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HOME RANGE FORMATION AND DISPERSAL OF
SUBADULT MOOSE IN INTERIOR ALASKA

By

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                                            and Dispersal of
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                                            Interior Alaska

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SUMMARY

Dispersal of 1- to 6-year-old moose (Alces alces) was investi-
gated in a moderate-density, but rapidly growing, moose
population. Radio collars were placed on 20 offspring of 16
previously radio-collared adult cows. Comparison of home
ranges of independent offspring with their parental home range
(i.e., range when accompanying their mother) indicates a close
spatial relationship among home ranges. Independent off-
springs' home ranges overlapped their parental ranges in 19 of
20 cases. In the 1 exception, mother and offspring's ranges
were less than 1 km apart at the closest points. After shift-
ing home ranges during the 1st independent year, the spatial
relationship of successive years' home ranges remained rela-
tively consistent for most moose. No differences were detected
between males and females. Because of overlap of home ranges,
inbreeding can occur between mothers and sons and between
siblings.

Moose dispersed short distances from their parental range in
our study area, in other areas of North America, and in Sweden.
For managers, this observation has important consequences.
First, newly created habitat may be slowly located and
occupied. Second, immigration may offset little exploitation
of moose by man or predators; hence, locally overexploited
populations will be repopulated primarily by offspring of the

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area's surviving moose. Finally, each moose population should be managed as an entity unless the contribution of dispersal has been quantified.

CONTENTS

BACKGROUND

Dispersal has been documented by studies of range expansion of moose (Alces alces) populations in North America (Houston 1968; Mercer and Kitchen 1968; Peek 1974a, 1974b; Coady 1980; Rolley and Keith 1980), the Soviet Union (Likhachev 1965, Yurlov 1965, Filonov and Zykov 1974), and Europe (Pullainen 1974). Dispersal has also been studied by marking individual moose (Lynch 1976, Gasaway et al. 1980, Rolley and Keith 1980). These studies and others (Peterson 1955, LeResche 1974, Peek 1974a, Roussel et al. 1975) show dispersal of moose has occurred during both high and low densities. Yearling and 2-year-old moose dispersed more frequently than adults (Likhachev 1965; Houston 1968; Peek 1974a; Roussel et al. 1975; Lynch 1976; Mytton and Keith 1981; Cederlund (unpubl. data). Adult bull and cow moose were relatively faithful to previously established seasonal home ranges (Houston 1968; Goddard 1970; Berg 1971; Saunders and Williamson 1972; Phillips et al. 1973; LeResche 1974; Coady 1976; VanBallenberghe 1977, 1978). Therefore, fidelity of adults to established home ranges minimizes their role in the colonization of new ranges.

Dispersal of individuals from and within a moose population can alter the management strategy for that population and adjacent populations. Therefore, it is useful to be able to predict

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when dispersal may occur, which sex and age classes are most prone to disperse, and the effect of dispersal on population dynamics.

Many moose populations in Interior Alaska have declined to low densities relative to carrying capacity. Mercer and Kitchen (1968) and Rolley and Keith (1980) showed dispersal can strongly influence the dynamics of low- to moderate-density moose populations. An understanding of dispersal may help biologists rebuild and manage Alaskan moose populations. Therefore, we initiated research to investigate dispersal in a rapidly growing moderate-density population in Interior Alaska. The study spanned the years 1977 through 1984.

OBJECTIVES

To determine the extent to which offspring adopt the movement patterns of their mother, and to estimate the distance offspring disperse from their parental home range.

To determine home range consistency among years.

To determine if yearling and young adult moose, produced in a rapidly increasing population, emigrate to adjacent populations.

To determine the extent to which rapidly increasing populations can provide hunting recreation in adjacent areas as a result of emigration of young moose.

To determine relative sightability of yearling and adult moose during aerial surveys and to develop survey methods that minimize bias in estimating yearling abundance.

STUDY AREA

The study area in Interior Alaska (Fig. 1) includes the lowlands of the Tanana Flats, the rolling uplands of the Tanana Hills, and the alpine zones and mountainous terrain of the north side of the Alaska Range. The Tanana Flats is a mosaic of habitat types ranging from herbaceous bogs to deciduous and white spruce (Picea glauca) forest and includes shrub-dominated seres following wildfires. Habitat of the Tanana Flats is described in detail by LeResche et al. (1974). Vegetation on hillsides and river bottoms of the Tanana Hills is influenced by aspect of the slope. Warm, well-drained soils support white spruce, quaking aspen (Populus tremuloides), and paper birch (Betula papyrifera) that grade into extensive stands of black spruce (Picea mariana) on saturated and cold soils. Shrub

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communities are located along creek and river bottoms and in recent burns. Vegetation in the Alaska Range is characterized as an upland climax community (LeResche et al. 1974). Willows (Salix spp.) are found along streams and intergrade into a shrub zone and eventually into alpine tundra on ridgetops and higher elevations. Spruce, aspen, and birch are characteristic of lower elevations.

The moose population was of moderate density and rapidly increasing during the study (1977-84). Prior to the study, the population declined from a high of approximately 1.8 moose/km² in the mid-1960's to about 0.2 moose/km² in 1975 (Gasaway et al. 1983). Following a reduction in harvest by hunters and the reduction in numbers of wolves (Canis lupus), moose increased to about 0.3/km² by 1978 (Gasaway et al. 1983) and about 0.6/km² by 1984 (S. DuBois, unpubl. data).

METHODS

Sixteen adult cows were immobilized and radio-collared from 1976 through 1979 and 20 of their yearlings were radio-collared between 1978 and 1980. Cows were immobilized with a mixture of 7-8 mg M99 (etorphine hydrochloride, Lemmon Company, Sellersville, Pa.), 200-300 mg Rompun (xylazine hydrochloride, Haver-Lockhart, Shawnee, Kans.), and 525-600 National Formulary Units of Wydase (hyaluronidase, Wyeth Laboratories, Philadelphia, Pa.). Yearlings were immobilized with 5 mg M99, 200 mg Rompun, and 375 units of Wydase. Radio collars were produced by AVM Instrument Co. (Dublin, Calif.) and Telonics, Inc. (Mesa, Ariz.). Yearlings were collared during early May, after spring migration and just prior to breaking of the cow-calf bond.

Moose were located from a fixed-wing aircraft and positions recorded on 1:63,360-scale maps and aerial photos. During 1977 and 1978, cows were located about 20 times per year, but there were some gaps of 1-3 months between locations. From 1979 through 1984 moose were located twice monthly, with the exception of a few months when only 1 flight was made and the period from August 1982 through April 1983 when no locations were made.

Several types of home ranges were defined and each was in the form of a convex polygon drawn using Mohr's (1947) method. The parental home range was the range of a cow-calf pair from parturition to the time the calf left its mother, usually when 12 months old, although 2 of 20 left when 24 months old. The parental home range defines the home range knowledge that offspring accumulated while accompanying their mother. A cumulative home range was drawn for each mother, i.e., a range

including all locations for all years. Annual home ranges were drawn for offspring for each year (from 21 May-20 May of the following year) they were independent from their mothers.

Physiographic home range polygons were drawn for moose that migrated between the uplands (Tanana Hills and Alaska Range) and the lowlands of the Tanana Flats. Thus, the parental home range of a migratory moose consisted of 2 polygons connected by a straight line depicting an assumed migratory route, unless moose were located during migration. The migratory route was drawn between the last location point in 1 physiographic home range to the 1st location point in the other. If moose made multiple migrations per year between the polygons, multiple migratory routes were drawn.

Dispersal from the parental home range was quantified by measuring the following parameters: (1) percentage overlap (measured using a planimeter) of parental home range by the independent offspring's range; (2) straightline distance from an independent offspring's location point to the parental home range, including migratory routes; and (3) straightline distance from an independent offspring's location point during the rut (15 Sep-15 Oct) to the cumulative home range polygons (excluding migratory routes) of its mother. If an offspring was located in its parental home range, the straightline distance was zero. Each of these parameters was analyzed for differences between sexes, years of independence, and between migratory and nonmigratory moose. We used the Mann-Whitney U-test to compare populations where observations were independent, e.g., males vs. females. We applied the Wilcoxon Signed Ranks procedure (Conover 1980) when using paired observations on individual animals, e.g., comparing across years.

RESULTS

Association of Mother and Offspring

Offspring generally accompanied their mother until they were 1 year old. Offspring separated when the mother gave birth to another calf. Only 2 of 20 offspring in this study remained with their mothers for over 1 year. Both offspring were females and maintained the parental bond for 24 months. In both cases, mothers were not observed with newborn calves when their offspring reached 1 year of age. The mothers may have had little incentive to break the bond with their yearlings if they did not produce a calf or if the calf died shortly after birth.

Fracturing of the mother-offspring bond was permanent; therefore, the 1st year of life is the only period during which most

moose can learn movement patterns from their mother. Of 20 collared mother-offspring pairs observed for 1-6 years following the fracturing of the bond, mother and offspring were never seen together.

Home Range Formation

In general, offspring selected home ranges that partially overlapped their parental home range for at least 6 years after becoming independent (Table 1). Only 1 offspring had a range exclusive of its parental range and, in this case, home range separation was < 1 km at the closest point. For analysis, we pooled all offspring by years of independence because no statistical differences (P > 0.05) were detected between sexes or between migrant and nonmigrant offspring for percentage of home range overlap or for offspring mean distance from parental range during the 1st year of independence (Table 2). The 1st year was the only year where sample size was adequate to test for these differences.

During the 1st independent year, the average offspring shifted home range location but made little change in home range size. Their home ranges overlapped about half the parental range (Table 2). Location points averaged 3.1 km from the parental range (Table 2), and the maximum distance offspring were observed from their parental range averaged 10.1 km (Table 3). The parental and 1st independent home ranges did not differ (P > 0.1, Wilcoxon test) in size (121 km^2, N = 8, SD = 99 vs. 148 km^2, N = 8, SD = 101, respectively). These values were based on home ranges of 8 offspring that averaged 20 locations during both the parental year (SD = 5) and 1st independent year (SD = 3), and they offer the best test of change in home range size. Comparable parental and 1st independent home range sizes for 19 offspring were 88 km^2 (SD = 30.1) and 131 km^2 (SD = 43.5), respectively; however, the parental home range areas were likely underestimated because parental ranges during the 1st year of the study were based on fewer locations than subsequent home ranges. Small but real changes in annual home range size may have occurred; however, imprecise methods of home range estimation prevented us from detecting small changes.

Migratory moose in their 1st independent year shifted home range more in upland than lowland portions of their ranges. Migratory moose used 2 distinct ranges, one in the lowlands and another in the uplands. Upland home ranges overlapped less of the parental range than did lowland ranges (36%, N = 8, SD = 37 vs. 56%, N = 10, SD = 22), though this difference is significant only at the P < 0.1 level (Wilcoxon test). Also, 3 of 8 upland ranges had no overlap, whereas all lowland ranges overlapped by >31% (Fig. 2). Additionally, 1 offspring that migrated as a calf remained year-round in the lowlands after

becoming independent. A 2nd offspring probably followed this same pattern as its mother migrated in all 7 years that we monitored her. However, no parental home range was documented for the calf.

After shifting home ranges during the 1st independent year, the spatial relationship of successive years' home ranges remained relatively consistent for most moose. Offspring with 2 or more independent home ranges were given a subjective consistency ranking for home range location; 9 were classed consistent, 2 moderately consistent, and 4 inconsistent. Fig. 3 illustrates consistent and inconsistent patterns. Spatially inconsistent moose continued to overlap most prior independent and parental ranges (Table 1), and the long home range axis of migratory moose remained nearly parallel to the axis of the parental range (e.g., Fig. 3B).

Consistency in home range locations was demonstrated in several other types of data. First, the mean overlap of the parental home range during independent years 2-6 changed little when compared to the overlap during the 1st independent year (Table 4). Second, moose were consistent in the mean distance they were located from parental home ranges during 2nd and 3rd years of independence (Table 5). Only during years 4-6 did the distance increase substantially; however, this was based on only 3 home ranges, one for each of 3 moose. Third, the mean maximum distances moose were located from their parental range remained constant (Table 3). Finally, home range size remained fairly consistent when median values were considered (Table 6). In this case, the median differed markedly from the mean, and the median rather than the mean best represents the 2nd year change in size made by the typical moose in the population. The mean indicated home range size during the 2nd year increased 88% over the 1st year size; in contrast, the median indicates a 27% decline. The high mean value was a result of 2 moose that increased their ranges by about 700% each; however, most moose (9 of 13) decreased home range size. The 700% increases were largely due to a shortcoming of estimating home range size from a convex polygon, i.e., a location well out of a cluster of locations causes disproportionate increases in estimated home range size.

Home Range During the Rut

During the rut, 15 September-15 October, offspring were observed mostly within or near their mother's cumulative home range. Cumulative ranges were based on an average of 4.2 years of data per mother (SD = 1.5, range = 1.8-5.8). About one-third of the offspring, males and females alike, remained out of their mother's range during the rut (Table 7). The average distance all offspring were observed from their mother's range

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during the rut was small, averaging 2.4 km (Table 8). Again, distance was not different (P > 0.05, Mann-Whitney U-test) between sexes (Table 8).

Sightability of Moose

Data on sightability of moose during aerial surveys were presented in a final report by Gasaway et al. (1982).

DISCUSSION

Home Range Formation

In our study area, general location and size of home ranges were largely determined by the home range the moose experienced while accompanying its mother. Usually the maternal bond was broken after 1 year, and once broken, it was not reestablished. Offspring in their 1st year of independence established home ranges that partially overlapped their parental ranges and were similar in size. Location and size of subsequent annual ranges were relatively consistent with the 1st independent range. Male and female moose followed a similar pattern. These findings on home range formation were similar to those of Cederlund (unpubl. data), who conducted a similar study in a high-density Swedish moose population.

Contrary to these findings, Houston (1968) reported yearling moose in Wyoming wandered more widely than adults and did not establish a home range until their 2nd year of independence. Houston suggested agonistic behavior by adults forced yearlings away from areas of high moose density.

Inbreeding

Evidence of home range overlap in this study and in Sweden (Cederlund, unpubl. data) suggests that inbreeding may occur. In our study, males commonly rut within their mother's cumulative home range and, therefore, may breed their mothers. Breeding between siblings is also possible because dispersal patterns were similar for males and females. However, the probability of breeding between mother and son or between siblings is low because home ranges are large, moose tend to rut in specific portions of their range, and many other moose share the home ranges.

Dispersal Distance and Rate

Moose dispersed short distances during our study. Moose were observed an average of 3 km (Table 5) and an average maximum distance of 10 km (Table 3) from their parental range. These

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distances are small compared to the large home range size. Cederlund (unpubl. data) also observed short dispersal movements, and, although data are not in a directly comparable form, it appears that dispersal distances for Swedish moose were shorter than those reported here.

Moose in North America and Sweden have rapidly expanded their ranges during the past century (Peterson 1955, Pullainen 1974, Coady 1980). Mean expansion rates ranged up to 24 km per year (Table 9). However, dispersal distances reported here and by Cederlund (pers. commun.) appear too low to produce the high observed rates of range expansion. Therefore, at times, dispersal distances and frequency of dispersal must be greater than observed during our and Cederlund's (unpubl. data) studies.

Dispersal Relative to Moose Density and Population Growth Phase

Lidicker (1975) defined 2 types of dispersal for small mammals (presaturation and saturation) and relates each to population growth phase and available resources. Presaturation dispersal occurred during the growth phase when habitats were not filled to capacity. In contrast, saturation dispersal occurred when the population was at or near carrying capacity, i.e., when essential resources were limited. The motivation for dispersing under these 2 conditions would be clearly different. In a recent review, Lidicker (in press) indicates that presaturation dispersal is the most common among small mammals. His concept is useful when considering dispersal of moose or other species.

Dispersal of moose occurs over a wide range of densities. At very low densities (well below carrying capacity) moose have dispersed rapidly, expanding their range in Alaska (Coady 1980), Alberta (0.02-0.2 moose/km², Rolley and Keith 1980), Labrador (< 0.02 moose/km², Mercer and Kitchen 1968), Newfoundland (Pimlott 1953), and Ontario (Peterson 1955). At moderate densities, presaturation dispersal of marked individuals was observed in Alaska (0.2-0.6 moose/km², present study) and in Alberta (0.2-0.7 moose/km², Rolley and Keith 1980, Mytton and Keith 1981). Saturation dispersal of marked moose has occurred in Wyoming (8-15 moose/km² of wintering area, Houston 1968) and in Sweden (1-9 moose/km², Cederlund, unpubl. data).

Dispersal of moose may be a dynamic process that varies with the phase of population growth, as in small mammals (Lidicker 1975); however, based on the available literature, no clear pattern emerges for moose. One reason for lack of clarity is that few studies of dispersal exist. Additionally, a variety of methods have been used to estimate dispersal parameters, making comparisons difficult. For example, dispersal from low-density populations has been studied by calculating mean

rates of range expansion for a population (Peterson 1955). These data tell us little about dispersal of individuals, but give us good insights into rates of population dispersal. The technique is useful only at the periphery of moose range. Studies of dispersal both within a population's range and at higher densities than found at peripheries have used marked moose. These data give good insights about dispersal of individuals, but data are difficult to convert to estimates of potential rates of range expansion.

Despite our inability to compare dispersal rates and distances among studies and to correlate the dynamics of dispersal with population growth phase, some contrasts can be made. Clearly, presaturation dispersal is occasionally a dominant factor in the dynamics of growing populations at the periphery of their range. A high proportion of subadult moose and some adults probably dispersed long distances for populations to expand at 10-25 km:year while maintaining a low density over a large area (Mercer and Kitchen 1968). Rolley and Keith (1980) showed that presaturation dispersal remained a powerful influence on population dynamics as a moose population grew to a moderate density. They estimated net annual egress of up to 8% of the population. At peak density in Wyoming, Houston (1968) reported that yearlings frequently dispersed from areas of best habitat and highest density to areas of marginal habitat and lower density; however, we conclude from his data and description that dispersal distances were probably shorter than distances in our study. Houston suggested aggression by adults toward yearlings forced the dispersal. Similarly, in a Swedish moose population, saturation dispersal distances for yearlings were short in comparison to moose in our study (Cederlund, unpubl. data). Moose in this peak density Swedish population probably demonstrated the least tendency to disperse, among moose in studies using radio-collared 1- and 2-year-old moose. "Probably" qualifies the above statement because of the difficulty in comparing findings among studies. The magnitude of dispersal observed in the Swedish population suggests little effect on the dynamics of the population at that time. However, this subspecies (A. a. alces) has a high capacity to disperse under certain conditions. Moose in Sweden and other parts of Europe have rapidly expanded their range in this century (Pullainen 1974).

The above studies indicate that presaturation dispersal may have the greatest effect on moose population dynamics. However, 3 reviews of moose range expansion in Europe and Asia contradict this (Yurlov 1965, Filonov and Zykov 1974, Pullainen 1974). These authors concluded that dispersal led to significant range expansion only after populations had grown to high densities and in some cases showed signs of local overpopulation, i.e., saturation dispersal. Moose may well have behaved

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differently in these 3 situations compared to those discussed above. However, there may also be a chance that the early observations reviewed by these authors were not detailed enough to detect dispersal at low densities.

In summary, dispersal has been observed over a wide range of densities, but data are inadequate to generalize about the effects of dispersal on the dynamics of growing and peak density populations. Additionally, dispersal has not been studied in declining populations. Dispersal characteristics in declining moose populations probably differ from those of increasing populations, as in small mammal populations (Lidicker 1975, in press).

Dispersal, Population Dynamics, and Moose Management

The survival rate of calves affects the potential for range expansion and dispersal within populations. Moose tend to deviate from their parental range during their 1st year of independence and then follow the 1st year's pattern in subsequent years (Cederlund, unpubl. data; present study). The number of moose with a high probability of dispersing is directly related to the number of yearlings recruited. All else being equal, populations with high recruitment will be the most dynamic and provide the widest variety of management options.

We speculate that the rate of dispersal into improved habitat (e.g., resulting from wildfire) probably varies with the population growth phase. Incentives for presaturation and saturation dispersal differ, and the number of dispersers, and probably distance dispersed, varies as populations grow. During presaturation dispersal, moose may be slow to colonize new high-quality habitat because resources are not limiting elsewhere (Gasaway et al. 1985). Additionally, the absolute numbers of dispersers may be low because of low densities and/or low calf survival. At saturation, dispersing moose have the incentive to remain in areas with abundant resources once the area is encountered; however, the rate at which they encounter and move into improved habitat varies widely. For example, Peek (1974a) observed rapid ingress into a 59 km^2 burned area in Minnesota; moose increased 5-fold after 2 growing seasons. In contrast, it is conceivable that a population increase resulting from immigration could be slow if saturation dispersers make short movements, as in Sweden (Cederlund, unpubl. data).

The greatest source of dispersers would be from moose having a tradition of using a portion of improved areas and from offspring of these moose (Gasaway et al. 1985). In this situation, dispersal may take the form of small home range shifts or simply increasing the time spent in that portion of their

home range with improved habitat. Because of the short dispersal distances, moose living as close as 5-10 km from improved habitat would have a low probability of encountering and using the improved habitat. Therefore, the potential rate of immigration into improved habitat would depend on the number of moose traditionally using the area, the number adjacent to the area, and the survival rate of these moose and their offspring. Because of the paucity of knowledge, we are unwilling to speculate how dispersal in naturally declining populations would affect use of improved habitat.

Even though immigration into improved habitat may be slow in Interior Alaska or the Yukon Territory, where moose density and calf survival are low, there is value in habitat improvement programs. High-quality habitat is necessary for long-term maintenance of high moose densities, and, in some areas where habitat quality is low, habitat manipulation should precede other management actions that will lead to moose population growth.

Immigration can help repopulate areas and help offset localized exploitation by man or predators; however, the contribution of immigration is likely to be small. Lynch (1976) and Goddard (1970) found no dispersal from high-density areas into heavily exploited areas. Dispersal characteristics of a high-density moose population in Sweden and our moderate-density population indicate low rates of immigration into adjacent areas would occur. Even during periods of range expansion, when immigrants are proportionally abundant, density has been low (Pimlott 1953, Mercer and Kitchen 1968, Rolley and Keith 1980), so the number of immigrants was small. Immigration has unequivocally caused a rapid increase in moose density to a high level in only 1 area of North America, a small burn (59 km^2) in Minnesota (Peek 1974$\underline{a}$).

If immigration generally does not contribute substantially to restocking depleted ranges, then the offspring of surviving adults must be the primary stock for repopulating these areas (Goddard 1970). As Gasaway et al. (1980) and Cederlund (pers. commun.) point out, managers should consider each moose population an entity and manage it with respect to its unique demographic parameters, unless the contribution of dispersal has been quantified, e.g., Rolley and Keith (1980).

ACKNOWLEDGMENTS

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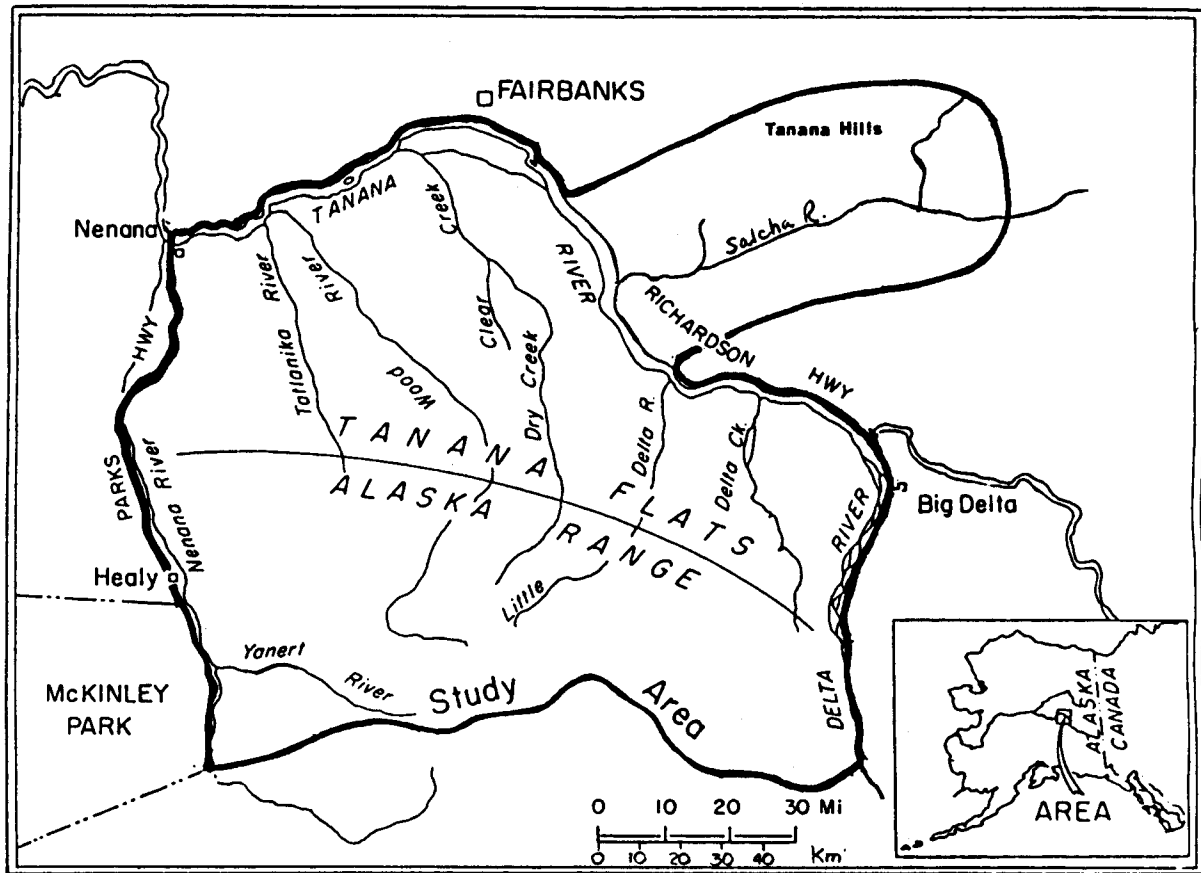
Fig. 1. The study area in Interior Alaska, 1977 through 1984.
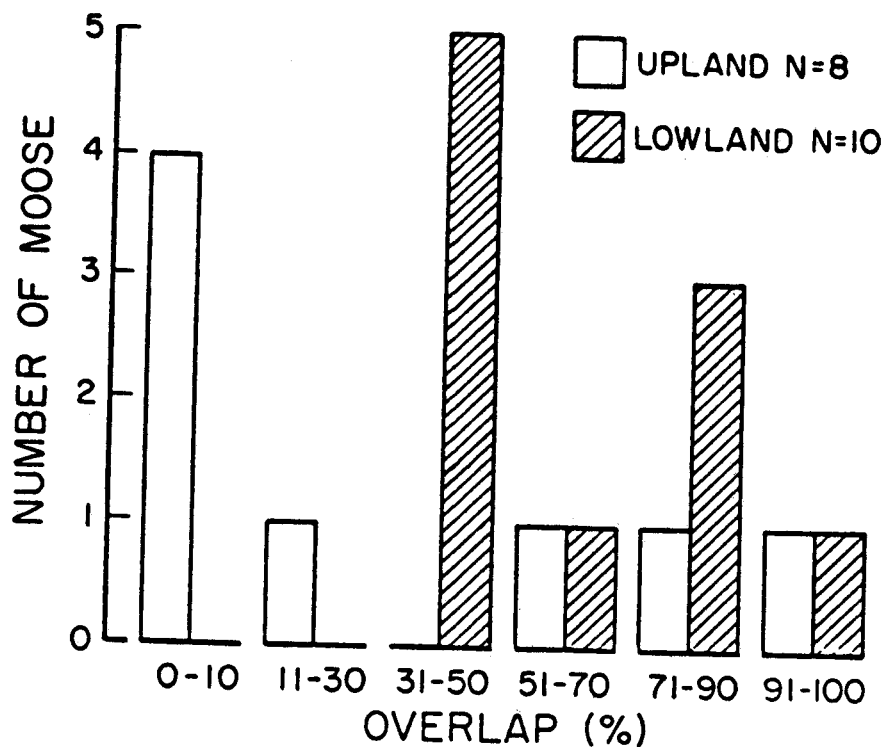
Fig. 2. Frequency distribution comparing percentage overlap of an individual's parental physiographic home range with its physiographic home range in the 1st year of independence, Interior Alaska, 1977-81. All moose occupied both lowlands of the Tanana Flats and upland mountain foothills, distinct physiographic portions of the annual home range with interconnecting migration routes.

A.

B.

Parental (25)
1st (17)
2nd (18)
3rd (27)
4th (10)
6th (19)

Parental (18)
1st (20)
2nd (21)
4th (19)

0   5   10 km

0   5   10 MILES

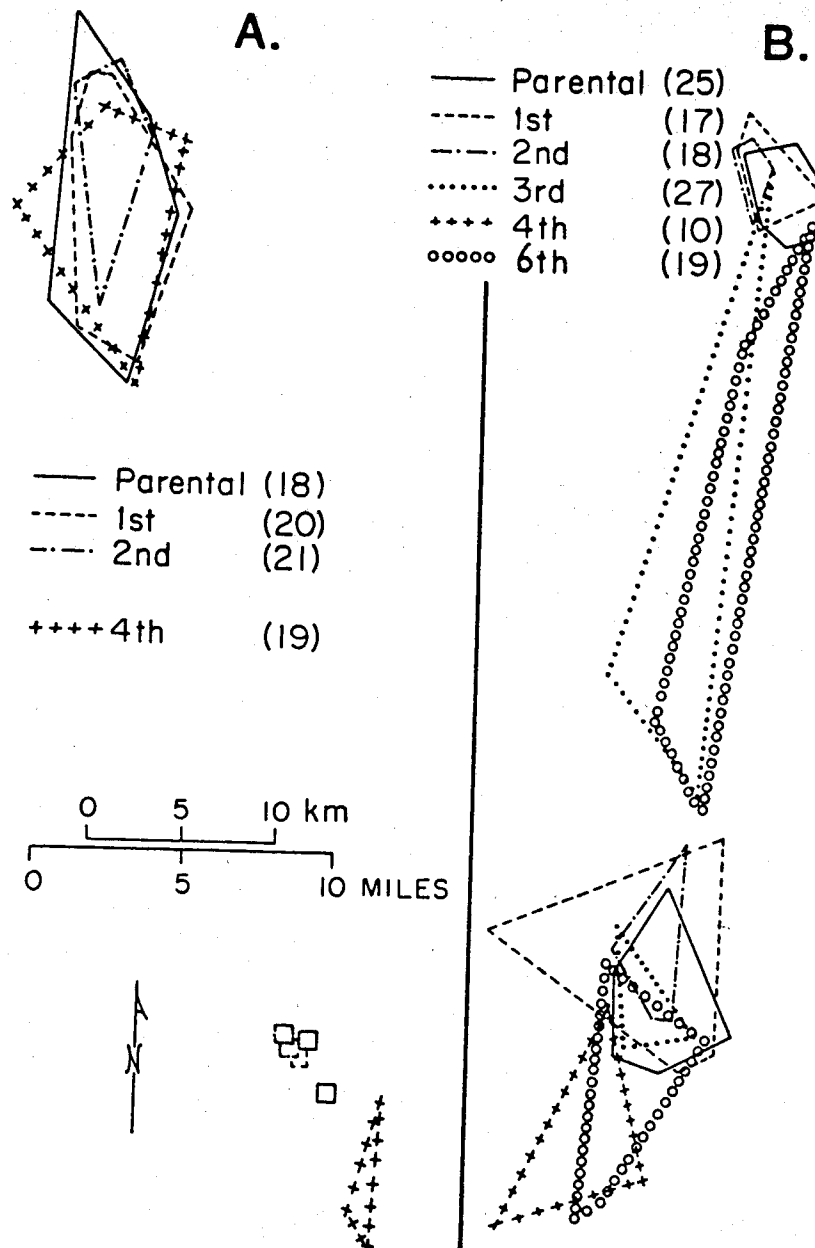Fig. 3. Examples of moose with consistent (A) and inconsistent (B) annual home range locations, Interior Alaska, 1977-84. The numbers in parentheses are numbers of locations used to construct parental home range (when the calf accompanied its mother) and ranges for independent years. Squares in portion A indicate single locations; the rapid migration and brief stay in the southern end of its range precluded obtaining more points.

Table 1. Frequency distribution of the percentage of the parental home range that was overlapped by the independent offspring's home range, Interior Alaska, 1977-84.

Year of independence	Number of moose in the following percentage overlap classes[a]			
	0	1-19	20-80	81-100
1	1	1	13	3
2	0	3	5	3
3	0	0	4	0
4-6	0	0	3	0
All years	1	4	25	6

[a] Percentage overlap classes that would show the extremes in home range overlap were chosen.

Table 2. Spatial relationship between offspring's home range during its 1st year of independence and its parental home range, Interior Alaska, 1977-81.

	Percentage overlap of parental home range by offspring's home range			Distance of offspring's relocations from parental home range (km)		
	$\bar{x}$	N	SD	$\bar{x}$	N	SD
Sex						
Male	51[a]	8	26	4.3[a]	8	5.5
Female	52	11	24	1.9	11	1.6
Movement pattern						
Migratory	54[a]	12	18	3.5[a]	12	4.5
Nonmigratory	48	7	34	2.1	7	2.1
All moose	52	19	24	3.1	19	3.9

[a] Within columns, no difference (P > 0.05, Mann-Whitney U-test) was found between sexes or between movement patterns.

Table 3. The maximum distance moose were observed from their parental home range during their 1st year of independence and the percentage decrease (-) or increase (+) in maximum distance during subsequent years of independence compared to the 1st year, Interior Alaska, 1977-84.

	Maximum distance during 1st year of independence (km)	Percentage change in the following years of independence		
		2	3	4-6
Mean	10	-14^a	-13^a	-16^a
No. of moose	19	11	5	3^b
SD	9	66	67	35
Range	0-39	-87-(+152)	-44-(+61)	-47-(+22)

[a] The percentage change was calculated from paired observations of individual moose in the 1st year and subsequent year.

[b] Sample size was 3 moose and 1 year for each moose.

Table 4. Percentage overlap of parental home range by moose during their 1st year of independence, and the percentage change during subsequent years as compared to the 1st year, Interior Alaska, 1977-84.

| | Percentage overlap during 1st year of independence | Percentage change in the following years of independence | | |
		2	3	4-6
Mean	52	-7^a	-18	-24
No. of moose	19	12	5	3^b
SD	24	33	20	27

[a] Calculated as follows: Σ [(% overlap of parental home range by offspring in $\geq$ 2nd year of independence) - (% overlap parental home range in 1st year of independence)] $\div$ number of moose.

[b] Sample size was 3 moose and 1 year for each moose.

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Table 5. The mean distance moose were observed from their parental home range during their 1st year of independence and the percentage change in distance during subsequent years as compared to 1st year distance, Interior Alaska, 1977–84. Pluses indicate a percentage increase in distance.

	Mean distance during 1st year of independence (km)	Percentage change in the following years of independence		
		2	3	4–6
Mean	3.1	+16[a]	+8	+59
No. of moose	19	11	5	3[b]
SD	3.9	88	86	79

[a] The percentage change was calculated from paired mean distances for individual moose during the 1st year and the subsequent year.

[b] Sample size was 3 moose and 1 year for each moose.

Table 6. The mean and median home range size for moose in their 1st year of independence and percentage change in subsequent years as compared to 1st year, Interior Alaska, 1978-84. Plus and minus signs indicate increase and decrease.

| | Home range size during 1st year of independence (km^2) | Percentage change in following years of independence | | |
		2	3	4-6
Mean	130	+88[a]	-5	+1
Median	101	-27	-14	+27
No. of moose	20	13	6	3[b]
SD	111	272	35	50

[a] The percentage change was calculated from paired size estimates for individual moose during the 1st year and the subsequent year.

[b] Sample size was 3 moose and only 1 year for each moose.

Table 7. Number of moose that remained out of their mother's cumulative home range during the rut (15 Sep-15 Oct) compared to total number of moose in category, Interior Alaska, 1976-84.

Year of independence	Male	Female	Sexes combined
1	3/9	2/10	5/19
2	3/6	3/8	6/14
3	2/3	1/3	3/6
4-7	0/2	2/6	2/8
All years	8/20	8/27	16/47

Table 8. Mean distance moose were from their mother's cumulative home range, during rut (15 Sep-15 Oct), Interior Alaska, 1976-84.

Year of independence	Distance (km)											
	Male				Females				Sexes combined			
	$\bar{x}$	No. of moose	No. of locations	SD	$\bar{x}$	No. of moose	No. of locations	SD	$\bar{x}$	No. of moose	No. of locations	SD
1	3.2[a]	9	14	3.9	1.1	10	16	2.1	2.1	19	30	3.2
2	4.0[a]	6	11	4.5	0.8	8	17	1.1	2.1	14	28	3.4
3	4.0	3	6	3.5	1.7	3	6	1.4	2.9	6	12	2.7
4-7	0.0	2	3	0.0	1.1	6	8	1.4	1.0	8	11	1.3
All years	3.7	9	34	3.7	1.4	11	50	1.9	2.4	20	84	3.1

[a] No difference (P > 0.05, Mann-Whitney U-Test) between sexes. Only 1st and 2nd years of independence were tested.

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Table 9. Range expansion rates for low-density moose populations in North America.

Area	Period	Range expansion (km/yr)	Reference
Alaska (upper Kobuk-Kivalina)	1880–1960	5	Coady 1980
Alberta	1965–1972	2	Rolley and Keith 1980
Labrador	1953–1961	10	Mercer and Kitchen 1968
	1880–1950	13	Mercer and Kitchen 1968
	1949–1961	24	Mercer and Kitchen 1968
Newfoundland	1904–1934	11	Pimlott 1953
Ontario	1895–1955	6	Peterson 1955
	1875–1895	24	Peterson 1955