was elevated most by data from 1983 (black bears killed 80% twins; total predators killed 78% twins). We concluded from our 1st year's data (1982) that there was no differential predation mortality between single and twin calves. However, data from 1983 indicates there may be a higher susceptibility of twin calves to predation.

The above calculations were based on the assumption that each calf was equally susceptible to predation at the onset of the study. When only 1 calf of a twin pair was monitored, it was considered a twin calf as were the calves of a twin when both were radio-collared. We therefore separated these categories and made mortality comparisons between twin calves when both were monitored and we also compared these to single calves monitored (Table 7). Breaking down these data did not clarify the issue. All we can conclude is that our sample size for a single monitored twin was too small and that it appears that black bears were more effective predators on twin calves (both monitored) than on single calves (45% black bears on twins, 29% black bears on singles). This influenced the total predation percentage as well. Total mortality between single calves and twins (both monitored) was similar (twins 55%, singles 52%).

Habitat and Black Bear Predation

The hypothesis we developed in planning this study stated black bear density was keyed to the food resource and these food resources were more abundant in older successional stages of forest. If this hypothesis were true, then bear numbers should be less in recently burned forests. We assumed that bear density and predation rates on moose calves were related: Areas devoid of overstory cover, or in an earlier successionals stage (such as the 1969 burn), would not favor black bears to the degree of an older successional stage (such as the 1947 burn), and moose calf predation rates from black bears should be significantly reduced.

We reject our hypothesis based upon differences in black bear predation rates on moose calves (Table 8). Black bear predation in the 1947 burn on radio-collared moose calves was 34%, and it was 35% in the 1969 burn. There was no difference. Total predator mortality was 49% in the 1947 burn and 45% in the 1969 burn. (Table 8).

Several primary reasons may be presented that negated the acceptance of our hypothesis: (1) greater moose calf density in the 1969 burn; (2) more usable mature forest in island stands in the 1969 burn for bears; and (3) high density of black bears in the 1969 burn. Each factor will be discussed in light of our present information base. Factors that we cannot assess from our present information base are those related to black bear predator strategy differences. The black bear is a very adaptable animal, and it is not inconceivable that predator strategy could vary in different habitats. How the bears use the available cover and to what extent their home ranges and activity centers correspond to available moose calves are factors requiring long-term black bear ecology studies.

Moose calf density between the 1947 and 1969 burns was significantly different. This was evident from our experiences in capturing calves in the 2 areas. In the 1947 burn, we had difficulty locating calves to collar in the traditional Moose River Flats calving area and had to expand our study area to include the surrounding area and the Willow Lake rehabilitated area (Franzmann and Schwartz 1979). No problems were associated with locating moose calves in the 1969 burn. We were able to capture 20 calves in 2½ hours in the 1969 burn and less than 10 calves in the 1947 burn. A higher twinning rate in the 1969 burn definitely favored higher moose calf density (see Twinning Rate's section of this report).

The greater intensity of the 1969 burn resulted in fewer "islands" of unburned forest than in the "cooler" 1947 burn (46% of area inside the 1947 burn was unburned compared to 7% in the 1969 burn, Bangs et al. 1983). However, the remaining forest stands in the 1969 burn provided adequate edge, overstory, and cover to permit black bears to effectively utilize the entire area to prey on moose calves. Moose calves killed by black bears were all within 0.8 km of mature forest except 1 (1.6 km from forest). Three kills were in mature forest, 5 at the edge of forest, 6 were 0.2 km from forest, 3 at 0.3 km, 2 at 0.4 km, 2 at 0.5 km, 1 at 0.6 km, and 3 at 0.8 km from forest (Table 9). The farthest any mortalities were recorded from mature forest was 3 km, and that mortality was attributed to a brown bear. Preliminary findings from black bear studies in the 1969 burn indicate that black bear movements and activities are closely associated with mature forest. The distribution of black bear kills in or in close proximity to the forests reflected this activity. Density of black bears in the 1947 burn ranged from 3.9 to 7.5 bears/km^2 (Schwartz et al. 1983a). Black bear studies are currently underway in the 1969 burn (Schwartz et al. 1983b), and density estimates are not yet available.

The 3 factors listed (high moose calf density, islands of mature forest in the burn, and high black bear density), which provided the basis for rejecting our hypothesis, were each factors of potentially great impact on a predator/prey relationship. In the 1969 burn, all 3 factors were working to favor high predation rates of black bears on moose calves.

LITERATURE CITED

Bailey, T. N., A. W. Franzmann, P. D. Arneson, and J. D. Davis. 1978. Kenai Peninsula moose population identity study. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-3 through 9 . Job 1.7R. Juneau. 84pp.

Ballard, W. B., T. H. Spraker, and K. P. Taylor. 1981. Causes of neonatal moose calf mortality in southcentral Alaska. J. Wildl. Manage. 45:335-342.

__________, A. W. Franzmann, K. P. Taylor, T. Spraker, C. C. Schwartz, and R. O. Peterson. 1979. Comparison of techniques utilized to determine moose calf mortality in Alaska. Proc. North Am. Moose Conf. Workshop. 15:362-387.

Bangs, E. E., T. N. Bailey, M. F. Portner, and R. A. Richey. 1983. Moose movement and distribution in response to winter seismological exploration on the Kenai National Wildlife Refuge. Kenai Natl. Wildl. Refuge Prog. Rep. 7. 2pp.

Bishop, R. H., and R. A. Rausch. 1974. Moose population fluctuations in Alaska, 1950-1972. Nat. Can. 101:559-593.

Franzmann, A. W., and T. N. Bailey. 1977. Moose Research Center report. Alaska Dep. Fish and Game. Fed. Aid in Wild. Rest. Prog. Rep. Proj. W-17-9, Job 1.14R and 1.21R. Juneau. 76pp.

__________, and R. O. Peterson. 1978. Moose calf mortality assessment. Proc. North Am. Moose Conf. Workshop. 14:247-269.

__________, and C. C. Schwartz. 1978. Moose calf mortality, Kenai Peninsula. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-17-10, Job 1.24R. Juneau. 32pp.

__________, and __________. 1979. Kenai Peninsula moose calf mortality study. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-10 and W-17-11. Job 1.24R. Juneau. 18pp.

__________, __________, and R. O. Peterson. 1980. Moose calf mortality in summer on the Kenai Peninsula, Alaska. J. Wildl. Manage. 44:764-768.

LeResche, R. E., and J. L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 37:279-287.

__________, R. H. Bishop, and J. W. Coady. 1974. Distribution and habitat of moose in Alaska. Nat. Can. 101:143-173.

Mansell, W. D. 1974. Productivity of white-tailed deer in the Bruce Peninsula, Ontario. J. Wildl. Manage. 38:808-814.

McCullough, D. R. 1979. The George Reserve deer herd: population ecology of a K-selected species. Univ. Michigan Press, Ann Arbor. 271pp.

Oldemeyer, J. L. 1981. Estimation of paper birch production and utilization and an evaluation of its response to browsing. Ph.D. Thesis. Pennsylvania State Univ., College Park. 58pp.

__________, A. W. Franzmann, A. L. Brundage, P. D. Arneson, and A. Flynn. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41:533-542.

Rausch, R. A., and R. H. Bishop. 1968. Report on moose studies. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-15-2 and W-15-3. Juneau. 263pp.

Robinette, W. L., N. V. Hancock, and D. A. Jones. 1977. The Oak Creek mule deer herd in Utah. Utah Div. Wildl. Resour. Publ. 77-15. 148pp.

Schwartz, C. C., and A. W. Franzmann. 1980. Black bear predation on moose. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-17-11 and W-17-12, Job 17.3R. Juneau. 82pp.

__________, and __________. 1983. Effects of tree crushing on black bear predation of moose calves. Int. Conf. Bear Res. and Manage. 5:40-44.

__________, __________, and D. C. Johnson. 1983*a*. Black bear predation on moose (bear ecology studies). Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-10, W-17-11, W-21-1, W-21-2, and W-22-1. Job 17.3R. Juneau. 135pp.

__________, __________, and __________. 1983*b*. Moose Research Center report. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-22-1, Job 1.28R and 1.31R. Juneau. 65pp.

Sigman, M. J. 1977. The importance of the cow-calf bond to overwinter moose calf survival. M.S. Thesis. Univ. Alaska, Fairbanks. 185pp.

Spencer, D. L., and J. B. Hakala. 1964. Moose and fire on the Kenai. Proc. 3rd Tall Timbers Fire Ecol. Conf. 3:11-33.

Stephens, F. R. 1967. Soils of the Kenai Moose Range enclosure study area. U.S. For. Serv. Rep. 8pp.

Verme, L. J. 1965. Reproduction studies on penned white-tailed deer. J. Wild. Manage. 29:74-79.

__________. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. J. Wildl. Manage. 33:881-887.

__________. 1983. Sex ratio variation in *Odocoileus*: a critical review. J. Wildl. Manage. 47:573-582.

__________, and J. J. Ozoga. 1981. Sex ratio of whitetailed deer and the estrous cycle. J. Wildl. Manage. 45:710-715.

Woolf, A., and J. D. Harder. 1979. Population dynamics of a captive white-tailed deer herd with emphasis on reproduction and mortality. Wildl. Monogr. 67. 53pp.

PREPARED BY:

Albert W. Franzmann
Game Biologist III

SUBMITTED BY:

Karl B. Schneider
Regional Research Coordinator

APPROVED BY:

W. Lewis Pamplin, Jr. /JB
Director, Division of Game

Steven R. Peterson /JB
Research Chief, Division of Game

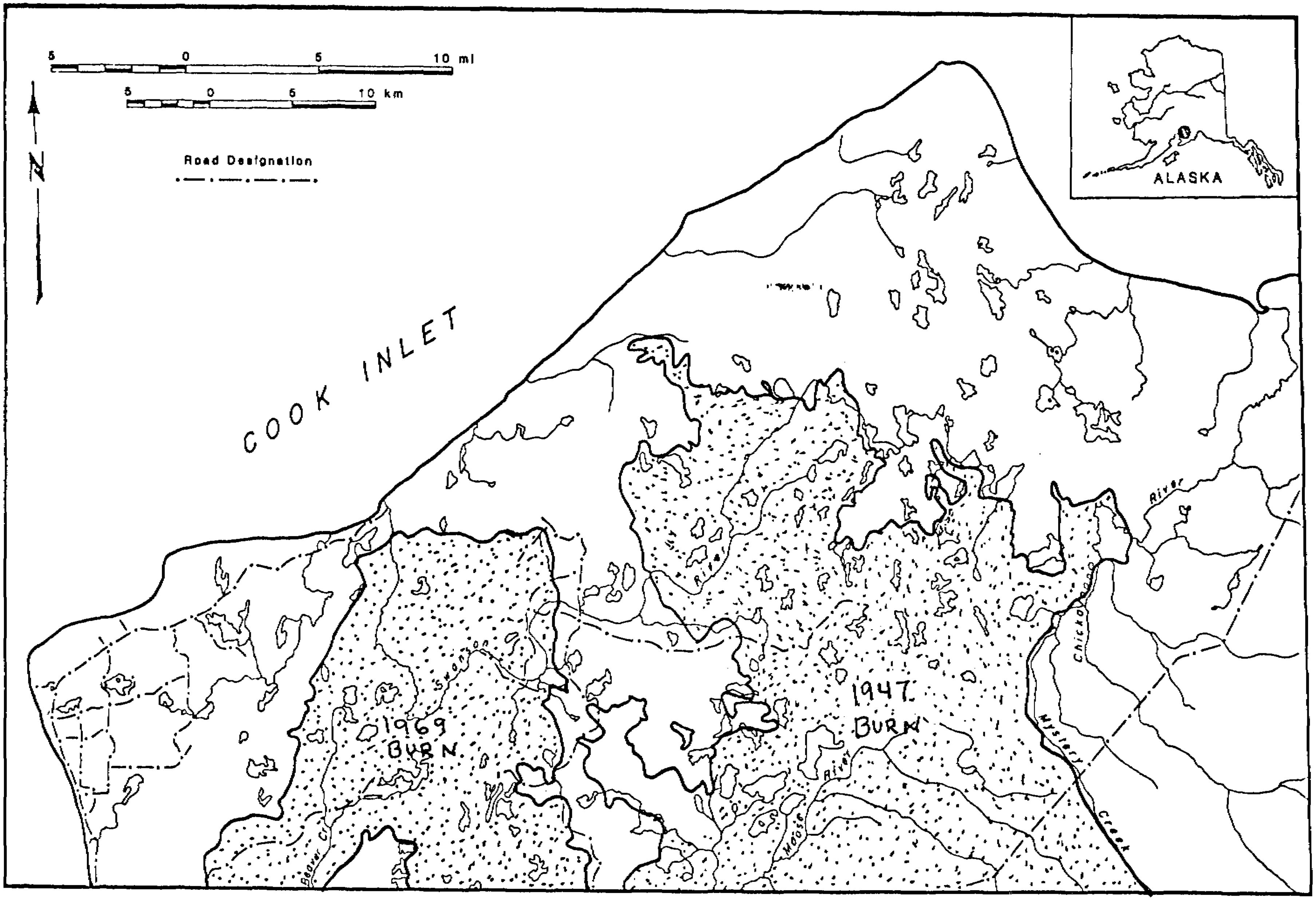

Fig. 1. The 1947 and 1969 burns on the northern Kenai Peninsula, Alaska.

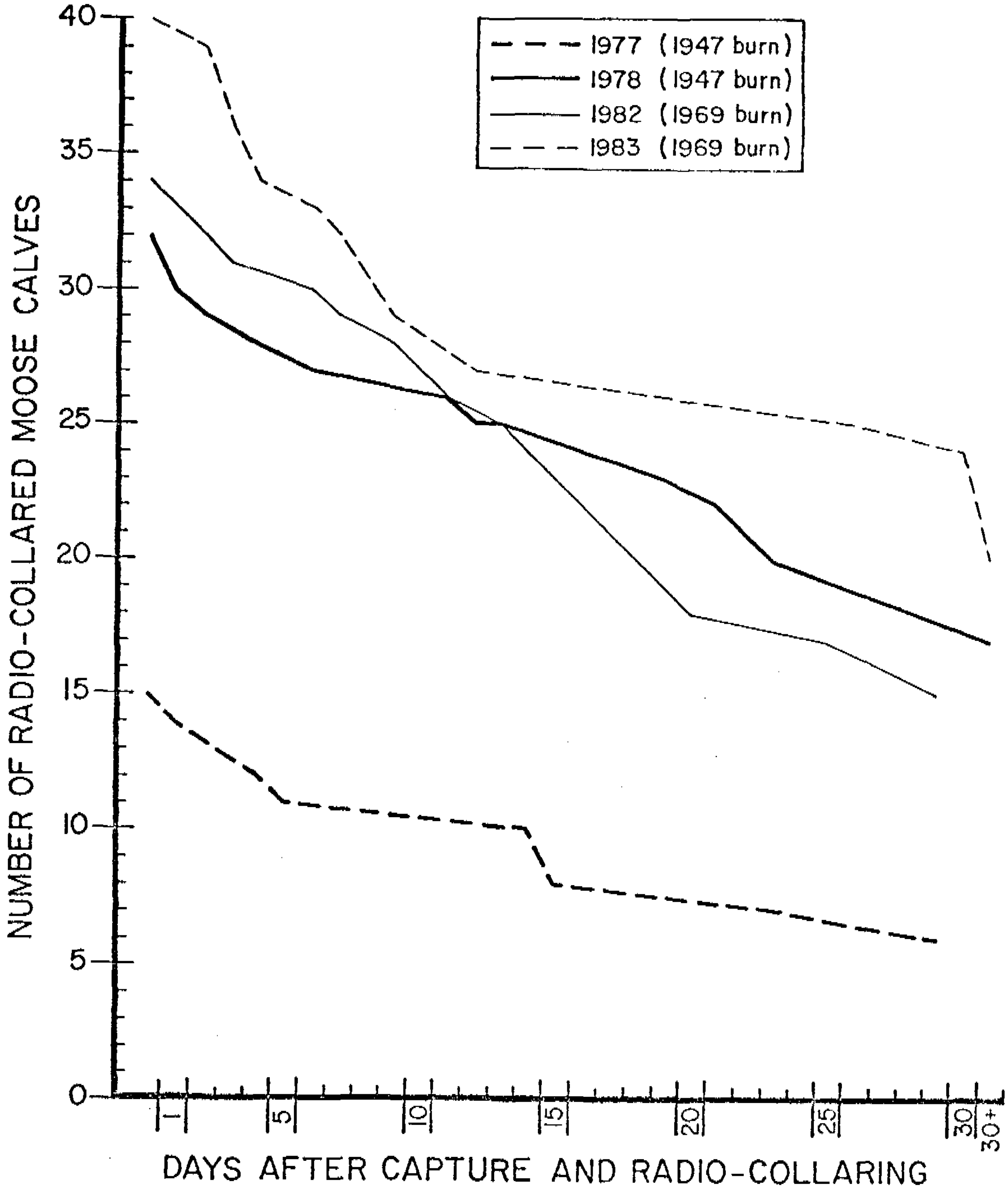

Fig. 2. Daily mortality for the 4 segments of moose calf mortality studies on the Kenai Peninsula, Alaska (1977-83).

Fig. 3. Typical position and character of moose calf killed by black bears.

Table 1. Mortality data from moose calves captured in the 1969 burn, Kenai Peninsula, Alaska, 1982.

Calf No.[a]	Single or twin calf	Sex	Bonded	Comment
1	Single	F	Yes	Ear tag transmitter fell off 23 Sep
2	Single	M	Yes	Transmitter last heard on 19 Jul
3	Twin @#4	M	No	Capture abandonment
4	Twin @#3	F	Yes	Alive, transmitter functioning 4 Oct
5	Single	F	Yes	Transmitter last heard 17 Aug
6	Single	M	Yes	Black bear predation 20 Jun
7	Twin @#8	F	Yes	Alive, transmitter functioning 4 Oct
8	Twin @#7	M	Yes	Black bear predation 9 Jun
9	Twin @#10	M	No	Capture abandonment
10	Twin @#9	M	Yes	Alive, transmitter functioning 4 Oct
11	Twin @#12	F	Yes	Black bear predation 28 May
12	Twin @#11	F	Yes	Black bear predation 11 Jun
13	Twin @#14	M	Yes	Black bear predation 4 Jun
14	Twin @#13	F	Yes	Black bear predation 12 Jun
15	Single	M	Yes	Black bear predation 16 Jun
16	Twin @#17	M	Yes	Unknown predator 24 Jun
17	Twin @#16	M	Yes	Black bear predation 29 May
18	Twin @#19	M	Yes	Ear tag transmitter fell off 24 Jul
19	Twin @#18	M	Yes	Transmitter last heard 24 Jul
20	Single	F	Yes	Black bear predation 30 May
21	Twin	F	Yes	Natural abandonment 7 Jun
22	Twin @#23	M	Yes	Unknown mortality 16 Jun
23	Twin @#22	M	Yes	Black bear predation 14 Jun
24	Twin @#25	M	Yes	Alive, transmitter functioning 4 Oct
25	Twin @#24	M	Yes	Black bear predation 5 Jun
26	Twin @#27	M	Yes	Alive, transmitter functioning 4 Oct
27	Twin @#26	F	No	Capture abandonment
28	Twin @#29	M	Yes	Alive, transmitter functioning 4 Oct
29	Twin @#28	M	Yes	Alive, transmitter functioning 4 Oct
30	Twin	F	Yes	Natural abandonment 3 Jun
31	Single	M	Yes	Alive, transmitter functioning 4 Oct
32	Twin @#33	M	Yes	Alive, transmitter functioning 4 Oct
33	Twin @#32	M	Yes	Unknown predator 9 Jun
34	Twin	M	Yes	Alive, transmitter functioning 4 Oct
35	Single	F	Yes	Unknown bear predation 12 Jun
36	Single	M	Yes	Wolf predation 7 Jun
37	Single	M	Yes	Transmitter last heard 17 Aug

[a] Calf Nos. 1 through 19 captured 26 May, 20 through 35 captured 27 May, and 36 and 37 captured 1 June.

Table 2. Mortality data from moose calves captured in the 1969 burn, Kenai Peninsula, Alaska, 1983.

Calf No.[a]	Single or twin calf	Sex	Bonded	Comment
1	Single	M	Yes	Alive, transmitter functioning 18 Oct
2	Single	F	Yes	Transmitter shed 4 Oct
3	Twin @#4	M	Yes	Black bear predation 1 Jun
4	Twin @#3	M	Yes	Black bear predation 29 May
5	Twin	M	No	Capture abandonment
6	Twin @#7	F	Yes	Transmitter shed 18 Oct
7	Twin @#6	F	Yes	Black bear predation 25 Jun
8	Twin @#9	F	Yes	Black bear predation 27 May
9	Twin @#8	M	Yes	Black bear predation 11 Jun
10	Twin	F	Yes	Black bear predation 30 May
11	Twin	M	Yes	Black bear predation 22 Jun
12	Twin @#13	F	Yes	Transmitter shed 4 Oct
13	Twin @#12	F	Yes	Transmitter shed 15 Aug
14	Twin @#15	F	Yes	Transmitter shed 15 Aug
15	Twin @#14	M	Yes	Black bear predation 7 Jul
16	Single	M	Yes	Alive, transmitter functioning 18 Oct
17	Single	M	Yes	Natural abandonment 1 Jun
18	Single	F	Yes	Black bear predation 6 Jun
19	Single	F	Yes	Drowned 5 Jun
20	Single	F	Yes	Transmitter ceased 23 Jun
21	Twin @#22	F	Yes	Transmitter shed 15 Aug
22	Twin @#21	F	Yes	Transmitter shed 22 Aug
23	Twin @#24	M	Yes	Black bear predation 20 Jun
24	Twin @#23	M	Yes	Brown bear predation 2 Jun
25	Twin @#26	M	Yes	Black bear predation 29 May
26	Twin @#25	M	Yes	Alive, transmitter functioning 18 Oct
27	Single	M	Yes	Alive, transmitter functioning 28 Oct
28	Twin @#29	M	Yes	Alive, transmitter functioning 18 Oct
29	Twin @#28	M	Yes	Black bear predation 18 Jul
30	Twin @#31	M	Yes	Transmitter shed 15 Aug
31	Twin @#30	M	Yes	Transmitter shed 4 Oct
32	Twin @#32	M	Yes	Alive, transmitter functioning 18 Oct
33	Twin @#32	F	Yes	Transmitter shed, 4 Oct
34	Twin @#35	M	Yes	Black bear predation 28 May
35	Twin @#34	M	Yes	Black bear predation 27 May
36	Twin	F	Yes	Transmitter shed 4 Oct
37	Single	F	Yes	Black bear predation 30 May
38	Single	M	Yes	Brown bear predation 30 May
39	Single	M	Yes	Black bear predation 9 Jul
40	Twin	M	Yes	Alive, transmitter functioning 4 Oct
41	Twin	M	Yes	Transmitter shed 39 Aug
42	Single	F	Yes	Transmitter ceased 10 Jun

[a] Calf Nos. 1 through 17 captured 23 May, 18 through 35 captured 25 May, and 36 through 42 captured 27 May.

Table 3. Causes of moose calf mortality based upon monitoring 75 radio-collared calves during summers 1982-83 in the 1969 burn on the Kenai Peninsula, Alaska.

Causes of mortality	1982 (N)	% (N = 34)	1983 (N)	% (N = 40)	1982-83 (N)	1982-83 % (N = 74)
Black bear	11	32.4	15	37.5	26	35.1
Brown bear	--	--	2	5.0	2	2.7
Black or brown bear	1	2.9	1	2.5	2	2.7
Wolf	1	2.9	--	--	1	1.4
Unknown predator	2	5.9	--	--	2	2.7
Total predator mortality	15	44.1	18	45.0	33	44.6
Natural abandon.	2	5.9	1	2.5	3	4.1
Drowning			1	2.5	1	1.4
Unknown	1	2.9			1	1.4
Total mortality	18	52.9	20	50.0	38	51.4

Table 4. Sex ratios of moose calves radio-collared for mortality studies in 2 habitats on the Kenai Peninsula, Alaska, 1977-78 and 1982-83.

	1947 burn area			1969 burn area			Combined years and areas
	1977	1978	1977-78	1982	1983	1982-83	
Total calves	15	32	47	34	40	74	121
Male (N)	9	20	29	23	24	47	76
Male %	60	63	62	68	60	64	63
Female (N)	6	12	18	11	16	27	45
Female %	40	37	38	32	40	36	37
Calves killed by predator	9	14	23	15	18	33	56
Male (N)	5	9	14	10	13	23	37
Male %	56	64	61	67	72	70	66
Female (N)	4	5	9	5	5	10	19
Female %	44	36	39	33	28	30	34

Table 5. Adult female moose observed during calf capture part of study in 1969 burn, Kenai Peninsula, Alaska, 1982-83.

Date	No. calves w/each cow	No. cows observ.	% cows with calves	% total cows observ.	Status of bonded calves captur.	% captur. calves
1982[a]	0	10	--	16	0	--
	1	17	32	27	10	29
	2	35	66	56	24	71
	3	1	2	1	0	--
1983[b]						
	0	13	--	21	0	--
	1	14	28	22	12	30
	2	36	72	57	28	70
1982-83 combined	0	23	--	18	0	--
	1	31	30	25	22	30
	2	71	69	56	52	70
	3	1	1	1	0	--

[a] Capture dates in 1982 were 26-27 May and 1 Jun.
[b] Capture dates in 1983 were 23 May, 25 May, and 27 May.

Table 6. Predation and total mortality rates of twin vs. single calves in the 1969 Kenai Peninsula burn, 1982-83.

Year	Total monitored[a]		Total killed by blk bear		Total killed by predators[c]		Total mortality[d]	
	Single (%)	Twins (%)	Single (%)	Twins (%)	Single (%)	Twins (%)	Single (%)	Twins (%)
1982	10(29)	24(71)	3(27)	8(73)	5(33)	10(67)	5(28)	13(72)
1983	12(30)	28(70)	3(20)	12(80)	4(22)	14(78)	6(30)	14(70)
1982-83	22(30)	52(70)	6(23)	20(77)	9(27)	24(73)	11(29)	27(71)

[a] N = 34 in 1982; N = 40 in 1983.
[b] N = 11 in 1982; N = 15 in 1983.
[c] N = 15 in 1982; N = 18 in 1983.
[d] N = 18 in 1982; N = 20 in 1983.

Table 7. Predation and mortality rates comparisons with single calves, twin calves with 1 calf monitored, and twin calves with both calves monitored in the 1969 Kenai Peninsula burn, 1982-83.

	Twin calves w/both calves monitored[a]			Twin calves w/1 calf monitored[b]			Single calves monitored[c]		
Year	No. killed by black bears (%)	No. killed by predators (%)	Total mortality (%)	No. killed by black bears (%)	No. killed by predators (%)	Total mortality (%)	No. killed by black bears (%)	No. killed by predators (%)	Total mortality (%)
1982	8(44)	10(56)	11(61)	0	0	2(33)	3(30)	5(50)	5(50)
1983	11(46)	12(50)	12(50)	2(40)	2(40)	2(40)	3(27)	4(36)	6(55)
1982-83	19(45)	22(52)	23(55)	2(18)	2(18)	4(36)	6(29)	9(43)	11(52)

[a] *N* = 18 in 1982; *N* = 24 in 1983.
[b] *N* = 6 in 1982; *N* = 5 in 1983.
[c] *N* = 10 in 1982; *N* = in 1983.

Table 8. Comparison of causes of moose calf mortality on the Kenai Peninsula, Alaska, between the 1947 and 1969 burn habitats, 1977-78 and 1982-83.

Mortality cause	1947 burn (1977-78) No.	1947 burn (1977-78) % (N = 47)	1969 burn (1982-83) No.	1969 burn (1982-83) % (N = 74)	Combined areas No.	Combined areas % (N = 12)
Black bear	16	34	26	35	42	35
Brown bear	3	6	2	3	5	4
Brown or black bear	--	--	2	3	2	2
Wolf	3	6	1	1	4	3
Unknown predator	1	2	2	3	3	2
Total predator mortality	23	49	33	45	56	46
Natural abandon.	--	--	3	4	3	2
Accident	2	4	--	--	2	2
Drowning	--	--	1	1	1	1
Unknown	2	4	1	1	3	2
Total mortality	27	57	38	51	65	54

Table 9. Distance of black bear kills from stands of mature forest in the 1969 Kenai Peninsula burn, 1982-83.

Year	Calf No.	Distance from mature forest (km)
1982	11-309	0.6
	17-052	0.2
	20-140	0.2
	13-330	At edge
	25-222	At edge
	8-212	0.3
	12-262	At edge
	14-062	0.8
	23-302	In forest
	15-173	0.2
	6-583	0.2
1983	35-592	0.4
	34-352	0.2
	37-221	0.8
	8-613	0.8
	825-512	At edge
	4-553	0.3
	4-434	0.2
	18-583	0.5
	9-292	0.5
	23-002	In forest
	11-402	1.6
	7-433	0.3
	15-313	0.4
	5-562	At edge
	29-393	In forest

Appendix A. Case histories of moose calves that died or were killed in the 1969 burn on the Kenai Peninsula, Alaska, 1982-1983.

1982 Calves

Calf 11-309 was captured on 26 May (2 km NW Wolf Lake) and was on fast mode on 28 May. We were on the site 1.6 km NW of Wolf Lake within a few hours. The birch (*Betula papyrifera*)-spruce (*Picea mariana*) regrowth canopy was approximately 10%. A stand of mature forest was within 0.6 km. An adult black bear was lying in a day bed within 15 m of the carcass, which was 90% consumed. The hide was inverted. This is the only calf whose bonding may be questioned. On 27 May, the cow and calf were both located; however, the cow was 30-40 m from the calf. The calf was killed the next day. Mortality was classified as black bear predation.

Calf 20-140 was captured on 27 May and was on fast mode on 30 May, when it was located by fixed-wing aircraft 2 km SE of Elephant Lake in birch-spruce regrowth within 0.2 km of mature forest. A black bear was observed feeding on the calf. Mortality was attributed to black bear.

Calf 36-442 was captured on 1 June 1 km E Elephant Lake, and a fast mode signal was received on 7 June. The calf was in mature forest at the edge of Eagle Lake and was nearly completely consumed (98%); only bone fragments remained. We detected 1 fresh wolf scat at the site. The bone fragments were scattered, and there appeared to be several feeding sites. Wolf predation was the assigned cause of death.

Calf 30-183 was captured 27 May on the N edge of Sunken Island Lake and was on mortality mode on 3 June. The calf was lying intact in a grassy area surrounded by mature forest 2 km SE of Sunken Island Lake. A necropsy was done at the site. The calf was dead for only a few hours. Stomach contents contained grass and forbs, no milk. The calf was emaciated and had died due to natural abandonment. The cow and calf were bonded following capture and were seen together 3 times prior to its death.

Calf 13-330 was captured on 26 May 4 km ENE of Beaver Lake and was on fast mode on 4 June on a forested peninsula on Beaver Lake. A black bear sow with 3 cubs was feeding on the calf when we initially monitored the fast signal. Mortality was classified as black bear predation.

Calf 25-222 was captured on 26 May 2 km N Tree Lake and was on fast mode on 5 June 0.5 km SE Cisca Lake in an open bog surrounded by mature forest at the boundary of the 1969 burn. The calf was 90% consumed and a day bed was located nearby with black bear tracks going from bed to carcass. Predation was attributed to black bear.

Calf 21-072 was captured 2 km SE Elephant Lake on 27 May and was on fast mode on 7 June. The calf was located 2 km NW of Tree Lake in a birch regrowth area with 25% canopy cover 0.5 km from edge of 1969 burn. The carcass was intact, but emaciated. Grass and forbs were found in the stomach, but no milk was present. Death was attributed to natural abandonment since the cow and calf were seen together several times since rebonding after capture.

Calf 33-562 was captured 0.5 km N Cow Lake on 27 May, and the transmitter was located with fast signal near the capture site in birch-spruce regrowth with 50% canopy cover on 9 June. The calf was not located, but the collar had fresh flesh and blood on it. We classified the kill as unknown predator, although a large brown bear was seen in the area the day before.

Calf 8-212 was captured at S end of Beaver Lake 26 May and was located on 9 June with fast signal on the Beaver Lake peninsula 0.3 km from mature forest in birch regrowth with nearly 100% canopy cover. The calf was 60% consumed, and it was inverted in black bear fashion. The kill was very fresh (few hours), and black bear tracks were at the site. No scats were found. We believe we may have forced the bear or bears from the kill. A sow and 3 cubs were located in the area the day before. Mortality was classified as black bear.

Calf 12-262 was captured 2 km NW of Wolf Lake on 26 May and was detected on fast signal near the capture site on 11 June. On the initial flight over the calf, a radio-collared black bear (C-19) and her 2 yearlings were sighted 75 m from calf. The kill site was in birch regrowth with 20% canopy cover 0.1 km from mature forest. The calf was 80% consumed and inverted as typically associated with black bear kills. Six black bear scats were located near the kill, and mortality was classified as black bear.

Calf 35-602 was radio-collared on 27 May 2 km NE Woodpecker Lake and was located with a fast signal on 12 June in a grassy area 0.1 km from mature forest 3 km S Beaver Lake. The calf was 97% consumed; all that remained were bone fragments and hooves. There were 4 feeding areas within 15 m, and 2 large bear scats were found. We could find no hair to identify black or brown bear so the kill was classified as unknown bear predation.

Calf 14-062 was radio-collared 2 km NW Wolf Lake on 26 May and was killed on 12 June 50 m from Beaver Lake in birch regrowth 0.8 km from mature forest. The carcass was 70% consumed, and the hide inverted and positioned similar to the pattern we identified with black bears. One fresh black bear scat was found at the scene. Mortality was classified as black bear.

Calf 23-302 was captured 2 km NW Tree Lake on 27 May and located with a fast signal 100 m S of the gas well near Sunken Island Lake in a grassy bog surrounded by mature forest. The calf was

80% consumed and was left with hide inverted. Black bear tracks were identified in the bog, and mortality was classified as black bear.

Calf 22-242 was radio-collared 2 km NW Tree Lake on 27 May and was found intact 16 June lying along Gagara Lake. The calf was lying on its side, and there were no external marks. Gross necropsy was performed and tissues collected. The stomach had milk curd present. We classified the mortality as unknown.

Calf 15-173 was captured on 26 May 1 km NE Wolf Lake and was detected on fast mode on 16 June near the north lake of Finger Lakes in birch regrowth 0.2 km from mature forest. The carcass was 70% consumed and in the typical black bear position with hide inverted. Black bear scats and track were identified at the scene. Mortality was classified as black bear.

Calf 6-583 was radio-collared on 26 May 1 on the E edge of Wolf Lake and was found on the east edge of Finger Lakes on 20 June in birch regrowth with 100% canopy cover 0.2 km from mature forest. The carcass had the typical inverted hide-legs extended posture. Black bear hair, tracks, and scats (4) were found at the site; the mortality was classified as black bear.

Calf 16-032 was radio-collared 1 km N Finger Lakes on 26 May and was located with fast signal on 24 June east of Finger Lakes in mature forest near cutting area. The carcass was 98% consumed, with only a small piece of hide remaining. The kill was classified as unknown predator.

1983 Calves

Calf 35-592 was radio-collared 1 km E Doroshkin Lake on 25 May and was monitored on fast mode on 27 May 50 m from capture site 0.4 km from a mature forest island. The calf was 85% consumed, had the hide inverted, and was in the black bear predation posture. Black bear scats were located at the site, as was a day bed with black bear hair on twigs. Black bear predation was determined as cause of mortality.

Calf 34-352 was the twin of 35-592 and was monitored on fast mode the day following its twin. Its collar was located 2 km E of Doroshkin Lake at the edge of a bog 0.2 km from mature forest. We did not find the carcass but 50 m from us was a sow with 3 cubs in a large birch tree. The collar was bloody. We classified the mortality as black bear predation.

Calf 38-062 was radio-collared on 27 May on W side of Finger Lakes and was located with fast signal on 30 May 1 km NE Rhode Lake in birch regrowth. The carcass was 95% consumed, with only a piece of hide and fractured bones remaining. These parts were scattered over a 10-m area. Brown bear guard and long hair was collected at the site. Track was not well defined, but large. We attributed the kill to a brown bear.

Calf 37-221 was captured on 27 May 1 km N of Rhode Lake and was on fast mode on 30 May 1 km W of Rhode Lake. A black bear was seen moving away from site on the initial overflight with fixed-wing aircraft. We returned with a helicopter in a few hours and found the carcass only 20% consumed. The viscera was eaten as were parts of the loin and thigh. Black bear hair was found in a bed next to the kill, and black bear scat was collected 6 m from kill. Mortality was classified as black bear.

Calf 8-613 was radio-collared on 23 May 1 km S Beaver Lake and was detected on fast mode 2 km W of Rhode Lake on 27 May in thick birch regrowth with 80% canopy cover 0.8 km from mature forest. The carcass was 90% consumed and was in the inverted position. Two black bear scats were collected at the site. Mortality was classified as black bear.

Calf 25-512 was captured on 25 May 1 km NE Savka Lake and was on mortality mode on 29 May 1 km N Savka Lake at the edge of mature forest. The viscera and part of the loin were consumed. A tree 5 m from kill had fresh bear teeth and claw marks (bear tree); however, no scats or track were found. Black bear hair was found on bushes by the kill, and death was presumed caused by black bear.

Calf 4-553 was captured on 23 May 2 km NE of Beaver Lake and was on mortality mode on 29 May 2 km E of Beaver Lake in birch regrowth with 20% canopy cover adjacent to mature spruce forest.

The carcass was 90% consumed and in the hide-inverted position. Six black bear scats were found near the carcass, and a day bed was 10 m from the carcass. Mortality was classified as black bear.

Calf 10-183 was captured on 23 May 2 km SW Beaver Lake and was on fast mode 30 May 2 km NW Rhode Lake in birch regrowth area 1 km from mature forest. At the site, we discovered an uncollared calf 20 m from our radio-collared calf, which was also killed. We believe it was the twin calf of 10-183. Both calves had viscera and parts of thigh eaten and were about 20% consumed. The hide was not inverted. Logs were ripped open 25 m from calves, and bear claws marks were detected 15 m from calves on a log. Bear track, indistinct but large, was found. We were not sure if it was a brown or black bear kill and classified it as such.

Calf 3-423 was captured on 23 May 2 km NE Beaver Lake and was detected on fast mode 2 km E Beaver Lake on 1 June in birch regrowth with 20% canopy cover. Mature forest was within 2 km. The carcass remains were quite old, perhaps 72 hours. The carcass was 90% consumed and in the hide-inverted position. Some bones were scattered throughout the area. A sow (C-19) with cubs was located in the area on 31 May 1983, and we believe the fast mode signal was delayed by the cubs moving the collar, keeping it activated. There were 4 beds in the area, 2 scats, and scratch marks on a nearby tree. Calf 4-553 was found 50 m from area on 29 May. Both were determined to be black bear kills.

Calf 17-333 was captured on 23 May at edge of Sunken Island Lake and was located on mortality mode 1 km N Sunken Island Lake in birch regrowth at the edge of a small lake on 1 June. The carcass was intact, except for bird picking at abdomen. No predator signs were detected. Gross necropsy was negative; no milk was found in the stomach. The calf had rebonded with its mother, after capture and they had been seen together on 24 May, 26 May, and 30 May. We classified the mortality as natural abandonment.

Calf 24-193 was radio-collared on 25 May at edge of Savka Lake and was located 50 m W of Swanson River Road and 2 km N of Kenai National Wildlife Refuge (KNWR) boundary in mature forest on 2 June. The carcass was buried under leaves and was only 10% consumed. The skull was opened, most of head and neck were eaten, and a large piece of flesh from hind limb was removed. The carcass was otherwise intact. A skull puncture was 1.4 cm in diameter. There was a day bed 10 m from calf carcass, and brown bear hair was found in the bed and on several low shrubs near the carcass. We classified the predator as brown bear.

Calf 19-533 was radio-collared on 25 May on E side of Wolf Lake and was on fast mode on an island in Beaver Lake on 6 June. The calf signal was from the water's edge and a bit confusing. After some searching, the calf was spotted tangled in a submerged tree. The calf was intact, and we attributed death to drowning. The calf had apparently tangled in the tree when swimming to or from the island.

Calf 18-523 was captured on 25 May on W side of Quake Lake and was located on fast mode at S end of Finger Lakes in birch regrowth with 80% canopy 0.5 km from mature forest on 6 June. The calf was in the inverted-hide position and was 80% consumed. Black bear hair was found on brush limbs by the carcass. Mortality was classified as black bear.

Calf 9-292 was captured on 23 May 1 km S Beaver Lake and was on fast mode on 11 June 2 km E Beaver Lake in birch regrowth with 80% canopy cover 0.5 km from mature forest. The carcass was 90% consumed, with hide inverted. Black bear scats were collected from near the carcass and near 2 beds in the area. Black bear hair was hanging on the vegetation. Mortality was classified as black bear.

Calf 23-002 was radio-collared on N end of Savka Lake on 25 May and was located 2 km N of Savka Lake in mature forest. The carcass was 80% consumed and in the hide-inverted position. Two black bear scats were collected at the site. Mortality was classified as black bear.

Calf 11-402 was captured on 23 May 1983 1 km S Wolf Lake and was on fast mode signal on 22 June 1983 2 km NE Rhode Lake 1.6 km from mature forest. On the initial overflight, a radio-collared black bear (C-6) was on the kill with an ear-tagged yearling. Mortality was classified as black bear.

Calf 7-433 was captured on 23 May on the large peninsula on Beaver Lake and was located on fast mode at the S edge of Beaver Lake in thick birch regrowth (80% canopy) 0.3 km from mature forest. The carcass was found in the inverted-hide position and was 90% consumed. Black bear scats (2) were collected between the site and several day beds (10 m apart). Black bear hair was found in the beds. Mortality was classified as black bear.

Calf 15-313 was radio-collared on 23 May 1983 on the S end of Donkey Lake and was located on mortality signal in a bog at N end of Donkey Lake 0.4 km from mature forest. The calf was 30% consumed and had several puncture wounds in the shoulder. Two black bears were seen near the area on the initial overflight. No predator sign (scats, beds, hair) was found at the site. We believe the kill was made by the black bears in the area and classified it as such. This could be debated and perhaps classified as an unknown predator. However, we felt strongly that we had chased the black bears from the kill site and used this circumstantial evidence to classify it.

Calf 5-562 was captured on 27 May 1983 on W side of Finger Lakes and was located with fast signal 0.5 km N of Shadura Lake on 9 July 1983 in birch regrowth at edge of mature forest. A large black bear was feeding on the calf. Two feeding areas and 1 bed were located at the site. The carcass was 25 m from the bed. The carcass was 80% consumed and hide-inverted. The bear was nearly finished feeding on the calf. Mortality was classified as black bear.

Calf 29-393 was radio-collared on 25 May 1983 2 km N of KNWR boundary just W of Swanson River Road and was located with fast signal 3 km SW Flat Lake in mature forest on 18 July 1983. The carcass was nearly completely consumed. Five black bear scats were collected at the site, and several day beds were located. The mortality was from black bear predation.

Appendix B. Condition assessment of moose populations via productivity expressed as twinning rates by A. W. Franzmann and C. C. Schwartz. (Submitted to Journal of Wildlife Management as a Short Communication).

Condition assessment of wildlife populations has long been and continues to be an important objective of wildlife managers. Body weight and measurements, subjective classifications, fat stores, antler growth, and blood parameters have been used to make population condition assessments in moose (Alces alces) (Franzmann 1977). These criteria are valid for applying the animal indicator concept, whereby the animal living in an environment functions as an indicator of the state of the environment. However, the ultimate measure or best method to assess the population's response to its environment would be through its reproductive success--primarily its natality.

Natality rates for moose populations are seldom are seldom used in productivity assessments. Calves/100 cows are regularly quoted for moose populations, but most of these determinations are made in late fall during population composition counts. These data are important and are relied upon heavily for management decisions. Bishop and Rausch (1974) reviewed the application of these data for moose management in Alaska.

Recent information suggests that additional emphasis should be made by managers to obtain natality information, particularly twinning rates, from moose populations to better assess that population's response to its environment.

STUDY AREA AND METHODS

Moose calf mortality studies were conducted in the 1947 burn on the Kenai Peninsula, Alaska in 1977-78, and methods and study area were described (Franzmann et al. 1980). During 1982-83, a calf mortality study was conducted in the 33,500-ha 1969 burn, also located in the central lowlands of the Kenai Peninsula, Alaska. Description of the physical aspects, vegetation, soils, and specific habitats of the Kenai Peninsula have been widely published (Spencer and Hakala 1964; Rausch and Bishop 1968; LeResche and Davis 1973; Bishop and Rausch 1974; LeResche et al. 1974; Oldemeyer 1981).

During the calf capture segment of these calf mortality studies, calves were located by visual search from both fixed-wing aircraft (Piper Super Cub) and helicopter (Bell Jet Ranger) during the peak calving period (late May, early June). The area was covered daily beginning 20 May until calving commenced. At that time, calf capture began and all adult female moose observed and number of calves by side were recorded.

RESULTS AND DISCUSSION

The twinning rate during the peak calving season in 1977 in the 1947 Kenai Peninsula burn was 23% (3 of 13); in 1978, 22% (8 of 36); and in combined years, 22% (11 of 49) (Franzmann and Schwartz 1979, Franzmann et al. 1980) (Table 1). During the 1977-78 studies, we only calculated the twinning rate based on cows with calves.

The twinning rate for cows observed with calves in the 1969 Kenai Peninsula burn was 67% (35 of 52 cows had twin calves) in 1982, 72% (36 of 50) in 1983, and the combined years' rate was 70% (71 of 102) (Table 1). The twinning rate for al l cows observed in the area, including those with no calves, was 56% (35 of 62) in 1982, 57% (36 of 63) in 1983, and the combined years' rate was 56% (71 of 125) (Table 1). The twinning rates using only cows with a calf or calves by side (70% combined years) were considered more representative of the population because at that early part of the calving period (23 May-1 June) some, if not most, of the cows without calves may yet produce calves. However, the twinning rate calculated using all cows, including those with no calves, was also high (56%). In 1982, we also observed a cow with newborn triplets that were still wet.

Twinning rates observed in the 1969 burn were the highest we have seen reported from North America. Pimlott (1959) summarized reported data from various regions and listed these twinning rates: Newfoundland, 15% (1950-56, N = 1,217); Isle Royale, 5% (1919-30, N = 87); British Columbia, 12% (1946-47, N = 102); Ontario, 23% (1947-49, N = 415); New Brunswick, 12% (1946-47, N = 102); Quebec, 28% (1950, N = 274); and Alaska, 13% (1951-53, N = 1,217). Lowest twinning rates reported were 4.5% (1960's, N = 1,058) in Jackson Hole, Wyoming (Houston 1968). For the area in 1948, a 15% rate was reported by Dennison (1956). Bailey (1920) had no quantitative data, but reported that during the period 1894 through 1917 "two calves are so often seen with a cow that twins seem to be the rule rather than the exception."

Skuncke (1949) reported that in Sweden twins are the rule. Norwegian moose regularly give birth to twins (Haagenrud and Markgren 1974).

Markgren (1982) indicated that Swedish hunters in 1969 were asked to record the number of cows with twins and they reported 65% from the coastal region, 39% from the inland region, and 17% from the foothills. These data are from fall observations and support the concept that twins are frequently seen in Sweden. It should be noted that Swedish moose are not subject to much predation, if any, and Swedish moose populations have been highly productive in recent years (Strandgaard 1982).

It is also important to note that the data reported herein from the Kenai Peninsula were gathered at the peak of calving with intensive aerial search over the calving areas. Other data from

North America as reviewed by Pimlott (1959) were not obtained during the calving period, but much later, mostly in fall. Therefore, these data may not reflect true "twinning rates" due to high postnatal mortality, primarily from predators, as detected in recent studies in Alaska (Franzmann et al. 1980, Ballard et al. 1981).

Markgren (1969) concluded that twinning rates vary widely from one region to another. We detected wide variation within a region but in different habitat types. A twinning rate of 22% (11 of 49) was detected in the 1947 Kenai Peninsula burn during 1977-78 studies, and a rate of 70% (71 of 102) was detected in the 1969 Kenai Peninsula burn. We believe these differences are a result of habitat differences. Twinning rates were observed 30 years following the 1947 burn when habitat quality was declining (Oldemeyer et al. 1977). Spencer and Hakala (1964) estimated that the productive life of a burn as good moose range was 20 years. The 1947 burn was attracting moose in 5 years following the burn. High levels of browse production occurred 7 years postburn, with maximum production in 15 years postburn. Oldemeyer and Regelin (In Press) compared biomass estimates in the 1969 and 1947 Kenai Peninsula burns during 1979 for the primary browse species (willow, Salix spp; paper birch, Betula papyrifera; and aspen, Populus tremuloides). In the 1969 burn, the total browse estimate was 908 ± 394 kg/ha (95% CI) and 365 ± 121 kg/ha in the 1947 burn. Total browse estimates in 1980 for the 1969 burn increased to 1,200 kg/ha. No data were available for the 1947 burn during 1980, but no significant change was expected. The 1969 Kenai Peninsula burn was essentially in its prime for moose range during this study (13 and 14 years following fire), and the high biomass twinning rate (70%) reflected this. We reported the 1947 burn production and twinning rate as high (Franzmann et al. 1980), but in fact the rate was probably low. We based our assessment from comparisons of rates reported from other North American populations. We know now that these rates were not comparable due to timing and method of data collection.

Frequency of twinning in moose has been related to climate and nutrition in other studies (Hosley 1949; deVos 1956; Edwards and Ritcey 1958; Pimlott 1959; Markgren 1969, 1982; Schladweiler and Stevens 1973). Markgren (1982) compared twinning rates in 3 regions in Sweden, and the great differences in rates were attributed to climate and nutrition (65%, 39%, 17%).

It is apparent that twinning rate comparisons of populations must be standardized to be valid. Where predators contribute significantly to neonatal mortality, twinning rates may be useful if data are collected intensively during the peak calving period. In Alaska, this would require helicopter search over the calving area every other day beginning approximately 22 May through 31 May. High postnatal mortality rates in most areas necessitate this. Mortality from all factors in early summer on the Kenai

Peninsula was 57% in the 1947 burn (Franzmann et al. 1980) and 51% in the 1947 burn (Franzmann et al. In Press). Data on twinning rates can be used to compare the reproductive response of a moose population to its habitat and thereby the condition of the population evaluated. The 1969 and 1947 burn areas on the Kenai Peninsula provided a good example or model.

The age structure of the reproducing females in a population can influence fecundity. Markgren (1969) described a juvenile phase of low fecundity and then a phase of decreasing fecundity in moose. Populations under a high plane of nutrition experience a high rate of yearling pregnancies (Pimlott 1959, Markgren 1969, Schwartz et al. unpubl. data). However, most observers conclude that yearling pregnancies most often produce single calves (Skuncke 1949, Pimlott 1959, Simkin 1974). Pimlott (1959) suggested that a single birth may also be the rule for a 2-year-old moose. Saether and Haagenrund (1983) reported very few female Norwegian moose give birth to twins in their 1st 2 pregnancies. Therefore, if the population of concern has a young age structure, particularly a high proportion of yearlings, the twinning rate may be thereby depressed.

Twinning data from moose population are not proposed as a panacea for determining productivity, but we believe their value has been underestimated and when properly obtained will provide the manager with an important additional condition assessment. Where postpartum predation rates are high, a low productivity estimate from fall composition counts in a population may be caused primarily by postnatal mortality. Without natality data, the productivity assessment may be wrong, or at least incomplete.

LITERATURE CITED

Bailey, V. 1920. Animal life in Yellowstone National Park. C. Thomas and Co., Springfield, Illinois. 241pp.

Ballard, W. B., Spraker, T. H., and K. P. Taylor. 1981. Causes of neonatal moose calf mortality in Southcentral Alaska. J. Wildl. Manage. 45:335-342.

Bishop, R. H., and R. A. Rausch. 1974. Moose population fluctuations in Alaska, 1950-1972. Nat. Can. 101:559-593.

Dennison, R. H. 1956. Ecology, behavior and population dynamics of the Wyoming or Rocky Mountain moose. Zoologica 41:105-118.

deVos, A. 1956. Summer studies of moose in Ontario. Trans. North. Am. Wild. Conf. 20:560-567.

Edwards, R. Y., and R. W. Ritcey. 1958. Reproduction in a moose population. J. Wild. Manage. 22: 261-268.

Franzmann, A. W. 1977. Condition assessment of Alaska moose. Proc. North Am. Moose Conf. Workshop. 13:119-127.

__________, and C. C. Schwartz. 1979. Kenai Peninsula moose calf mortality study. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-17-10 and W-17-11. Job 1.24R. Juneau. 18pp.

__________, __________, and R. O. Peterson. 1980. Moose calf mortality in summer on the Kenai Peninsula, Alaska. J. Wildl. Manage. 44:764-768.

__________, __________, and D. C. Johnson. In Press. Kenai Peninsula moose calf mortality study. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-22-2. Job 1.33R. Juneau.

Haagenrud, H., and G. Markgren. 1974. The timing of estrus in moose (Alces alces L.) in a district of Norway. Proc. XI. Int. Cong. Game Biol., Stockholm. 1973:71-78.

Hosley, N. W. 1949. The moose and its ecology. U.S. Fish and Wildl. Serv. Leaflet 317. Washington, D.C. 51pp.

Houston, D. B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Nat. Hist. Assoc. Tech. Bull. No. 1. 110pp.

LeResche, R. E., and J. L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 37:279-287.

__________, R. H. Bishop, and J. W. Coady. 1974. Distribution and habitat of moose in Alaska. Nat. Can. 101:132-173.

Markgren, G. 1969. Reproduction of moose in Sweden. Viltrevy 6:127-299.

__________. 1982. Moose populations along a climatic gradient across Sweden. Nat. Swedish Environ. Protection Board Rep. 1571. Stockholm. 52pp.

Oldemeyer, J. L. 1981. Estimation of paper birch production and utilization and an evaluation of its response to browsing. Ph.D. Thesis. Pennsylvania State Univ., College Park.

__________, and W. L. Regelin. In Press. Forest succession, habitat management, and moose on the Kenai National Wildlife Refuge. Viltrevy.

__________, A. W. Franzmann, A. L. Brundage, P. D. Arneson, and A. Flynn. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41:533-542.

Pimlott, D. H. 1959. Reproduction and productivity of Newfoundland moose. J. Wildl. Manage. 23:281-401.

Rausch, R. A., and R. H. Bishop. 1968. Report on moose studies. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-15-2 and W-15-3. Juneau. 263pp.

Saether, B., and H. Haagenrud. 1983. Life history of moose (Alces alces): Fecundity rates in relation to age and carcass weight. J. Mammal. 64:226-232.

Schladweiler, P., and D. R. Stevens. 1973. Reproduction of Shiras moose in Montana. J. Wildl. Manage. 37:535-544.

Simkin, D. W. 1974. Reproduction and productivity of moose. Nat. Can. 101:517-526.

Skuncke, F. 1949. Algen, Studier jaktoch rard. P. A. Norstedt and Sons, Stockholm. 400pp.

Spencer, D. L., and J. B. Hakala. 1964. Moose and fire on the Kenai. Proc. Ann. Tall Timbers Fire Ecol. Conf. 3:11-33.

Strangaard, S. 1982. Factors affecting the moose population in Sweden during the 20th century with special attention to silviculture. Swedish Univ. Agr. Sci., Dep. Wildl. Ecol. Rep. 8. Uppsala, Sweden. 31pp.

Table 1. Adult female moose twinning rates at peak. Calving (late May) in 2 habitats on the Kenai Peninsula, Alaska.

Number of calves with each cow	Number observed	% of cows with calves	% of total cows observed
	1947 burn(1977)		
1	10	77	--
2	3	23	--
Total	13		
	1947 burn (1978)		
1	28	78	--
2	8	22	--
Total	36		
	1947 burn (1977-78 combined)		
1	38	78	--
2	11	22	--
Total	49		
	1969 burn (1982)		
0	10	--	16
1	17	33	27
2	35	67	56
Total	62		
	1969 burn (1983)		
0	13	--	21
1	14	28	22
2	36	72	57
Total	63		
	1969 burn (1982-83 combined)		
0	23	--	18
1	31	30	25
2	71	70	56
Total	125		