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EFFECTS OF REDUCING BROWN BEAR DENSITY ON MOOSE CALF SURVIVAL IN SOUTHCENTRAL ALASKA

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ABSTRACT: During 1979 brown bear (*Ursus arctos*) density within a 3,346 km² study area in southcentral Alaska was lowered by 60% by capturing and translocating 47 bears away from the study area. The reduction resulted in a significant ($P < 0.05$) increase in the numbers of moose (*Alces alces*) calves surviving from birth to November.

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Brown bears have been identified as important predators of moose in North America (Ballard and Larsen 1987). In southcentral Alaska brown bears were responsible for 79% of mortalities to moose calves during their first 6 weeks of life (Ballard *et al.* 1981). Subsequently, an attempt was made to improve moose calf survival by temporarily reducing spring brown bear density in this area. This paper summarizes the results of these studies.

STUDY AREA AND METHODS

The study was conducted in a 3,436 km² area located in the headwaters of the Susitna River. Boundaries, topography, vegetation, climate, and summaries of other studies in the area have been described by Skoog (1968), Miller and Ballard (1982a, b) and Ballard *et al.* (1987).

Bear density was temporarily reduced by capturing and translocating 47 bears away from the study area. Bears were captured using standardized helicopter darting procedures during 22 May-7 June and 21-22 June 1979, and were transported varying distances away from the area (Ballard *et al.* 1980b, 1982; Miller and Ballard 1982a, b). Based on a density estimate of 24/1,000 km² derived from the capture of marked and unmarked bears (Miller and Ballard 1982b), we estimated that about 60% of the bear population was translocated.

The effects of bear removal on summer

and fall moose calf survival were evaluated by 2 methods: (1) autumn moose calf:cow ratios determined from low intensity surveys conducted from fixed-wing aircraft (Gasaway *et al.* 1986) within the bear removal area (count area 3; CA-3) were compared with ratios obtained in earlier years and with those from other comparative count areas; and (2) newborn moose calves were radio-collared in CA-3 and subsequent causes and rates of mortality were compared with those of previous years. Overwinter survival of moose calves following the bear transplant was determined by 2 methods: (1) 6-month-old calves were radio-collared and monitored through May of the following year (Ballard *et al.* 1982); and (2) spring calf:cow ratios were calculated from spring counts in CA-3 and compared with the following fall estimates.

When calf:cow ratios were positively correlated between groups of count units over a period of years (3 count areas over 10 years), we assumed that factors influencing these ratios were similar in both areas. The ratios were expected to continue exhibiting similar trends unless some factor was altered in 1 group of units but not the other. If reduced bear density strongly influenced moose calf survival, a divergence in trends was expected between units in which bears were reduced and units in which bear densities were not reduced.

Differences between annual calf:cow ratios for bear reduction and nonreduction areas were compared by *t*-test based on arcsine

transformation of observed ratios (Sokal and Rohlf 1969:607). Comparisons of trends in calf:cow ratios within and between areas were based on analysis of residuals (Everith 1977:46) to determine which cells in this analysis contributed significantly to rejection of the null hypothesis. Confidence intervals (CI) around predicted Y values were obtained by linear regression analysis following procedures described by Snedecor and Cochran (1973). Statistical differences in means and deviations for ratio data were tested with *t*-tests and Chi-square analyses, respectively (Snedecor and Cochran 1973).

RESULTS AND DISCUSSION

Reduction of brown bear density during late spring and early summer 1979 in CA-3 resulted in a large increase in moose calf survival as indicated by autumn calf:cow ratios (Fig. 1). The increase was evaluated by comparing autumn 1978 vs. 1979 calf:cow ratios, in the same area as well as with ratios in 2 other comparison areas (CAs-7 and 13) where bear numbers were not reduced. In CA-3

calf:100 cows (>2 years old) ratios increased from 34 in 1978 to 58 in 1979 ($t=5.9 P<0.05$); no changes were observed during the same time period within the 2 comparison count areas where bears were not reduced (Fig. 1).

Prior to bear removal in 1979, calf:cow ratios were correlated between CA's 3 and 7 ($r = 0.75, P < 0.05$), and between CAs-3 and 13 ($r = 0.55, P = 0.12$) from 1970-78 (Figs. 2 & 3). Based on these relationships, the predicted autumn 1979 calf:cow ratio in CA-3 was 29:100. The observed ratio of 58:100 fell outside the 95% CI for both comparisons, suggesting that the 1979 increase in CA-3 resulted from the bear reduction program.

Numbers of calves and cows (>2 years-old) observed in CAs-3, 7, and 13 from 1970-79 were tested to determine significant deviations from expected values based on comparisons of count areas. 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 number of calves observed between CAs-3 and 7 occurred only in 1979 following reductions in bear density. How-

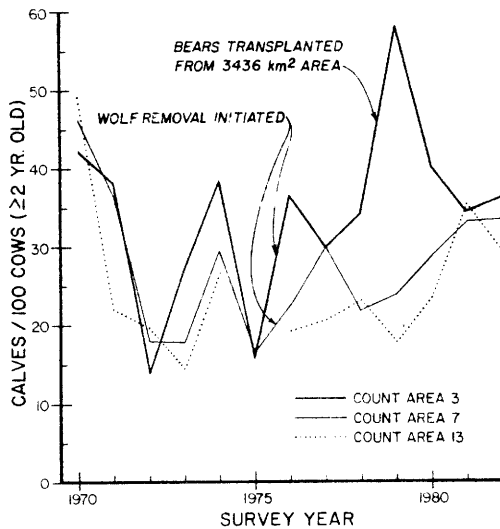


Fig. 1. Annual moose calf:cow (>2 years old) ratios from 3 count areas before and after brown bear translocation.

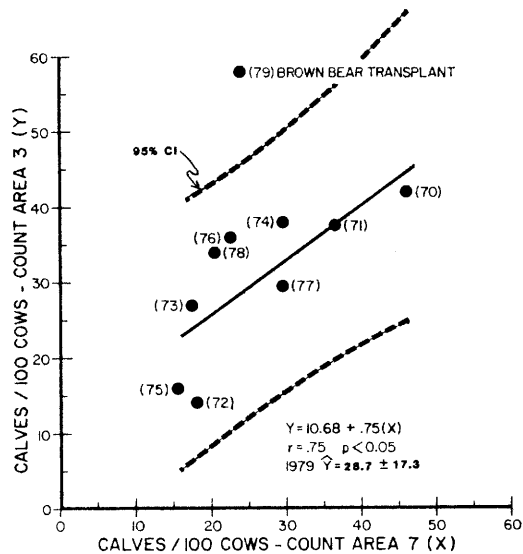


Fig. 2. Relationship between autumn moose calf:cow (>2 years old) ratios in count areas 3 and 7 in GMU 13 of southcentral Alaska, 1970-79 (survey year in parenthesis).

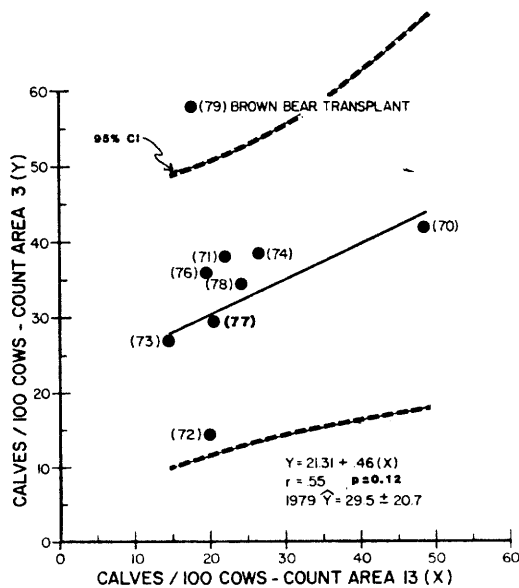


Fig. 3. Relationship between autumn moose calf:cow (>2 years old) ratios in count areas 3 and 13 in GMU 13 of southcentral Alaska, 1970-79 (survey year in parenthesis).

ever, between CAs-3 and 13 deviations ($P < 0.05$) occurred not only in 1979 but also in 1970 and 1972. Differences in 1970 and 1972 autumn counts may have resulted from differences in winter severity of the previous winters while the differences in 1979 probably resulted from the reduction in bear density in CA-3 (Ballard *et al.* 1980b).

Our 1979 moose survey results probably misrepresent the true sex and age composition of the moose herd. CA-3 moose have been annually surveyed in autumn using low-intensity (1 min/mi²) counts from fixed-wing aircraft. Following these counts in 1980, the area was censused using high-intensity (4.4 min/mi²) stratified random sampling techniques (Gasaway *et al.* 1986). This was done in an effort to estimate total population size and to obtain better sex-age composition data. The relationship of the low-intensity count to the moose population estimate based on high-intensity count in autumn 1980 was used to reconstruct annual estimates of the moose population in CA-3 for the period 1977-79.

These comparisons suggest that the 1979 calf:100 cow ratio and the percent of the moose herd composed of calves were both higher than indicated by the low-intensity surveys. Based on the relationship between low- and high-intensity surveys, calves:100 cows increased from 58 to 73, calf percentage in herd increased from 31 to 45%, and bull:100 cows decreased from 18 to 15. The differences in sex-age composition are largely due to differences in observability of various sex-age aggregations under different survey intensities (Gasaway *et al.* 1986).

We followed the above described procedure to calculate mortality rates and to compare differences in these rates between years for a hypothetical moose population of 1,000 individuals. If we assumed that the relationship observed in autumn 1980 between moose population composition data obtained during low intensity and high intensity searches is consistent from year to year, then this relationship can be used to reconstruct the moose population during the years prior to 1980 when only low-intensity searches were conducted. If a constant reproductive rate is also assumed, annual calf mortality rates can be calculated based on the differences between calculated calf production in spring and observed number of calves in the fall (based on composition of reconstructed population).

We assumed a productivity rate of 135 calves:100 cows (Ballard *et al.* 1980) and 0.29 calves:yearling cow (Blood 1974). The corresponding reconstructed autumn population for CA-3 in 1979 was 450 calves, 83 bulls, 60 yearling cows, and 407 adult cows. At the above productivity rate, this number of cows would have produced 511 calves. The difference between the expected number of 511 calves produced and the 450 calves "observed" in the reconstructed population provides a calf mortality estimate of 12% during the summer in 1979, the year the bears were translocated. Similar calculations for CA-3 in the summer of 1977 and 1978 indicated calf

mortality rates of about 60% and 55%, respectively, in the 2 years prior to bear translocation. These latter estimates were similar to the mortality estimates derived from radio-collared calves during 1977 and 1978 (Ballard *et al.* 1981).

Based on the above-described comparisons, the reduction in brown bear density by 60% resulted in a reduction of calf moose mortality from about 55% to about 12% from birth to November: a 78% reduction in total mortality for the period. Winter 1979-80 was relatively mild and only 2 of 33 radio-collared calves captured in November died during winter (6%). Therefore, moose calf mortality for the year following bear density reduction was 17% (May-October survival rate of 88% x November-April survival rate of 94% = 83% annual survival rate). High calf survival was also substantiated by spring 1980 counts in CA-3 which revealed a calf:cow (includes yearling cows) ratio of 58:100 (Ballard *et al.* 1982). This was the highest spring calf:cow ratio ever observed in southcentral Alaska.

The bear translocation resulted in changes in calf survivorship evident in fall composition data and in calculated mortality rates as discussed above. Corresponding changes did not occur in mortality rates of 27 moose calves radio-collared in spring 1979 during the time the bears were being captured and translocated. Studies conducted in 1977 and 1978 in CA-3 and 2 similar areas of GMU 13 indicated a 55% mortality rate of radio-marked calves with 79% of the deaths resulting from brown bear predation (Ballard *et al.* 1979, 1981). In 1979, using the same methods, we observed 56% mortality of the 27 radio-marked calves; brown bears caused 80% of these deaths. We suspect that several sources of bias offer the most probable explanation of why bears killed a similar proportion of the calves as were killed by bears in earlier years. These sources of bias include: (1) The sample size in 1979 was small compared with the earlier years ($N = 48$ and 72 collared calves in

1977 and 1978, respectively; (2) the bears were translocated simultaneously with collaring of moose calves so that some collared moose calves were subject to predation by bears not yet caught and removed; and (3) the collared calves in 1979 were situated in a relatively small area where they may have been subject to predation from a few individual bears that were not captured and translocated (an estimated 40% of the total bear population) and that were effective predators on calves. Data on 2 bears that were not translocated but could be individually identified on the basis of size and pelage support this third possible source of bias. These 2 individuals were known to have caused at least 6 of the 12 mortalities of radio-marked calves in 1979. Known minimum kill rates of these 2 identifiable bears were 1 calf moose kill/5.8 and 2.5 bear-days. These minimum rates exceeded the average kill rate of 1 moose calf/11.7 bear-days obtained in 1978, 1981, and 1984 (Ballard *et al.* 1990).

Once moose calves reached approximately 6 weeks of age, they became better able to evade brown bears (Ballard *et al.* 1980a). By 15 August 1979, 5 of 12 (42%) radio-collared translocated bears returned to the study area and by autumn at least 60% of the adult radioed bears had returned (Miller and Ballard 1982a). Subsequent autumn calf:cow ratios returned to approximate pre-translocation levels. This was due in part because addition of the improved cohort as yearlings and 2 year-olds to the adult female segments of the herd would temporarily lower calf:cow ratios because these age classes are less productive (Blood 1974, Markgren 1969). A 60% reduction of bear density during the first 6 weeks following moose parturition was sufficient to significantly improve calf moose survival. Whether lesser reductions in bear density would automatically result in proportional increases in moose survival is unknown and warrants further study.

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