Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Progress Report
1 July 1996-30 June 1997

Population Dynamics of Moose and Predators in Game Management Unit 13

J Ward Testa

Ken Whitten

Grant W-24-5
Study 1.49
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STATE OF ALASKA
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RESEARCH PROGRESS REPORT

STATE: ALASKA **STUDY NO.:** 1.49

GRANT NO.: W-24-5

STUDY TITLE: Population dynamics of moose and predators in Game Management Unit 13

PERIOD: 1 July 1996 - 30 June 1997

SUMMARY

An intensive study site in western Game Management Unit (GMU) 13A, the Nelchina Study Area (NSA), was chosen for detailed study of moose population dynamics. Mortality of adult females there is low, while calf and possibly yearling mortality is high. The low survival of calves to adult age is probably not sustainable long-term because the present adult age structure contains a high proportion of prime-age adults born before and during the peak of moose numbers around 1987. As these adults age, their susceptibility to mortality agents will probably increase (Peterson 1977) and increased calf recruitment will be necessary to offset increasing adult mortality. Studies in the NSA also have shown a relationship between the energy stores of adult female moose, as measured by rump fat thickness, and reproductive performance in both the year before and after the autumn of capture. This was especially apparent between pregnant and nonpregnant cows and was suggested by a trend ($P<0.20$) toward fewer twins among cows with low rump fat measurements. Twinning rates in the NSA (9-21%) were low. Browsing intensity appears also to be high relative to 2 other drainages in Interior Alaska.

Historical trend data indicate the moose population in Unit 13 is at generally high density. Evidence for a population decline is strongest in the northern part of the unit, where cow moose density is approximately 17% below historic highs in 1986-87 and a decline of 30% has occurred in the fall calf:cow ratio. The rate of decline was not as great as the rate of population increase in the 1970s and early 1980s, and there is little evidence the adult female segment of the population has changed in the unit since 1991. With respect to trend count indices to cow moose abundance, Subunit 13A is the most variable subunit in the GMU, making the detection of population trends there difficult. Because changes in the cow moose index were not accompanied by appropriate changes in calf:cow ratios, most of the variability in Subunit 13A is probably related to temporary (interannual) migrations.

Key words: *Alces alces, Canis lupus*, Nelchina, population dynamics, population estimation, predator-prey, radiotelemetry.

TABLE OF CONTENTS

BACKGROUND

Ballard et al. (1991) documented the recent management and ecological history of moose in Game Management Unit (GMU) 13 from 1952-1984. Indices to moose abundance indicated the population underwent a decline from 1963-1976, then an increase through 1984. In recent years the population has stopped growing and has apparently declined since the late 1980s. This research program was undertaken in response to the perceived decline in moose numbers and a regional management priority of maximizing human harvest of moose and caribou in Unit 13. This annual report will summarize research results from 1993/94 to 1996/97.

OBJECTIVES

The objectives of this 5-year research program are to (1) more accurately track the dynamics of the moose population in Unit 13, (2) determine which causal variables (e.g., weather, predation, habitat, hunting) are driving population changes, and (3) help identify possible management strategies to anticipate or halt moose population declines and increase human harvests. In order to accomplish these objectives, I anticipated the following jobs as part of a 5-year core program:

1. Moose captures; condition and reproductive status
2. Moose mortality; temporal patterns and causes
3. Age of first reproduction; radio collars for yearlings
4. Surveys of winter browsing impact
5. Snow-course measurements
6. Wolf density estimates
7. Moose population estimate, trend-counts and composition surveys
8. Analyses of past trend-count data and population modeling
9. Preparation of annual reports and publications

The field objectives could not be met with a unitwide study, so I focused on an area that was logistically manageable, yet would encompass the important elements of the ecosystem. I selected the Nelchina Study Area (NSA) of approximately 4200 km^2 of moose habitat near the townsite of Nelchina in subunit 13A (Fig. 1), primarily because of its proximity to air charter operators for logistic support, relatively high moose densities, and historical importance to consumptive users in southcentral Alaska. The NSA also contains the principle calving area for the Nelchina caribou herd. Vegetation characteristics of the area were described by Skoog (1968). Previous studies in Unit 13 indicated an area this size should encompass 9-45 wolves in at least 3 packs (Ballard et al.1987) and 80-120 independent brown bears (Miller 1990).

METHODS

CAPTURE AND HANDLING OF ADULT MOOSE

Forty adult female moose were captured from March 6-28, 1994 and equipped with VHF radiocollars. Twenty-four more were captured and radiocollared from November 7 to December 12, 1994 and from November 7-10, 1995. Using a helicopter, we darted and captured 20 new adult female moose on November 7-8, 1995 and recaptured 21 collared moose on November 9-10, 1995. Except for 13 moose captured by helicopter net-gun on November 16-17, 1994, we captured all moose by darting with a mixture of carfentinil-citrate and xylazine hydrochloride (Schmitt and Dalton 1987) from helicopters. Blood was collected for pregnancy determination by serum assay for pregnancy-specific protein B (PSPB) (Wood et al. 1986, Rowell et al. 1989, Stephenson et al. 1996), and assays were performed in G. Sasser's laboratory (University of Idaho, Moscow). Serum samples were archived in the Fairbanks laboratory of Alaska Department of Fish and Game (R. Zarnke, pers commun). In collaboration with Gregg P. Adams, theriogenologist from the University of Saskatchewan, I used ultrasonography to measure the maximum thickness of rump fat as an index to body condition in autumn of 1994 and 1995 and winter of 1996 (Stephenson et al. 1993). Transrectal ultrasonography was used in the field to diagnose pregnancy and incidence of twinning *in utero* fall of 1994 and 1995 (Lenz et al. 1993, Stephenson et al. 1995). Eight moose diagnosed as pregnant with twins and 2 that had single fetuses were recaptured by helicopter darting on March 7-

8, 1996 for ultrasound assessment of pregnancy and twinning status, and measurement of rump fat. Statistical tests of categorical data were made with log-linear models (Feinberg 1981), or Chi-square and Fisher's Exact tests for 2 X 2 tables (Statistix, NH Analytical Software). Significance was accepted with $\alpha = 0.05$. Tests involving the effects of rump-fat thickness were one-tailed.

CAPTURE AND HANDLING OF YEARLING MOOSE

Female moose 10-11 months of age were captured by helicopter darting on April 19-20, 1995, April 14-15, 1996 and April 25-26, 1997. These were bled for genetic and serum archive and disease assessment (R. Zarnke, Alaska Department of Fish and Game, Fairbanks). We assessed rump fat thickness by ultrasound and weighed the animals from a portable tripod with a load-cell dynamometer to the nearest kilogram. Numbered, expandable radiocollars (Telonics, Mesa, AZ or Advanced Telemetry Systems, Isanti, MN) were attached.

MOOSE MORTALITY AND REPRODUCTION

Radiocollared moose were tracked in a PA/18 Super Cub aircraft at least once, and usually twice, each month, except from mid May to late June when they were tracked daily and July of 1995-1997 when they were tracked 2-3 times per week. Adult survival was estimated by the staggered entry, Kaplan-Meier estimator (Pollock et al. 1989). Animals were counted as having been alive in a given month if they were tracked after the midpoint of that month and found alive. Fatalities were assigned to the month in which the moose was found dead, unless tracks or other evidence indicated that death was likely before the 1st of that month. Animals were not included in survival analysis in the month of their capture to avoid inclusion of capture-related mortality in the analysis. Telemetry data were pooled across years of the study to provide estimates of annual survival from May to April. Cause of mortality was attributed to a predator if investigation showed evidence of chase or struggle, or if on daily sightings we saw a predator eating a moose that had previously been observed alive.

Daily radiotracking flights, including visual sightings of all adult and 2-year-old moose, were made from mid-May to mid-June to obtain parturition dates and reproductive rates. Survival of calves was estimated by treating calves of collared cows as if they were also radiocollared. Sightability of calves known to be alive (from subsequently being sighted) was lowest in the first 2 months after birth (97% per day), when telemetry flights took place daily (June) or twice weekly (July) and monthly sighting probability approached 1.0. Thereafter, calves were always sighted with the cows unless their disappearance was final and, again, we assumed a sighting probability of 1.0. Survival of calves was calculated from birth to the end of June (months of May and June were pooled in the Kaplan-Meier procedure), then monthly through April. Calf mortality to the end of July was also compared between years by calculating the daily mortality rate (based on the number of calves alive each day) and smoothing the data series using a 7-day running mean. Causes of mortality of calves could not normally be determined, although in some cases a predator or freshly eaten calf carcass was found at the previous day's location of a missing calf, or dead calves were seen alongside the collared adult. Eight dead calves were recovered by helicopter in 1995-97 and gross necropsies were performed by R. Taylor (ADF&G).

Parturition rates were calculated as the proportion of radiocollared females that were sighted at least once with a calf in a given year, given that the female was seen on all flights after calving had begun. Twinning rate was calculated as the proportion of adult females with calves that also had twins when first sighted with a calf. Twinning rate was augmented by observations of uncollared moose with calves during the telemetry flights prior to June 2 of each year and excluding sightings made within 1 km of those made previously. Parts of the NSA not usually overflown during telemetry flights were surveyed from an R-22 helicopter for twinning rate information on June 2, 1995 and May 29, 1996, and June 2-3, 1997.

SNOW-COURSE MEASUREMENTS

We continued to measure snow depths in Unit 13 in cooperation with the Natural Resources Conservation Service (NRCS). Five new sites in the NSA were added in 1994, and a sixth was repaired after many years of disuse. These augmented 3 sites that have been monitored since 1968. Rick McClure (NRCS) compiled and distributed those results to users. Ballard et al. (1991) used the mean snow depth (in inches) measured 3 times from late January to late March in the Susitna River Study Area, north and west of the NSA, as a "Winter Severity Index" (WSI). That index was calculated from 8 snow-course sites in the NSA for 1995 and 1996 and compared with a longer record from 1980-1996 from 3-4 sites in the NSA.

WOLF DENSITY ESTIMATES

Wolf density estimates were made in March 1995, February 1996, and April 1997 by Earl Becker, Biometrician II for Alaska Department of Fish and Game. The NSA was divided into a grid of 101 square sample units of 42 km^2 and classified into strata of low, medium, and high probability of finding wolves or wolf tracks. Border units of uneven shape were combined to keep the area of each to approximately 42 km^2. Area pilots and Alaska Department of Fish and Game biologists familiar with wolf abundance in the area assigned sample units to strata based on habitat quality and tracks seen in previous flights in the area. Surveys were flown in randomly selected quadrats within a few days of fresh snowfall, and tracks were followed to determine both the number of quadrats containing tracks and the numbers of wolves associated with the tracks. The sampling procedure was based on the Sampling Unit Probability Estimator derived by Earl Becker (Becker, Spindler and Osborne, unpubl data). Becker organized the wolf surveys in 1995-96 and calculated density estimates in all three years. Wolves harvested before the surveys, as determined from mandatory reporting forms submitted by trappers and hunters, were added to the survey results to estimate fall density of wolves in the NSA.

CENSUSES, TREND-COUNT AND COMPOSITION SURVEYS

From October 30 to November 5, 1994, a moose census was conducted on the western part of Subunit 13A in areas under 1230 m in elevation. The area included all of the NSA, plus an area of approximately 200 km^2 in the extreme NW of Subunit 13A that lies just outside the main study area. The total area was approximately 4400 km^2. We drew sample units of approximately 40 km^2 on a map of the area, choosing boundaries that could be easily identified from the air. The statistical method used was a modification of Gasaway et al.(1986) that employed a probability regression procedure (J. Ver Hoef and E. Becker, unpubl data) to relate low-intensity "stratification" counts made by observers in a Cessna 185 on one day to intensive counts made by pilot/observer teams in PA/18 aircraft the following day. Rather than classifying these sample units into strata of different moose densities (Gasaway et al. 1986), regression analysis was used to estimate the relationship between counts from the C-180 and more intensive (complete) counts from the PA/18 and then estimate the number of moose in sample units not surveyed by the PA/18 crews. Sightability correction factors were determined on the intensive sample units by resurveying a 2.6 km^2 subunit at higher intensity (Gasaway et al.1986).

Trend-count surveys to index moose abundance and determine herd composition are routinely made for management purposes in traditional Count Areas (CAs) around Unit 13, and 2 of these occur in the NSA (Fig. 1). As part of this study, surveys from PA/18 aircraft were made in CAs 13 and 14 in October 1994 and from 14-16 November 1995. The search procedure entailed a systematic search by a pilot and observer at 50-150 m height above ground level in a pattern chosen by the pilot for safety and efficient search coverage. When moose were spotted, the pilot circled the group to identify sex and age composition. We identified and counted in each group calves, cows, yearling bulls (identified by antler size), and adult bulls. Management reports from the area commonly standardize these counts by reporting moose per unit of time searched (moose/hour), or per unit of area searched, which can be used as an index of moose abundance.

ANALYSES OF PAST TREND-COUNT DATA

This is an ongoing task of exploratory data analyses and modeling. The most continuous record of moose abundance in Unit 13 is the series of counts made in autumn of traditional count areas. The boundaries for these units are shown in Fig. 1, but early surveyors (before 1980) often shifted boundaries in an effort to get larger counts and, therefore, better composition information. For this reason, we only considered counts from 1980 onward. The trend count database for Unit 13 is current, but analyses are preliminary. The traditional use of these data has focused on moose per hour of counting as an indicator of moose population size in the game management unit. Moose counted per unit area show very similar trends, but slightly higher yearly variability. Bull/cow ratios and calf/cow ratios vary substantially from year to year, due to harvest of bulls and annual changes in calf recruitment. Because these may tend to obscure multiannual trends in the demography and because cow moose are the most important segment to population growth, my approach is to emphasize the adult females in population analyses. Because they can more easily be compared to population estimates and appraised for sighting probabilities, I will present trend count data as moose or cows per km^2.

Only Count Areas 3, 5 and 6, in the northern part of Unit 13, and count area 13 in the western part have been surveyed each fall from 1980 to 1996. Count Areas 10 and 16 were surveyed all years except 1989, and the data series for CA 15 excluded years 1992 and 1995. Count Area 14 was surveyed in 1980, 1984-88, and 1991-96. CA 7 was surveyed in 1980-86, 1990-92 and 1995-96. Other parts of Unit 13 have been surveyed for moose numbers and composition, but I included only those surveyed at least 10 of the past 16 years.

Summaries presented in this report were based on cow moose per km^2. Because moose density, habitat quality, and size of each CA differ, and population trends are of the most interest, the moose count data from each CA were standardized by subtracting the mean value for that CA from 1980-1995. These "deviations from the mean" will be graphically illustrated. In order to pool different CAs and report subunit trends, the deviations from the mean were weighted by the size of each CA in the subunit. Because CAs 3 and 10 straddled subunit boundaries, they were weighted by half their area and included in both the subunits. Composition in the subunits was based on all moose seen in the respective CAs, except for CA 7 and CA 10, where totals were divided evenly between subunits sharing that CA.

RESULTS

Reproduction

Among 40 moose captured and released in March 1994, 35 (88%) were pregnant. During daily flights, we observed only 25 of these with calves the following May and June. The apparent decline in reproductive rate from 88% to 63% in the last 2 months of gestation is unusual. Parturition rates from 1994-1996 also differed significantly among years (P = 0.01), with 1994 being a negative outlier (Table 1). Subjective condition scores assigned to the animals in March 1994 (Franzmann 1977) were significantly lower (P<0.01) among the pregnant animals that were not subsequently seen with calves. It is not known whether the offspring were lost before or during the normal calving period. From 1995-97, adult calving averaged 86% ($s_{\bar{x}}$= 3%). Twinning rate in the NSA from 1994-97 was low (14.8%, $s_{\bar{x}}$= 1.7%) and differences among years were not significant (P = 0.09). Thus far, primiparity has been observed in none of 14 two-year-old moose and in 3 of 5 three-year-old moose.

Among 64 moose captured in November-December of 1994 and 1995, pregnancy status was determined by ultrasound examination in 62. Of 48 pregnant females sufficiently progressed in pregnancy for reliable fetus counts with ultrasound, 13 (27%) were carrying twins. Ten of these were followed the subsequent spring, and 8 gave birth to twins. One (#84) was seen only with a single calf, which died within 1 day. The following year she was not handled but gave birth to twins, both of which died within 2 days. In 1997 her single calf also died within 2 days of birth. Gross necropsies were performed on all 4 calves. They were of normal birth weight, but there was no discernible cause of death. The second female not seen with calves appeared pregnant in early June and made movements toward an alpine area typical of calving habitat for moose in the area but suddenly moved back to her normal home range and no longer appeared pregnant. We believe she gave birth and lost or abandoned her calf or calves within a few hours. Twinning rate determined *in utero* in fall (27%) was significantly greater (P<0.001) than that observed at parturition (13%, Table 1) in independent samples.

Analyses of the relationship between rump fat thickness and reproductive parameters were presented by Testa and Adams (see Appendix) and summarized here. Rump fat thickness, pregnancy rate, and embryo size were significantly less among female moose with a calf "at heel" in the autumn. Fifteen per cent of ovulations failed to result in a detectable embryo, and further reproductive losses occurred between early gestation, late gestation, and birth. Body condition in the autumn was positively correlated with pregnancy and calving rates, and negatively correlated with both early and late reproductive failures and with neonatal mortality. Thus, as in other northern cervids, body condition in moose is negatively correlated with current reproductive success and is, in turn, correlated with subsequent reproductive performance. This work is unique in documenting the extent to which body condition and prior reproductive success of an individual affect reproduction within a single reproductive cycle, resulting in differences between rates of ovulation, pregnancy, birth, and recruitment. Some management consequences of these relationships were modeled for a separate publication (see Appendix).

Mortality

Average annual survival after 4 years of study was 0.95 for radiocollared females (Table 2). Numbers dying in each year were too low to reliably test for statistical differences among years.

Five adults were killed by brown bears during the calving season, 4 were killed by wolves in late winter, 1 from either wolves or bear in fall, 1 died in March, apparently from a hip injury the previous January that left her unable to stand, and 1 died from an unknown cause in late winter. An additional female, not included in the survival analysis, was killed legally by a hunter in September 1994.

Survival of radiocollared yearling females from May to April was 0.79, but the small sample size causes poor precision in this estimate. (Table 3). Six yearlings were found dead; brown bear predation was the cause of 3 deaths, and probable cause of a fourth. From the air we observed the fifth yearling, dead without visible injury or attendant predator; however, the next day we observed a feeding brown bear at the site. Similarly, the sixth was observed dead in a lake without discernible injuries but had a feeding brown bear on it within a day. The 6 fatalities were not unusual in weight among those radiocollared. Most adult females quickly became reassociated with their yearlings if their calf of that year was lost. However, all yearling mortality occurred among yearlings not accompanied by their mother. Thus, it appears that maternal care can enhance yearling survival.

Most calf mortality occurred in the first month after parturition. The temporal pattern of calf mortality to the end of July, compared among years, is shown in Figure 2. Average annual survival of calves (Pollock et al. 1989) was 0.24 (Table 4).

Snow Course Measurements

The winter snow index (WSI) on the NSA was 28 in the winter of 1994/95, 17 in 1995/96 and 24 in 1996/97. By definition (Ballard et al. 1991), the winter of 1994/95 just exceeded the threshold for a "severe" rating (WSI = >28) in the NSA, whereas 1995/96 was "mild" (WSI = <18) and 1996/97 was "moderate." The longer term record from 3-4 sites on the NSA indicates that WSI in the last 16 years has occasionally exceeded 28 but never exceeded 29 (Fig.3). More extreme values were noted by Ballard et al. (1991) for Unit 13, indicating somewhat milder conditions in Subunit 13A.

Jay Ver Hoef (ADF&G, Fairbanks) is analyzing statewide snow-course data and has produced a statistical model for data through 1993. The model output is a spatial map of snow depths for most of the state, including the NSA in Subunit 13A-West. Within this framework, it should be possible to evaluate snow depth from the perspective of total habitat available below certain snow-depth thresholds. Future analyses will focus on mean snow depths and total area of moose habitat with depths < 71cm (WSI<28).

Wolf Density Estimates

Late winter estimates of wolf density differed substantially among the 3 years from 1994/95 to 1996/97 (Table 5) due to the small annual harvest in 1995/96. Effects of temporary emigration (2 known packs) were greater in 1994/95 but involved only 2-3 wolves/1000 km^2. Fall densities differed little between years, but due to the low, late harvest in the 1995/96 winter, average wolf density was greater in that winter. Several wolf-killed or injured moose calves were seen near wolves during the wolf-estimation flights of 1995/96.

Moose Population Census and Trend-Counts

The moose census in November 1994 yielded an estimate of 0.81 moose/km^2 and 0.60 cows/km^2 in the NSA (Table 6). The number of moose seen per flight hour and per km^2 during trend-count surveys declined from 1994 to 1996 (Table 6). However, it is not clear that the observed difference represents a real change in population density because survey conditions were fair to poor in both 1995 and 1996 due to poor snow cover. There were no changes in mortality or recruitment estimates, or in composition of the counts (Table 6), that would explain a population decline. A significant ($P = 0.01$) increase in the proportion of cows with calves occurred in the trend-count areas, but this change was ambiguous, given the calf:cow composition during the population estimate of 1994 was higher than the trend-count composition of that year and virtually identical to the trend-count composition of 1995 (Table 6). It is expected that cows with calves, being more solitary, would be more easily missed in trend-count surveys than in the more intensive moose estimation surveys. The difference in calves/100 cows between surveys in 1994 probably reflects this bias in methods. The conclusion that the calf:cow ratio, measured by comparable methods, had improved in 1995 is valid, though the magnitude of that increase was not great.

LONG-TERM TREND-COUNT SUMMARIES

Trend-count data for CA 13 and CA 14 are summarized in Fig. 4. The extraordinary yearly variation in the index to cow moose density (cows/km^2 minus the 15-year mean) is more than is expected to result from natural dynamics of a closed population. For this reason, migration must play a substantial role in sudden changes of moose abundance in the area. This is especially apparent in the unusual counts of 1983 and, especially, 1987, which have had substantial influence on interpretations of total moose numbers in Unit 13. These sharp "spikes" in the index to moose abundance were accompanied by weak declines in calves/100 cows, a feature expected if cows with calves were less likely to move than lone moose. The sharp decline in the cow index in 1995 was strongly influenced by poor survey conditions and is an unreliable indicator of real population decline. Fall composition surveys showed no indications that sharp changes in moose abundance were accompanied by appropriate changes in recruitment.

Changes in bull/cow ratios have followed changes in the harvest regime, which targets bulls and involved a hiatus on adult bull harvest from the late 1980s to 1992. There was limited protection for 2- to 3-year-old bulls via selective "spike-fork or 50 inch" antler restrictions when the season reopened in 1993, but harvest rates were high and the bull/cow ratio sharply declined. Calf recruitment in recent years has been below the long-term average and substantially below the highest values seen in the area. This is in accord with the high calf mortality seen in calves of radiocollared cow moose in the NSA, particularly in 1994 and 1995, and is a possible warning of pending changes in age structure and moose abundance.

Direct estimates of moose abundance were made in CA 14 in 1983 (Ballard et al. 1991) and in the western half of Subunit 13A in 1987 and 1993. The estimated density of moose in 1983 in CA 14 was nearly identical with that for the NSA in 1994, but the estimate in 1987 was 55% higher than either value. While this might be considered evidence for a peak in 1987 substantially above population levels now, the trend count data indicate the elevated density estimate in 1987 was the result of a sharp annual influx of moose that was reversed the following year and not a legitimate baseline on which to manage the population.

Moose density indices and total area differ substantially among CAs (Table 7). Differences from the mean are shown graphically in Fig. 5 for each of the subunits of Unit 13 for which we have significant CA data. I have omitted Subunit 13D because the CA for which we have data (CA 15) is small (924 km^2) relative to the size of the subunit and may be misleading about the status of Subunit 13D. In comparison to the rest of Unit 13, the NSA (Subunit 13A in Fig. 5) showed the most yearly variation in indices to moose abundance. From 1980-86, when CA 7 was included, Subunit 13E showed a tendency to vary in an opposite direction to Subunit 13A. CA 7 lies immediately north of CA 14 in Subunit 13A, probably sharing moose that occasionally change location. There are no traditional CAs in the portion of Subunit 13D that borders the CAs of Subunit 13A, so with present data we cannot test the hypothesis that yearly variation in the counts in Subunit 13A result from movements of moose across that boundary. Radiotracking of moose captured in the southern part of the NSA indicate some movements to Subunit 13D.

Trends in population density in Subunits 13B and 13C show much less annual variability and a fairly clear increasing trend until the late 1980s, followed by a small decline and relative stability for the last 5-6 years of the series. Subunit 13B (Fig. 6) has the most stable series of cow density indices, possibly due to the large proportion of the subunit that lies within trend count areas. The decline from the peak in cows observed in the subunit coincided with a decline in recruitment, evidenced by the drop in the proportion of cows with calves after 1988 (28% to 20%, $P < 0.005$). In Subunit 13C, the CAs comprise a small proportion of the subunit (Fig. 1), and there is more annual variation in composition and the cow density index than in Subunit 13B. However, the pattern in cow moose abundance is similar to that in Subunit 13B, and there was a drop in the proportion of cows with calves after 1988 (24% to 21%, $P = 0.04$). The pattern for Subunit 13E is probably not reliable because only CA 3, small in area and shared with Subunit 13B, was counted during the years the counts peaked in the other subunits. Trends in harvest density of moose in Subunits 13B and 13C also show a decline since the late 1980s, while harvest density increased in Subunit 13A following a hiatus on adult bull harvest.

PREPARATION OF REPORTS AND PUBLICATIONS

The following technical papers were presented at the 4th International Moose Symposium in Fairbanks this year and submitted as articles to two professional journals. Abstracts are given in Appendix.

TESTA, J.W. AND G.P. ADAMS. *Body condition and adjustments to reproductive effort in female moose (Alces alces)*. Poster presentation at Moose Symposium submitted to *Journal of Animal Ecology.*

TESTA, J.W. *Compensatory response to changes in calf survivorship: management consequences of a reproductive cost in moose*. Oral presentation at Moose Symposium and submitted to *Alces*.

DISCUSSION

The status of moose in Unit 13 is of great interest to public user groups and resource managers in the state. Historical trend data indicate the population is at generally high density. The evidence for a population decline is strongest in the northern part of the unit, where cow moose density is approximately 17% below historic highs in 1986-87 and the fall calf/cow ratio since 1988 is 30% less than that observed before 1988. The rate of decline was not as great as the rate of population increase in the 1970s and early 1980s, and there is little evidence the adult female segment of the population has changed in the unit since 1991. With respect to trend count indices to cow moose abundance, Subunit 13A is the most variable subunit in the GMU. Because changes in the cow moose index were not accompanied by appropriate changes in calf:cow ratios, this variability must be related to temporary (interannual) migrations of moose in Subunit 13A. While composition data from that area seem fairly stable and consistent with studies of calf mortality and changes in hunter harvest, they are probably representative of an area larger than that defined by the boundaries of the NSA and subunit. Similarly, the cessation of large swings in the count index since 1989 may reflect a decline in moose abundance and migration from adjacent areas.

Studies in the NSA have shown a relationship between the energy stores of adult female moose, as measured by rump fat thickness, and reproductive performance in both the year prior and year after the autumn of capture. Franzmann and Schwartz (1985) suggested that spring twinning rate is an indication of nutritional status of a moose population, and Gasaway et al. (1992) compiled evidence that moose near a resource-dependent carrying capacity may have low twinning rates. Twinning rates in the NSA (9-21%) were among the lowest recorded for moose (Gasaway et al. 1992), while twinning rates in the rest of Unit 13 in recent years were higher, but not above average (23-40%; R. Tobey, pers commun and J.W. Testa, unpublished data). In the NSA browsing intensity seems high relative to 2 other drainages in Interior Alaska (K. Keiland, pers commun). Two conclusions are relevant to moose in Unit 13. In the NSA, where moose densities are high and possibly stable, there is a moose-vegetation interaction that may have reduced moose productivity relative to that of moose in other parts of the unit. Indications of moose nutritional status elsewhere in the unit are no better than average.

Mortality of adult females is low, while calf and possibly yearling mortality is high. The low survival of calves to adult age is probably not sustainable because present adult age structure contains a high proportion of prime-age adults born before and during the peak of moose numbers in 1987. As these adults age, their susceptibility to mortality agents will probably increase (Peterson 1977), and increased calf recruitment will be necessary to offset increasing adult mortality.

The current rate of calf mortality in the NSA has been higher that that observed by Ballard et al. (1991), although the timing of mortality (almost all in the first 60 days) has been similar. Sightings of brown bears, often on moose kills in the spring, are high and support the assertion that brown bears remain the principal cause of calf mortality in the NSA and probably in the remainder of Unit 13 (Ballard et al. 1991). Brown bears also killed more adults than any other causative agent observed so far, although the number of adults dying was low. Assuming no major change in moose numbers occurred from 1994 to 1995 and using the average overwinter wolf densities, moose/wolf ratios in the NSA were approximately 123 in 1994/95, 82 in 1995/96, and 98 in 1996/97. Both are well above the densities at which Gasaway et al. (1983) suggested that wolves can limit moose populations but probably within the range at which all predators can limit the moose population (Gasaway et al. 1992). However, the combined effects of wolves and bears in a site where caribou are also abundant remain a matter of speculation (Gasaway et al. 1992). Bears appear to have a greater effect on moose calf survival in the NSA and Unit 13 than do wolves, and the effect of bears on moose population dynamics would be delayed when acting through persistently poor recruitment rather than directly through adult mortality. As such, the expected trajectory of a moose population preyed upon most heavily by bears may follow a slow decline, rather than a rapid one.

The management of predator numbers for the purpose of increasing human harvest of moose and caribou in Alaska is a matter of heated debate. In Unit 13 the Board of Game has modified harvest regulations to increase the take of brown bears in order to increase moose calf survival. An increase in calf survival will be necessary to increase moose in areas where that is the objective and to offset an expected increase in the mortality of aging adults, although that increase has yet to be seen. Because of the feedback loop between calving success and energy stores of adult female moose, increases in calf survival to autumn that may follow reductions in predator populations could result in compensating decreases in calving and/or twinning rates. Given the high densities and low productivity of moose in some parts of the unit (notably Subunit 13A) and average productivity in areas where moose have declined, care must also be taken to ensure moose densities are not allowed to increase beyond a supportable range. Predator impact is relatively gender neutral and distributed fairly evenly over the moose population. If management actions successfully reduce predation pressure on moose, human harvest of moose "released" from predation pressure should mimic normal predator impact as much as possible to avoid local irruptions or overharvest of the moose population.

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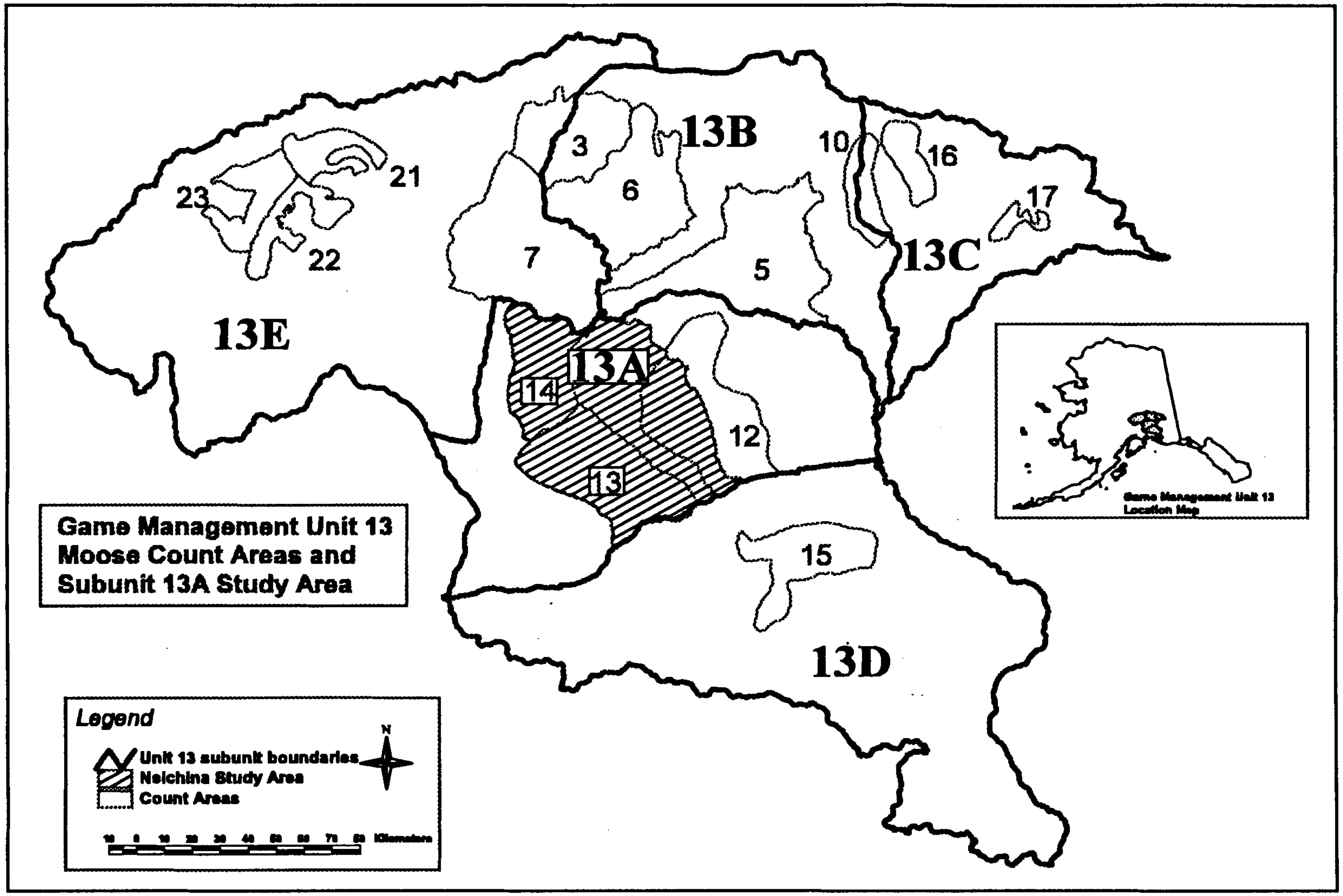


Figure 1. Map of Game Management Unit 13 showing location of trend count areas for moose.

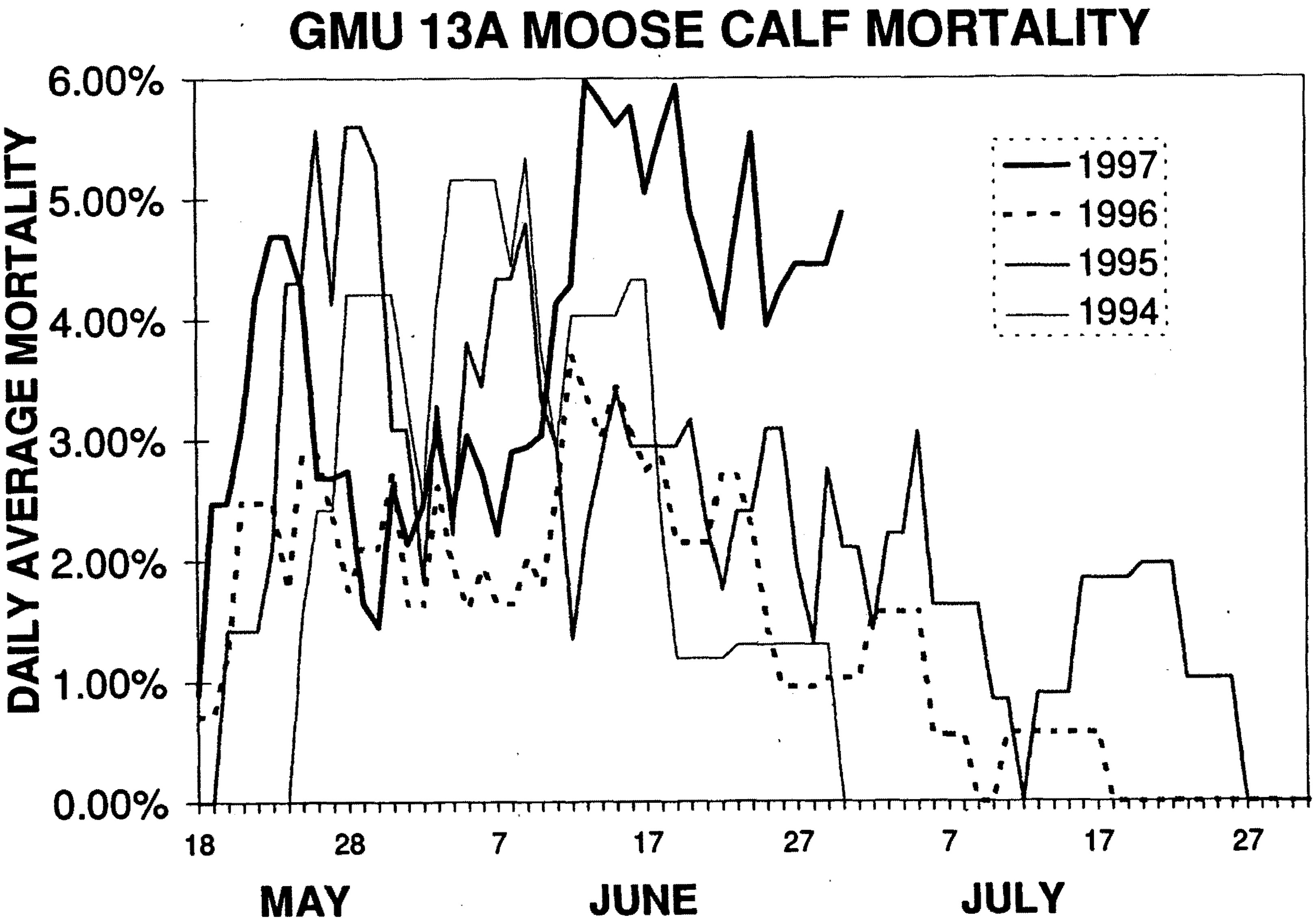


Figure 2. Seven-day running average of daily mortality rate of moose calves in the Nelchina Study Area in spring 1994-1996.

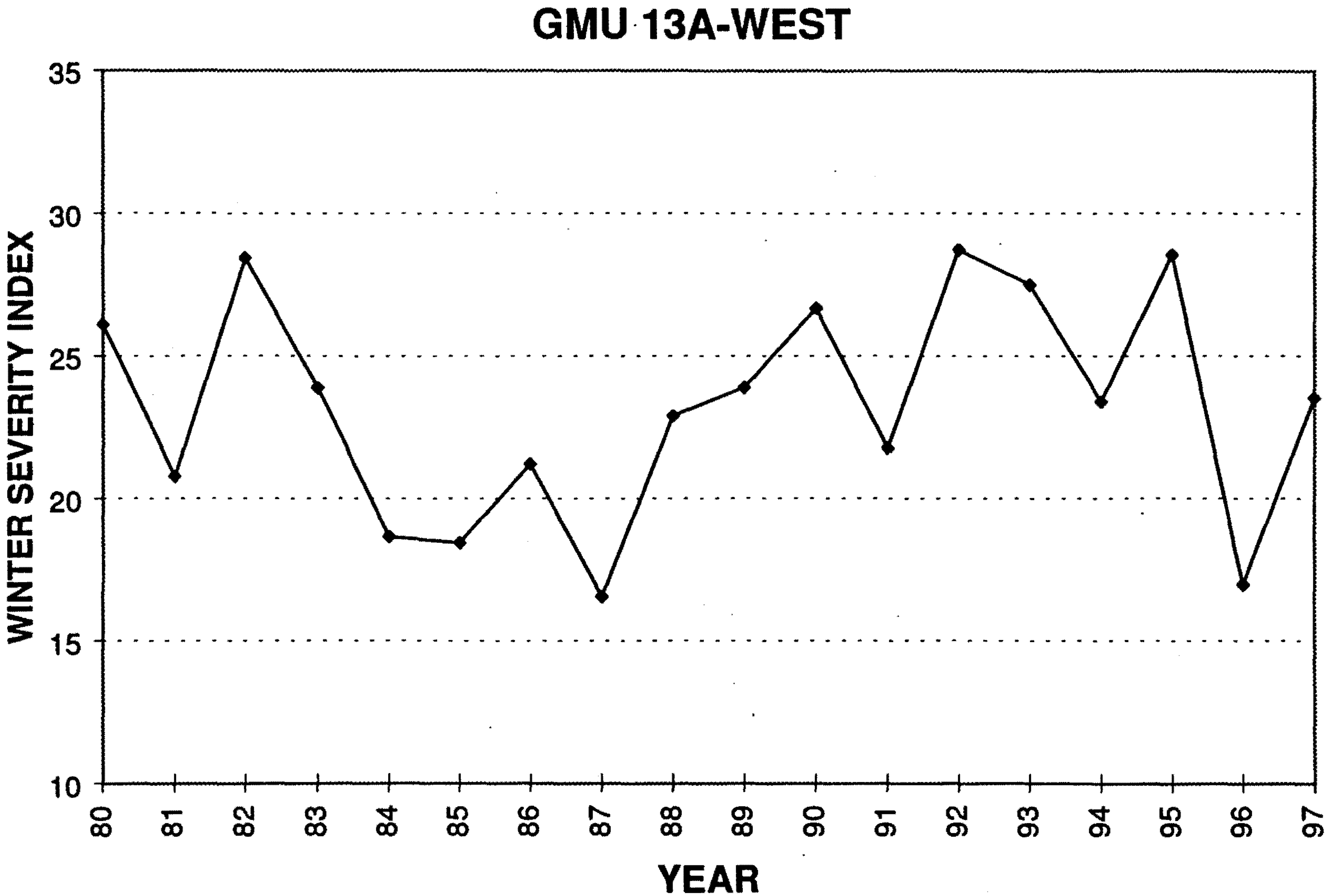


Figure 3. Annual index to winter severity in western GMU 13A from 1980-97.

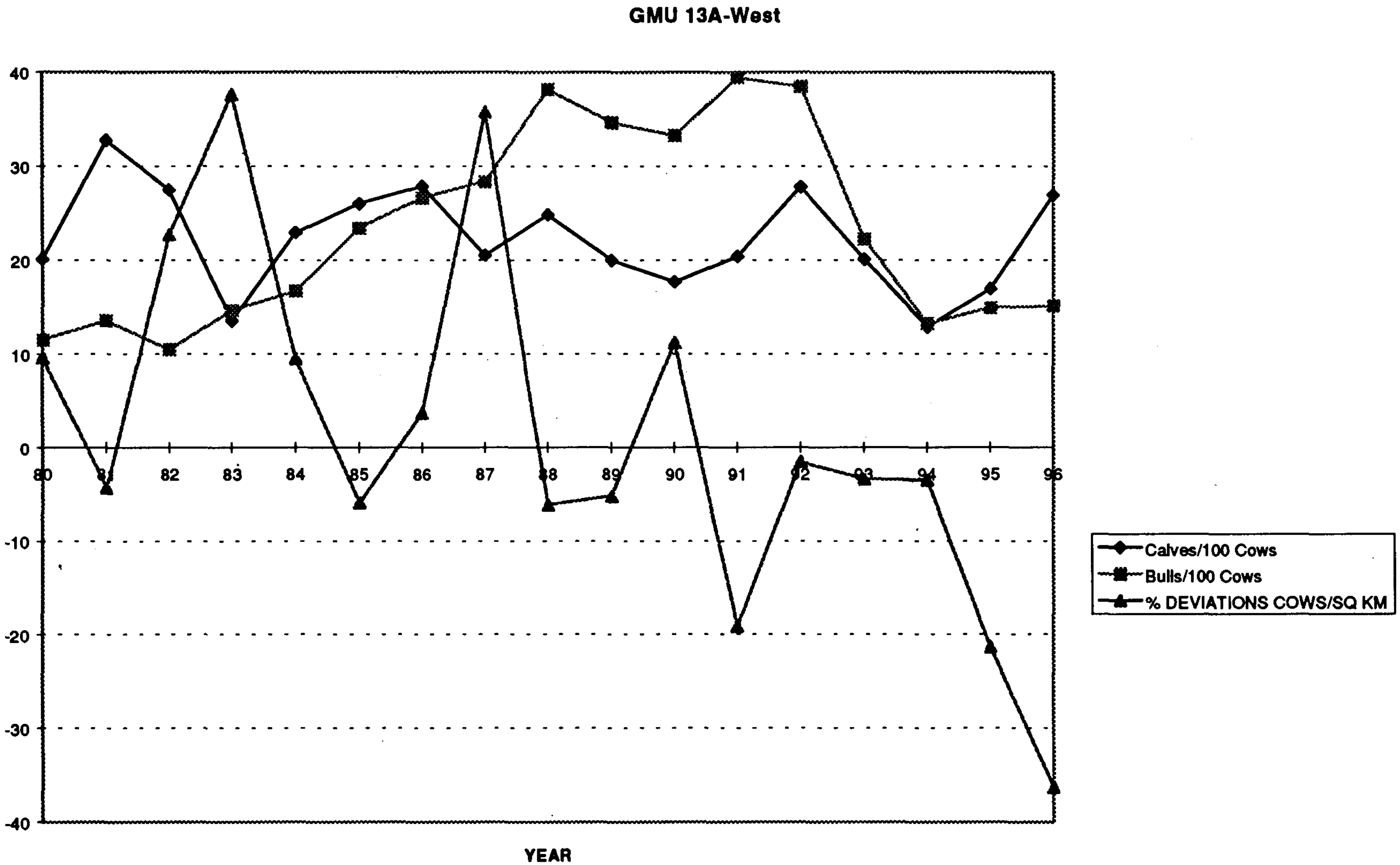


Figure 4. Fall composition apparent density of cow moose in the Nelchina Study Area from 1980-1996. Low counts in 1995 and 1996 were at least partially due to poor counting conditions during the survey, while composition estimates should be unaffected.

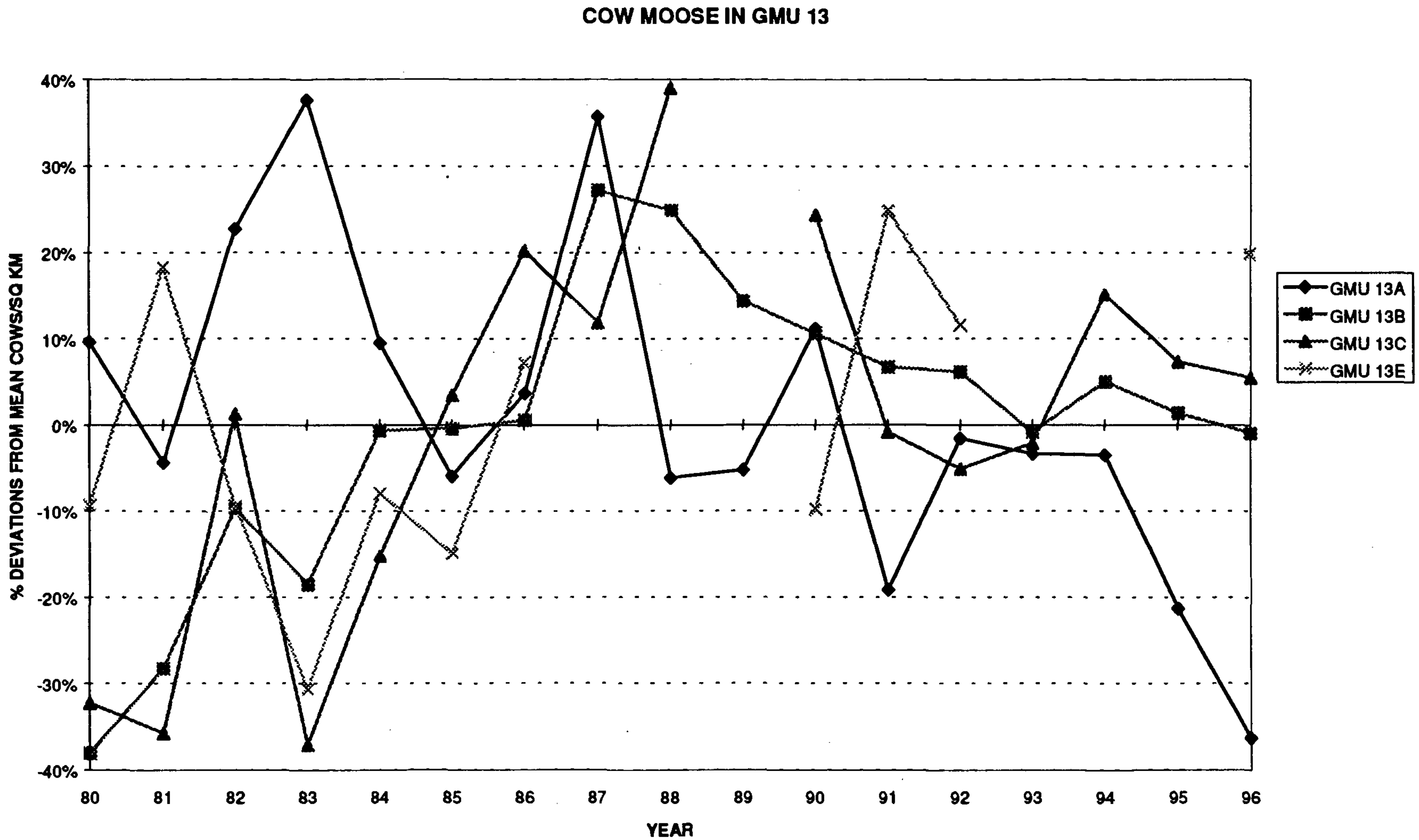


Figure 5. Annual deviations from the mean index (1980-1996) of cows/km^2 in the major subunits of Unit 13.

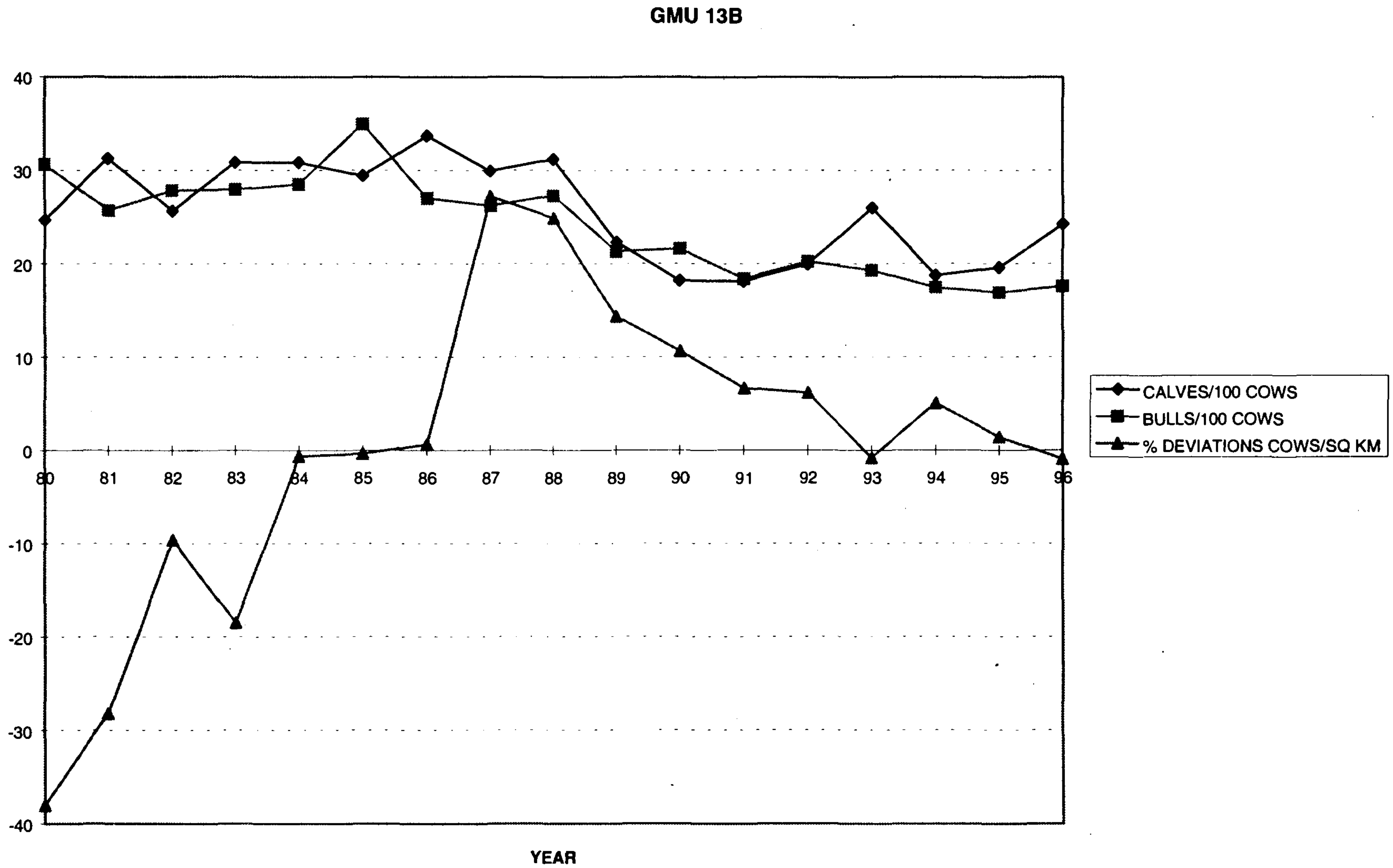


Figure 6. Fall composition and annual deviations from the mean index of cow moose/km^2 in GMU 13B from 1980-1996.

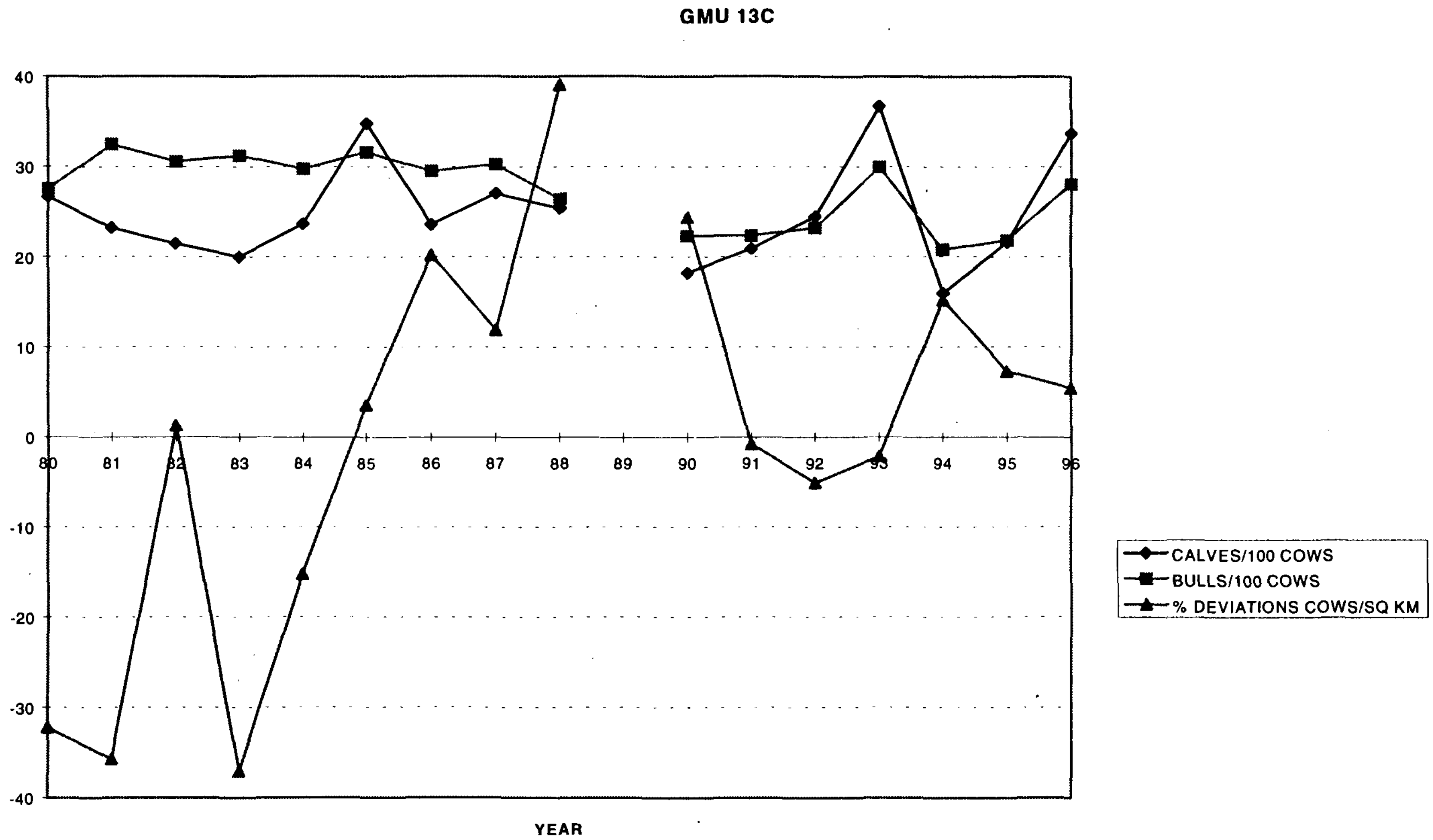


Figure 7. Fall composition and deviations from the mean index value of cow moose/km^2 in GMU 13C from 1980- 1996

Table 1. Rates of parturition and twinning in Unit 13A (sample size in parentheses).

Year	Parturition Rate (*n*)	Twinning Rate (*n*)
1994	63% (40)	9.1% (77)
1995	86% (58)	12.1% (116)
1996	88% (68)	15.0% (140)
1997	84% (50)	21.0% (113)

Table 2. Average monthly survivorship (Pollock et al.1989) of adult female moose in Unit 13A derived from data collected from April 1994 through June 1997.

Month	At Risk	Deaths	Survival	Lower 95%	Upper 95%
5	254	0	1.00	1.00	1.00
6	252	5	0.98	0.96	1.00
7	174	0	0.98	0.96	1.00
8	172	0	0.98	0.96	1.00
9	171	0	0.98	0.96	1.00
10	173	1	0.97	0.95	1.00
11	192	0	0.97	0.95	1.00
12	202	0	0.97	0.95	1.00
1	208	0	0.97	0.95	1.00
2	206	0	0.97	0.95	1.00
3	206	1	0.97	0.95	0.99
4	242	5	0.95	0.92	0.98

Table 3. Average monthly survivorship (Pollock et al.1989) of yearling female moose in Unit 13A derived from data collected from April 1995 through June 1997.

Month	At Risk	Deaths	Survival	Lower 95%	Upper 95%
5	33	1	0.97	0.91	1.00
6	31	4	0.84	0.73	0.96
7	16	0	0.84	0.68	1.00
8	16	1	0.79	0.61	0.97
9	14	0	0.79	0.61	0.98
10	15	0	0.79	0.61	0.97
11	15	0	0.79	0.61	0.97
12	15	0	0.79	0.61	0.97
1	16	0	0.79	0.61	0.97
2	15	0	0.79	0.61	0.97
3	16	0	0.79	0.61	0.97
4	16	0	0.79	0.61	0.97

Table 4. Average monthly survivorship (Pollock et al. 1989) of calves of radiocollared moose in Unit 13A derived from data collected from May 1994 through June 1997. Survival in months 5-6 is an estimate from parturition to the end of June.

Month	At Risk	Deaths	Survival	Lower 95%	Upper 95%
5-6	214	139	0.35	0.32	0.38
7	59	11	0.29	0.23	0.34
8	48	2	0.27	0.22	0.33
9	46	0	0.27	0.22	0.33
10	47	0	0.27	0.22	0.33
11	53	1	0.27	0.22	0.32
12	55	0	0.27	0.22	0.32
1	56	0	0.27	0.22	0.32
2	56	2	0.26	0.21	0.31
3	67	1	0.26	0.21	0.30
4	64	4	0.24	0.19	0.28

Table 5. Estimated density of wolves (per 1,000 km^2) in the Nelchina Study Area. In 1994/95, essentially all harvest took place prior to the population estimate in March. In 1995/96, due to unusually late snowfall, a harvest of 1.22 wolves/1,000km^2 took place after the population estimate in February.

Year	Estimate	90% C.I.	Pre-Survey Harvest	Fall Density
1994/95	4.5	(3.2-6.9)	4.2	8.7
1995/96	9.9	(9.7-11.3)	0.0	9.9
1996/97	6.2	(5.5-9.3)	4.1	10.3

Table 6. Results of surveys during a 1994 population estimate of the Nelchina Study Area (top row), and during trend-count surveys in Count Areas 13 and 14 within the Nelchina Study Area from 1994-96. Apparent densities of the trend-count surveys (rows 2-4) are not corrected for moose sightability, so are minimum estimates.

Year	Moose/hr	Cows/hr	Moose/ km^2	Cows/km^2	Calves/ 100 Cows	Bulls/ 100 Cows
1994 NSA Estimate	-	-	0.81	0.60	17.1	16.8
1994	60.5	48.0	0.50	0.40	12.8	13.2
1995	35.0	26.5	0.43	0.32	17.0	14.9
1996	33.1	23.3	0.37	0.26	26.9	15.1

Table 7. Count Area (CA) and average count indices observed in aerial surveys from 1980-1995. Survey flights were not intended to estimate actual densities, so values obtained each year were minimum moose densities.

CA	Area(km^2)	Moose/km^2	Cows/km^2	Moose/hr	Cows/hr
3	1103	0.42(0.06)	0.29(0.05)	66.8(15.6)	45.7(10.3)
5	2130	0.80(0.17)	0.53(0.10)	64.4(13.5)	42.4(6.8)
6	1677	0.46(0.11)	0.31(0.08)	71.0(12.5)	47.4(9.0)
7	2215	0.49(0.07)	0.33(0.06)	55.9(8.6)	37.8(5.8)
10	423	0.82(0.19)	0.56(0.14)	85.5(16.7)	58.4(11.9)
13	1594	0.61(0.10)	0.43(0.08)	64.6(13.0)	45.0(8.7)
14	968	0.61(0.16)	0.41(0.09)	64.8(15.0)	42.7(8.6)
15	924	0.19(0.04)	0.11(0.03)	35.5(9.0)	20.4(5.7)
16	341	0.48(0.13)	0.29(0.07)	47.4(13.6)	36.3(7.7)

APPENDIX SUMMARY AND ABSTRACT OF SUBMITTED PAPERS

TESTA, J.W. AND G.P. ADAMS. Body condition and adjustments to reproductive effort in female moose (*Alces alces*). Poster presentation submitted to *Journal of Animal Ecology*.

SUMMARY

1. We used ultrasonography in autumn and winter to determine reproductive features of moose in early and mid gestation and intensive radiotracking in spring to measure rates of calving and neonatal survival. Ultrasonography also was used to measure maximum rump fat thickness as an index of body condition.
2. Rump fat thickness, pregnancy rate and embryo size were significantly less among female moose with a calf "at heel" in the autumn.
3. Study of individuals determined that 15% of ovulations failed to result in a detectable embryo and that further reproductive losses occurred between early gestation, late gestation, and birth.
4. Body condition in the autumn was positively correlated with pregnancy and calving rates and negatively correlated with both early and late reproductive failures and neonatal mortality.
5. As in other northern cervids, body condition in moose is negatively correlated with current reproductive success and is, in turn, correlated with subsequent reproductive performance. Our study differs from others by documenting the extent to which body condition and prior reproductive success of an individual affect reproductive decisions within a single reproductive cycle, resulting in differences between rates of ovulation, pregnancy, birth, and recruitment.

Key words: body condition, gestation, juvenile survival, reproductive cost, ultrasonography

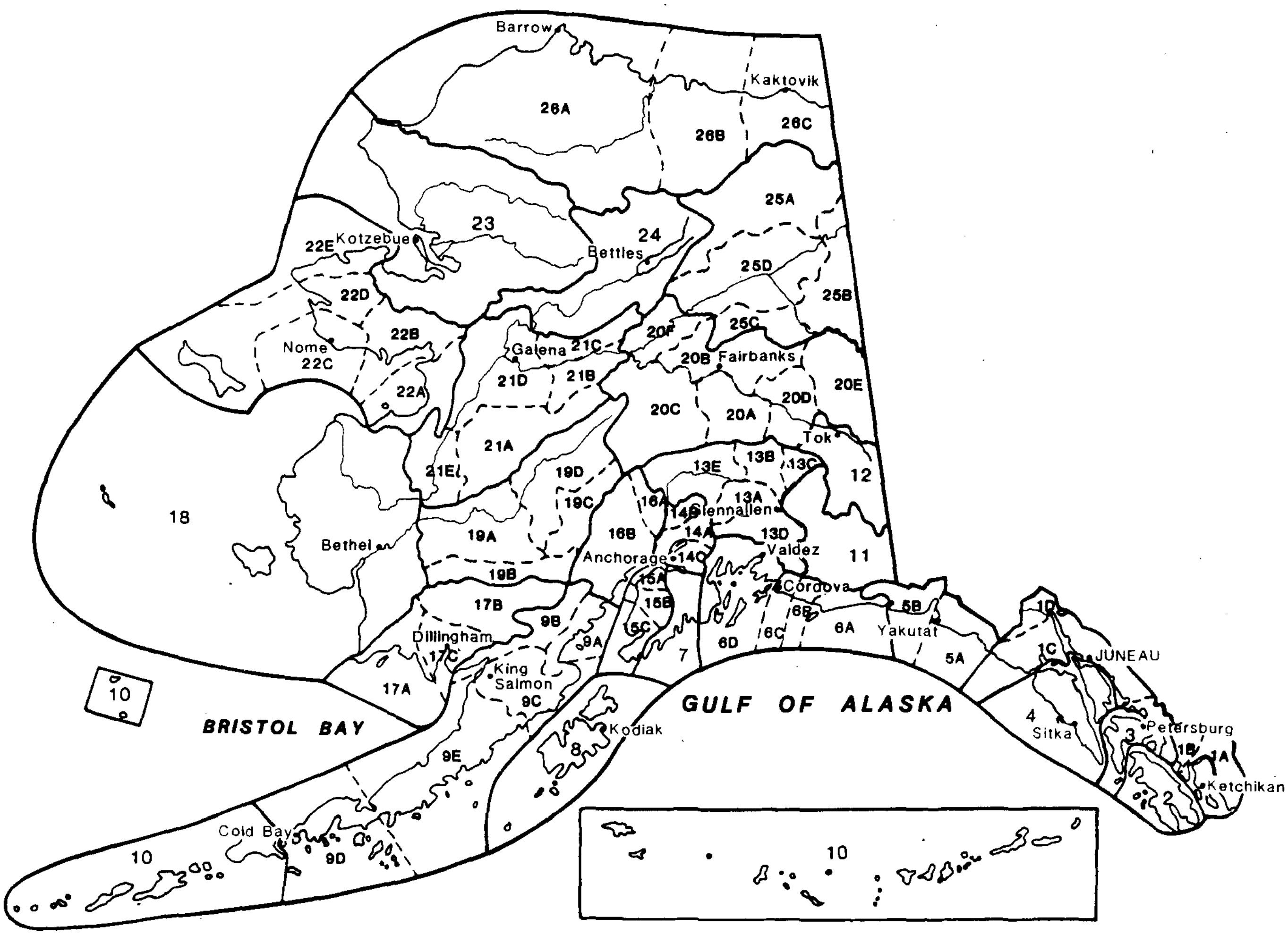
TESTA, J.W. Compensatory response to changes in calf survivorship: management consequences of a reproductive cost in moose. Oral presentation submitted to *Alces*.

ABSTRACT

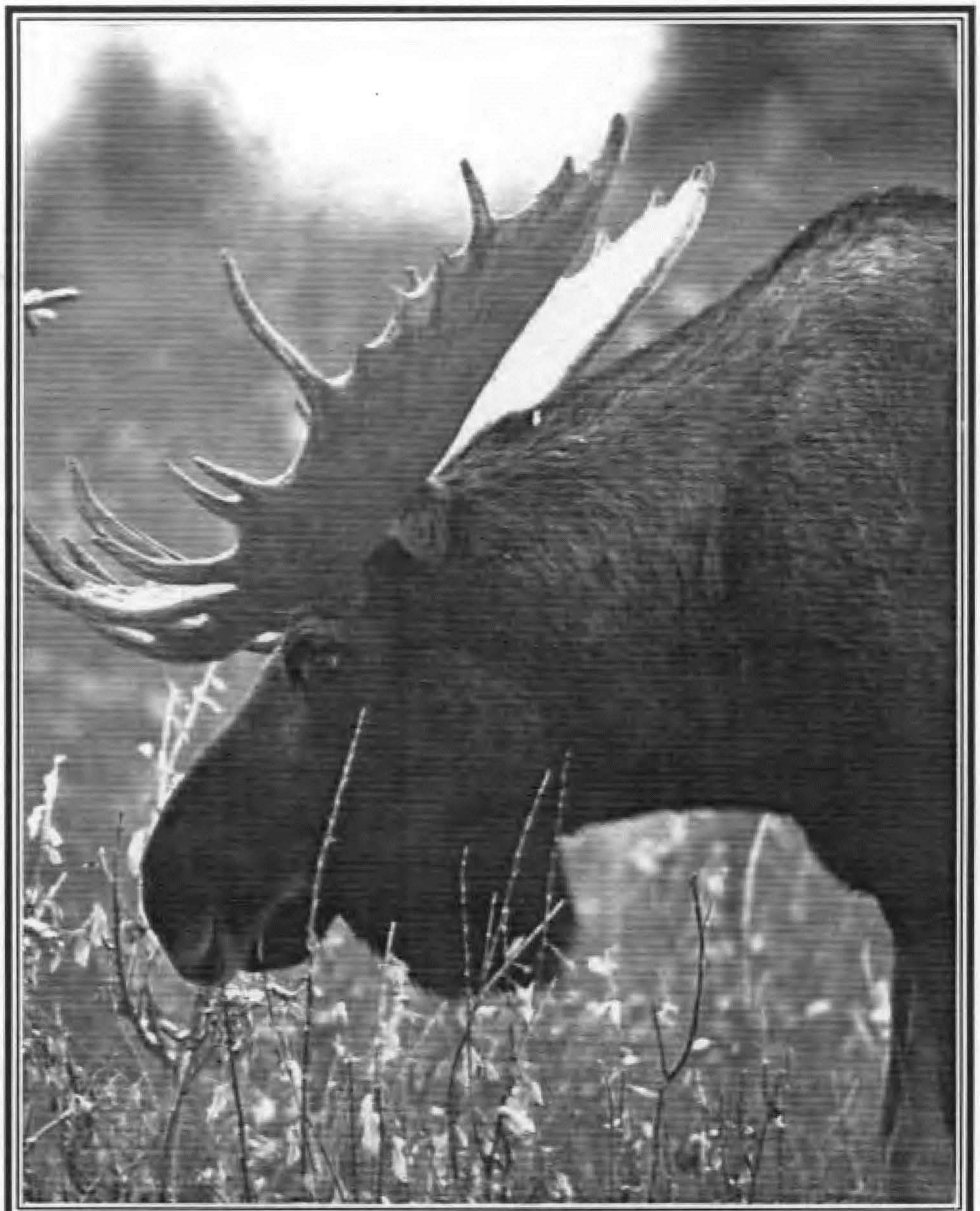
Life history tradeoffs are a well-documented feature in many large mammal species (e.g., Boyd et al. 1995, Clutton-Brock et al. 1983, 1996) but the management consequences of such tradeoffs are not usually explored. A cost to present reproduction, in terms of future reproductive success, for female moose is implied in recent work by Testa and Adams (unpubl data). By measuring rump fat thickness in moose with and without calves at heel in the autumn, and linking rump fat measurements to subsequent reproductive events with logistic regression models, an energetic link was suggested that results in lower reproductive success for female moose in years after successfully rearing a calf to autumn. That hypothesis is tested here by comparing a model of their results to an independent sample of female moose for which reproductive histories in successive years were known. This individual cost of reproduction in moose may play a role in populations having high and variable rates of additive perinatal mortality due to predation. The cost for individual moose of having and rearing a calf to autumn was estimated in the Nelchina Study Area and incorporated into a population model in which neonatal mortality was manipulated to simulate managed reduction of predation rates on neonates. The expectation is that such a tradeoff between current and future reproductive success in individuals could reduce the harvest benefits expected from reducing calf mortality. The measured cost of successfully rearing a calf to the fall in this study was a 44% reduction in fecundity, which led to modeled reductions of 10-13% in the gains

expected from better calf survival. This effect could be greater in years of unusually low reproduction or after an increase in population density.

Alaska's Game Management Units



The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program allots funds back to states through a formula based on each state's geographic area and number of paid hunting license holders. Alaska receives a maximum 5% of revenues collected each year. The Alaska Department of Fish and Game uses federal aid funds to help restore, conserve, and manage wild birds and mammals to benefit the public. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes for responsible hunting. Seventy-five percent of the funds for this report are from Federal Aid.



Ken Whitten