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KENAI PENINSULA MOOSE POPULATION IDENTITY STUDY

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BACKGROUND

In recent times, moose *(Alces alces)* became abundant on the Kenai Peninsula after man-caused wildfires in the late 1800's created extensive seral habitats of birch *(Betula papyrifera)*, aspen *(Populus tremuloides)* and willow *(Salix spp.)*. Although such wildfires were recorded on the Kenai as early as 1871, their beneficial impact on the moose population did not become apparent until about 1910, during the same period caribou *(Rangifer tarandus)* were extirpated from the Peninsula because of destruction of their lichen ranges, blockage of migration routes and overharvesting (Spencer and Hakala 1964). Many have believed that moose were absent or uncommon on the Kenai Peninsula prior to 1875 but archeological evidence has revealed moose were present in the area as early as 231 A.D. (Lutz 1960).

In 1947 a 1,276 km^2 region in the Peninsula's northern lowlands was accidentally burned. After this fire, moose increased in numbers to an apparent peak population density of 10.6 moose per km^2 in 1971, one of the highest densities reported for moose in North America (Bishop and Rausch 1974). In 1969, a 360 km^2 area was accidentally burned in the northern lowlands but this area has not yet provided optimum forage for moose. Spencer and Hakala (1964) estimated wildfires on the Kenai produced favorable forage conditions for moose 5 to 20, and occasionally 60 to 70, years after the fire.

Since the early 1950's, moose on the Kenai Peninsula have been subjected to a number of man-related and natural decimating factors. In the accessible northern and southern regions of the Peninsula, males have been subjected to heavy hunting pressure which has drastically depressed the bull:cow ratio (Bishop and Rausch 1974). Although antlerless seasons were held in some years between 1960 and 1974, the public in Alaska has generally been opposed to antlerless seasons (Rausch et al. 1974). Moose productivity and survival have also declined but the causes are uncertain. Severe winters, declining forage diversity and quantity and low bull:cow ratios have been suggested as causative factors. Predation is not believed to be responsible for this decline since wolves *(Canis lupus)* were absent from the Kenai Peninsula from about 1900 to the early 1960's, and brown bears *(Ursus arctos)* are not abundant. Black bears *(Ursus americanus)* are numerous but their impact on moose, especially calves, is unknown.

Concern over declining moose numbers and the welfare of "lowland" moose required specific knowledge of seasonal ranges, movement patterns, and populations on the Kenai Peninsula. Because certain areas were to be designated as trophy, foothunting only and maximum-sustained-yield hunting areas as well as potential wilderness areas, delineation of moose populations and their interactions, understanding of seasonal ranges and movements, and identification of rutting and calving areas became imperative. This information was needed to allow discriminate harvesting of portions of specific herds, to prevent overharvesting of trophy-class males away from trophy-management areas, to direct habitat enhancement activities to key winter ranges, to restrict development of areas seasonally critical to large numbers of moose and to provide valid data pertinent to possible obstructions to moose migrations by future proposed highways or other projects (LeResche 1972).

In a preliminary report based on 413 observations of northern Peninsula moose tagged before 1972, LeResche (1972) distinguished an apparently dense population of resident lowland moose which intermixed each winter and spring with a small migratory population of moose from the surrounding Kenai mountains. The current report, based on 1,775 observations of 636 neck-collared moose, presents previously unpublished information on moose tagged in the central and southern Kenai Peninsula and on additional moose tagged in the northern Peninsula. Our data cover the period from 1968 through 1976.

OBJECTIVES

To identify key habitat areas and populations and to learn seasonal movement patterns of moose on the Kenai Peninsula.

STUDY AREA

The Kenai Peninsula is located between Prince William Sound and the Cook Inlet in southcentral Alaska (Fig. 1). The 23,400 km^2 Peninsula can be divided into two distinct physiographic regions, a mountainous eastern half and a relatively flat and low western half. In the eastern half, the Kenai Mountains rise to 1,829 m (6,000 ft.) and are heavily glaciated or snowcapped especially along the southern peaks. Foothills and benchlands rising to 610 m (2,000 ft.) occur in the central and southern regions of the Peninsula. The lowlands, which are most extensive in the north, cover most of the western half of the Peninsula and vary in elevation from sea level to 122 m (400 ft.). Our study area included all the lowland, benchland, and foothills areas as well as about 900 km^2 of the Kenai Mountains adjacent to the northwestern lowlands. For convenience and to coincide with established game management subunits (15A, 15B, 15C), the study area was divided into northern, central and southern regions.

The northern region of the study area lay primarily in the lowlands which were apparently once the floor of a huge lake which last appeared as dry land about 5,000 to 7,000 years ago (Karlstrom 1964). Today, numerous small- to medium-sized lakes, bogs, and swampy areas characterize this poorly drained area. To the south, two of the Peninsula's largest lakes, Skilak and Tustumena, occupy glacially scoured troughs and are drained by the Kenai and Kasilof Rivers, respectively. Vegetation in the lowlands has been described in detail by LeResche et al. (1974). White spruce *(Picea glauca)* predominates on drier sites and black spruce *(Picea mariana)* on wetter sites. Birch, aspen and willow are characteristic hardwood species. A portion of the Kenai Mountains

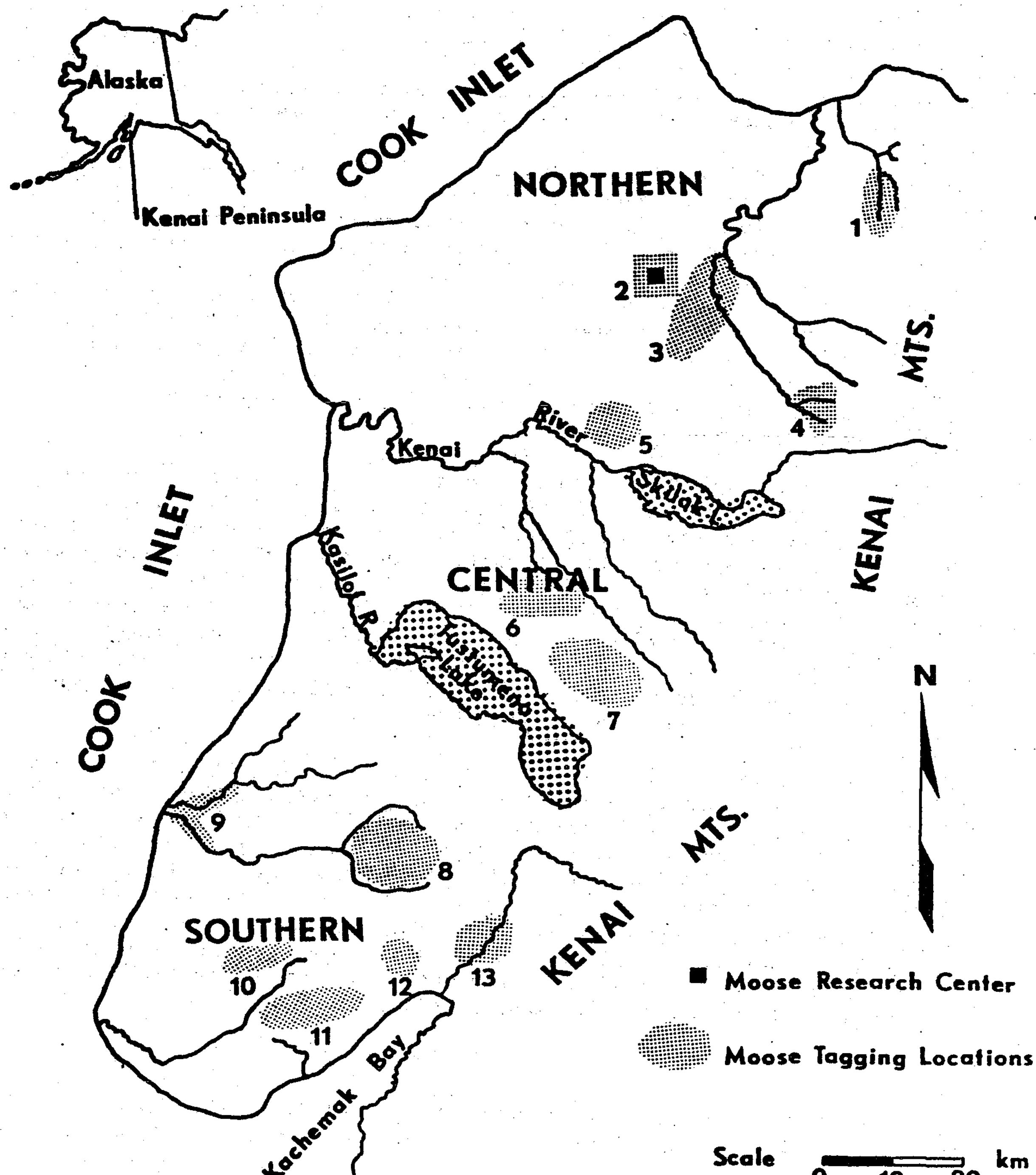

Figure 1. Kenai Peninsula study area and locations of moose tagging areas. Tagging areas: 1)Big Indian Creek. 2)Moose Research Center. 3)Moose River Flats. 4)Mystery Creek. 5)West of Skilak Lake. 6)Funny River. 7)Timberline Lake. 8)Caribou Hills. 9)Deep Creek–Ninilchik River. 10)Headwater Hills. 11)Bald Mountain. 12)Eagle Lake. 13)Fox River Flats.

included within this region of the study area supports tree communities at the lowest elevations, climax willow communities above timberline and alpine tundra communities at the highest elevations.

The central region of the study area was largely benchlands with a narrow extension of the northern lowlands, 16 to 24 km wide, along the western edge. These benchlands, which lie between Skilak and Tustumena Lakes, consist of a gently sloping plateau extending westward from the Kenai Mountains. This better-drained area has relatively few lakes and is crossed by two major streams, the Killey and Funny Rivers. Spruce, birch and aspen dominate most of this region but at the higher elevations on the benchlands, climax willow communities predominate.

The southern region of the Peninsula study area was primarily a broad glaciated upland area extending up to 914 m. (3,000 ft.) in the Caribou Hills area. This area is dissected by several streams such as the Ninilchik River, Deep Creek, and Anchor River which flow through deeply terraced canyons in glacial end moraines. At the southern edge of the area, the Fox River occupies a wide glacially-scoured valley which lies at the upper end of Kachemak Bay. The vegetation in the higher uplands area is climax willow, but in the lower lying timbered areas Sitka spruce *(Picea sitchensis)* as well as white and black spruce, birch and aspen are common. Willow communities dominate in the riparian zones and the broad Fox River Flats.

The climate on the Kenai Peninsula varies in a gradient to the southwest. In the northeastern part of the study area, the Kenai Mountains block the moisture-laden air coming off Prince William Sound and the northern lowlands lie in a precipitation shadow. In the southern region, temperatures are moderated and more moisture is received because of the proximity of the sea. Annual snowfall averages 151 cm (59.6 in.) at Kasilof on the western edge of the lowlands, and annual precipitation averages from 46 to 48 cm (18 to 19 in.) at Kenai in the north to 69 cm (27 in.) at Homer in the south (Karlstrom 1964). The mean annual temperature is about 0.6° C (33° F) (Spencer and Hakala 1964).

The Kenai Peninsula is only sparsely populated by humans, and the impact of agriculture and forestry on moose has been negligible so far. About 31 percent of the Kenai Peninsula and most of the study areas are within the 7,285 km^2 Kenai National Moose Range (KNMR), a wildlife refuge established in 1941 for the benefit of the Kenai moose. Moose hunting was permitted throughout the study areas including the KNMR. Our headquarters, the Moose Research Center (MRC), is located in the 1947 burn area of the northern lowlands. The MRC is comprised of four 2.6 km^2 enclosures initially established to gain information on the relationships between moose and the vegetation (LeResche 1970).

PROCEDURES

Moose at the MRC were captured in fenceline traps (LeResche and Lynch 1973). Elsewhere on the Peninsula they were immobilized from a helicopter

(Nielson and Shaw 1967). Most moose were immobilized with intermuscular injections of succinylcholine chloride (Franzmann et al. 1974). In addition to metal ear tags and flagging, captured moose were fitted with a variety of neck collars designed to enhance visual identification from the air. Early in the study, moose were fitted with monocolored neck collars designed only to differentiate sex and tagging site. Subsequently, striped, multicolored and numbered neck collars were used with and without large numbered pendants to permit individual recognition (Franzmann et al. 1974). Age of captured moose was determined by counting tooth cementum layers (Sergeant and Pimlott 1959).

At the MRC we captured moose year round but at other locations they were captured after they aggregated on winter, rutting or calving grounds. Tagging sites were selected that would provide information on specific herds of moose. Weekly reconnaissance flights were attempted in a Piper PA-18-150 aircraft to relocate collared moose. Collared moose were also observed by refuge personnel of the KNMR during their annual moose census flights, and seen by ADF&G biologists during annual moose composition and survival counts. The public also reported sightings of collared moose, particularly in the southern region of the Peninsula where a vigorous public appeal campaign was conducted. We also recorded observations of collared moose in our daily travels in the area surrounding the MRC.

Locations of collared moose were plotted on 1:250,000 topographic maps from which general habitat types were later assessed.

FINDINGS

Numbers of Moose Captured

A total of 636 moose, 162 males and 474 females, were tagged in 16 locations throughout the Kenai Peninsula (Table 1). Of these, 419 (66%) were from the northern Peninsula, 60 (9%) from the central Peninsula and 157 (25%) from the southern Peninsula (Fig.1). More moose were tagged on the northern Peninsula because fenceline traps were operated continuously at the MRC from 1970 through 1976. Forty-three percent (179) of the northern Peninsula captured moose were tagged at the MRC. We excluded 47 calves captured with females at the MRC because they were resighted only five times and because we deliberately avoided capturing calves with helicopters elsewhere on the Peninsula.

Many of the 457 helicopter-captured moose (166) were captured in rutting aggregations in mid- to late October. A total of 40, 60, and 66 moose were tagged on rutting grounds in the northern, central and southern regions of the Peninsula, respectively. An additional 131 moose were tagged on the Moose River Flats calving grounds using helicopters and fenceline traps at the MRC. Large numbers of moose congregated in this vast, open, swampy area each May and June during the calving period. The remainder of helicopter-captured moose were taken in late fall-early winter (59) and late winter-early spring (101).

Table 1. Numbers of moose captured on Kenai Peninsula, 1968 to 1976.

Region of Peninsula	Name of tagging location	Month and year	Type of aggregation	Number tagged		
				Males	Females	Total
Northern	Mystery Creek	October, 1968	Rutting	11	17	28
	West of Skilak Lake	March, 1970	Late winter	15	54	69
	Moose River	May-June, 1970-71	Calving	37	94	131
	Big Indian Creek	October, 1972	Rutting	2	10	12
	Moose Research Center	1968-1976	-	25	154	179
Central	Lower Funny River	October, 1972	Rutting	12	21	33
	Timberline Lake Area	October, 1972	Rutting	19	8	27
Southern	Caribou Hills Area	October, 1973	Rutting	32	34	66
	Eagle Lake Area	November, 1974	Early winter	-	10	10
	Headwater Hills Area	November, 1974	Early winter	6	19	25
	Bald Mountain Area	November, 1974	Early winter	2	22	24
	Deep Creek-Ninilchik River	April, 1975	Early spring	1	9	10
	Clearwater Slough-Fox River	April, 1975	Early spring	-	22	22
Total				162	474	636

Resighting Success

We evaluated the resighting success of Kenai Peninsula neckcollared moose elsewhere (Bailey et al., in review) (Appendix). In general, 73 and 68 percent of the collared males and females, respectively, were resighted, but the majority (59%) were seen less than three times. The mean observation rate per moose was 2.8. Of 1,775 observations 60 percent occurred between November and April when the ground was snow covered and deciduous trees were leafless. Only 10 percent of the total observations were made during the summers when visibility was most limited.

Seasonal Habitat Use

Four general habitats were used throughout the year by Kenai moose: lowland spruce-birch-aspen, muskeg, upland timber-climax willow and riparian. Lowland habitats, generally under 122 m. (400 ft.) in elevation, included fire-created seral communities dominated by birch, spruce and aspen and unburned spruce and birch. Muskeg habitats, most common in the lowlands, were swampy areas dominated by low-lying vegetation such as Labrador tea *(Ledum groenlandicum)*, bog blueberry *(Vaccinium uliginosum)* and sphagnum mosses *(Sphagnum spp.)*. Higher, better-drained hummocks were covered with black spruce. Upland habitat used by moose extended from 122 m. (400 ft.) to 914 m. (3000 ft.). Birch-spruce communities were found up to about 549 m. (1800 ft.), and climax willow communities usually predominated above timberline. Riparian communities were dominated by willow and alder *(Alnus spp.)*.

Northern Kenai Peninsula

Calving Period (May-June). Collared moose most frequently used muskeg and riparian habitats during the calving period (Table 2). Few collared moose were seen in upland habitats in May and June. Over half (62%) of the calving period observations were of moose on the Moose River Flats, a vast area of muskeg over 200 km^2 in extent. Most of these moose were seen in a 65 km^2 area south of Moose Lake and 4.8 km east of the MRC. This is a swampy area characterized by a network of small ponds, bogs, and tributaries of Mystery Creek and the Chickaloon and Moose Rivers. Movement data indicate that most of the moose utilizing the Moose River Flats for calving were migratory moose which spent the summers in the adjacent Kenai Mountains. Several females tagged in the central Peninsula uplands also calved here, but few (< 10%) of the females tagged on the flats during the calving period appeared to be lowland residents. Our data suggest that some migratory females returned to calve in the Moose River Flats each year.

Another moose calving area is adjacent to the Kenai River between Kenai and Skilak Lakes. Thirteen percent of the calving period observations were in this area. Movement data indicate that most of the collared moose utilizing this area came from migratory populations including

Table 2. Frequency neck collared moose were seen in seasonal habitats on the northern Kenai Peninsula, 1968-1976.

	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov-Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
Habitat	N	%	N	%	N	%	N	%	N	%	N	%
Lowland. Spruce-birch-aspen	49	20	34	27	53	33	81	42	131	71	96	49
Muskeg	151	62	13	10	5	3	23	12	16	9	69	35
Upland. Timber and climax willow	7	3	27	22	34	21	15	8	8	4	8	4
Riparian. Upland and lowland	38	15	51	41	69	43	73	38	29	16	24	12
Total	245	100	125	100	161	100	192	100	184	100	197	100

moose tagged at Mystery Creek. However, other moose tagged in the Mystery Creek drainage used the Moose River Flats instead of the Kenai River area for calving.

Collared females from the lowland resident population apparently calved throughout the numerous small, boggy areas of the lowlands instead of the Moose River Flats. During the calving period, only 33 percent of the observations of collared lowland resident females were at the Moose River Flats. Sixty-six percent of the observations were at other lowland areas. Unlike migratory females, lowland females did not appear to congregate in specific areas to calve.

It was unclear why so many, perhaps most, migratory females calved on the open Moose River Flats. A large number of calves concentrated in one locality would appear to attract predators. Black bears and brown bears were periodically observed on the Moose River Flats during the calving period, and timber wolves are also known to use this area. However, the extent and impact of predation on moose calves on the flats are unknown. Because there appears to be no cooperative effort among female moose to protect calves from predators, females must be individually attracted to such areas for other reasons. Although moose tend to congregate most often in open terrain (Peek et al. 1974), females with calves are very aggressive toward other moose (Houston 1968). Giest (1971) speculated such aggressive behavior was an anti-predator response directed mainly toward wolves. Concealment of calves, although perhaps important at first (Stringham 1974), appears less important to calf survival than a female's defensive behavior towards predators. Density of cover at calving sites may, therefore, be less important than the ability of females to protect their calves and the calves to outrun predators. Peek et al. (1974) noted that females with calves were often seen in open rather than dense cover.

The factors involved in the selection of calving sites are not well understood. Because moose often calve on peninsulas or islands in rivers and lakes, Petersen (1955) suggested seclusion was the influencing factor. Knorre (1961) speculated females gave birth near river margins in order to drink regularly without leaving their unprotected calves far behind, but Markgren (1966) found few birth sites near water. Altmann (1958, 1963) believed that birth sites were characterized by secluded shelter and available browse, and others (Rausch 1959, Peek 1971, Peek et al. 1974) suggested calves were born on islands or swampy areas because such areas were seldom visited by predators.

We speculate that moose (and perhaps bears) are attracted to the Moose River Flats because of its abundant emergent and submergent vegetation which provides some of the first green plants available as food following spring breakup (Kubota 1974). For three semi-tame moose at the MRC grass, sedges, and aquatics constituted only 10 percent of the observed summer diet. Nonetheless, moose appear to use aquatic plants in the spring and early summer if available (Peek 1974). Three aquatics moose appear to prefer are yellow pond lily (*Nymphaea spp.)*, pondweeds

(Potamageton spp.) and horsetail *(Equisetum spp.)*. A sample of Alaskan pond lily *(Nuphar spp.)* and horsetail revealed that they were a good source of nutrients for moose, being exceptionally high in potassium (Kubota 1974). The majority (63%) of 35 observations of collared males during May and June were made at the Moose River Flats, and it seems likely that factors other than those related to calving cause moose to use the area in May and June.

Summer (July-August). Migratory moose left the lower-lying wet areas and were frequently observed in upland habitats during summers (Table 2). As summers progressed, collared moose were observed at higher elevations near mountain streams and on mountainous slopes. Important summer upland habitats were those in the Mystery Creek, Chickaloon River, and Big Indian Creek drainages where 15, 9 and 4 percent, respectively, of all summer observations of collared moose occurred. Other upland drainages used by northern Peninsula tagged moose included Thurman Creek and Jean Creek in the northern Kenai Mountains and Funny River and Bear Creek in the central Peninsula benchlands. Few collared moose were seen in the zone of mature timber on the west slopes of the Kenai Mountains. Moose apparently moved rapidly through this zone to reach the areas of greater forage productivity at higher elevations. Distances between the lowland wintering areas and spring calving grounds and the upland summering areas generally exceeded 10 km and elevational differences exceeded 305 m. (1,000 ft.). Although some collared moose were seen on the west facing mountain slopes above timberline adjacent to the lowlands, others were observed higher in the mountains at the heads of drainages. A few moose crossed high mountain passes into the drainages of Resurrection and Juneau Creeks.

Thirty-eight percent of all summer observations of collared moose were in lowland habitats. A few collared moose remained in the Moose River Flats throughout the summers. Most collared moose seen in the lowlands were observed in the 1947 burn area and the least were seen in mature timber. Poor visibility limited our observations in the latter habitat.

Rutting Period (September-October). Most (64%) observations of collared moose during the rutting period were in upland habitats, often near mountain streams. Fifteen percent of our resightings were in the Chickaloon River drainage, 10 percent in the Mystery Creek drainage, 5 percent in the Big Indian Creek drainage, and the remainder (26%) in seven other mountain drainages. Our data thus supported the earlier observations of LeResche (1972) that northern Kenai Peninsula moose could be divided into lowland-resident and migratory segments. He speculated from the behavior of moose tagged at Mystery Creek that 10 to 15 breeding groups of migratory moose aggregated each fall in the smaller drainages emanating from the Kenai Mountains.

There is little descriptive information on moose rutting habitat. On the Kenai Peninsula, Lent (1974) reported sighting groups of moose in clearings or on the fringes of small bogs during the rut. However, Hosley (1949), citing Palmer's conclusions regarding Kenai Peninsula moose, reported that rutting moose were seldom seen in the open but almost always were in or near clumps of spruce or alder. Edwards and Ritcey (1958) observed that the locations of rutting groups of moose were variable and dependent on early snowfall. Giest (cited by Lent 1974) noted that rutting moose in northern British Columbia were frequently at or above timberline. Salt licks may also form focal points for rutting moose (Murie 1934).

Our data suggest that most groups of rutting migratory moose were at or slightly above average timberline. During September and October, the average elevation of males during 23 observations was 586 m (1,923 ft.), that of females during 84 observations was 552 m (1,811 ft.). Average timberline in the area was about 549 m (1,800 ft.). Because these moose were already using mountain drainages before the rutting period, and because moose in open habitats appear to form larger aggregations than moose in closed habitats (Peek et al. 1974), rutting habitats used by northern Peninsula migratory moose may be determined by prior habitat use and cover density, as well as by moose behavior. Moose using the slopes during the summer could rapidly aggregate for the rut by simple downward or upward movements. Thus they have access to the open narrow valleys for maximum visibility yet they are near timber should early snowfall occur. Average elevational changes of collared moose indicate that females move up drainages while males move down for the rut. Following rut, females move to much lower elevations (average 312 m) than do males (average 474 m).

Non-migratory lowland moose did not appear to congregate in large groups during the rut like migratory moose. Thirty-three percent of rutting moose observations were recorded in the lowland area, mainly in the vicinity of the MRC where we were more apt to see collared lowland moose during most of the year. Lowland resident females apparently bred within or near their year-round home ranges. In Minnesota, Philips et al. (1973) noted that during the rut males moved extensively outside their normal ranges, apparently in search of females. On the Kenai Peninsula, where the sex ratio is extremely skewed in favor of females, females may be more active than males during the rut. Occasionally, at the MRC, free-roaming females were apparently attracted to and attempted to associate with males inside the enclosures during the rut. At least one female was notably more active than the male and attempted to enter the enclosure containing the male. This behavior, if typical throughout the portion of the northern Peninsula having a low-male sex ratio, could indicate that lowland moose may breed wherever they meet, presumably at random.

Post-rut (November-December). Collared migratory moose remained in upland habitats until forced to lower elevations by winter snows. After the rut, fewer moose were seen on slopes and more were observed in riparian habitats along mountain drainages. On the lowlands, more collared moose were observed in spruce-birch-aspen habitats and in muskegs than were seen there the two previous months. As the frequency of moose observations in upland habitat decreased from 21 to 8 percent after the rut, frequency increased in lowland and muskeg habitats from 33 to 42 percent and 3 to 12 percent, respectively. Depending on the severity of the winters, some migratory moose remained in upland habitats throughout November and December. Other moose even moved over mountain passes into adjacent mountain drainages during this period and were seen in similar habitats in the drainages of Juneau and Resurrection Creeks. In general, the type of habitat used by moose during this period appeared to be determined by local weather and moose behavior. Migratory moose usually used upland habitats, especially riparian, and lowland moose presumably remained in their normal ranges.

Winter (January-February). The principal mid-winter habitat of northern Kenai Peninsula moose was the spruce-birch-aspen habitat of the northern lowlands. As previously noted by Spencer and Hakala (1964) and LeResche (1972), the major overwintering area was in the 1947 burn. At this time of year, moose were seldom seen in upland communities although a few remained in riparian zones along lower mountain drainages. Few moose were seen in open muskeg habitats. The Kenai River valley between Skilak and Kenai Lakes was another important overwintering area for migratory moose.

Although 71 percent of all winter observations of collared moose were in the lowlands, some moose apparently remained in upland habitats throughout the winter. Some moose tagged in the Big Indian Creek drainage in the Kenai Mountains were observed high in the mountains but within the drainage in December and at lower elevations in February during the comparatively mild winter of 1972-73. During the severe winter of 1974-75, moose from the same group were seen in the lowlands up to 40 km from their initial capture sites. Therefore, upland versus lowland habitat use by migratory moose in winters was apparently dictated largely by weather.

Spring (March-April). Snow usually persisted in the lowlands until mid- to late April and occasionally to mid-May. Migratory collared moose remained in the lowlands (49% of observations), although as the snow melted increased use of muskeg habitats was apparent, particularly in the Moose River Flats. The swampy area west of Skilak Lake was another important spring habitat of moose. Here, near Bottenintnin Lake, nearly 70 moose were tagged in March 1970. Collared moose also continued to use the Kenai River bottom above Skilak Lake during the early spring. These early spring moose habitats had several common features: 1) each was usually adjacent to overwintering areas where dense cover was available, 2) each was in swampy or boggy areas where the earliest green plants (aquatics) were available, and 3) each was also later used as a calving ground.

Central Kenai Peninsula

Determination of the seasonal habitats used by central Peninsula moose was based on 213 observations of moose collared in the central Peninsula benchlands (Table 3). Moose tagged in the benchlands were observed adjacent to Killey River and Bear Creek, and on the Moose River Flats during the calving period. Scarcity of observations anywhere during this period and the paucity of observations on the Moose River Flats suggest that many, if not the majority, of central Peninsula collared females calve throughout the central Peninsula benchlands and lowlands. Many of these females were observed in the benchlands prior to and after calving but were not observed during the calving period. The fact that several were seen in the lower-lying areas suggests that there may have been a movement to lower elevations during the calving period, followed by a return to upland areas. One collared central Peninsula female with a newborn calf was seen near the Sterling Highway in the lowlands. Males appeared to have the same movement pattern. The average elevations of collared females and males during resightings in May-June, and July-August were 399, 317 and 407 m and 514, 342 and 437 m, respectively. These average elevations and the pattern of resightings suggest that many central Peninsula collared moose left the elevations in early winter, returned in the late winter or early spring, and left again to utilize lower lying areas during May and June.

During summers, most moose collared in the benchlands utilized upland willow communities. Few of these collared moose were seen in lowland areas. Frequency of resightings increased from 29 to 86 percent in upland areas between calving and summer periods and decreased from 36 to 14 percent in riparian habitats for the same period. These data suggest either that after calving females returned to upland ranges, or that the collared females had been in the uplands during calving but were not observed because of post-parturition behavior.

During the rutting period, 95 percent of collared moose observations were made in upland areas, usually on northwest facing slopes adjacent to small drainages. Some distinct rutting groups of moose were not localized in sharply defined drainage systems as were rutting moose in the northern Peninsula. For example, when captured during the rut the lower Funny River group of moose was only 4.0 km from the Timberline Lake rutting group. These two groups of rutting moose were separated only by a patch of timber (Franzmann and Arneson 1973). The gently sloping terrain of the benchlands lacked such distinct physical barriers as the steep, narrow, mountainous ridges that tended to separate breeding groups of northern Peninsula moose.

After the rut, central Peninsula moose, like those on the northern Peninsula, moose, moved to higher elevations, especially along the slopes above the Killey and Funny Rivers. During this period, 38 percent of the resightings were of collared moose in riparian habitats of smaller upland drainages. These moose were subsequently forced into more protected

Table 3. Frequency neck collared moose were seen in seasonal habitats on the central Kenai Peninsula, 1972-1976.

	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
Habitat	N	%	N	%	N	%	N	%	N	%	N	%
Lowland. Spruce-birch-aspen	2	14	-	-	-	-	2	3	14	29	7	44
Muskeg	3	21	-	-	-	-	3	5	-	-	-	-
Upland. Timber and climax willow	4	29	32	86	40	95	30	54	26	54	9	56
Riparian. Upland and lowland	5	36	5	14	2	5	21	38	8	17	-	-
Total	14	100	37	100	42	100	56	100	48	100	16	100

lowland habitats or wind-swept upland habitats, probably by increasing snow depths.

In the winter (January-February), 29 and 54 percent of our observations of collared moose were in lowland and upland areas, respectively. This indicates that most collared moose remained to overwinter in the uplands. Others migrated to lowland areas, especially during severe winters. Moose that remained in the uplands were observed on west-facing slopes rather than on north-facing slopes where they had been observed earlier. Some moose were observed as high as 975 m (3,200 ft.) in the upper Killey River and Bear Creek drainages during mid-winters, but during severe winters others migrated up to 39 km to the lowlands north of the Kenai River, in the Sterling area or near the town of Soldotna. Lowland winter habitats in the Sterling area were seral birch or aspen dominated communities in settled areas where mature forest had been cleared or burned by man. It was noted that after snowstorms most moose in the uplands moved into heavily timbered areas below 549 m (1,800 ft.), but if winds blew some high areas clear of snow the moose would move back to elevations up to 914 m. (3,000 ft.) (Franzmann and Arneson 1973). After mid-winter, collared moose were seen more frequently in lowland habitats. From winter to spring, the frequency of resightings in these habitats increased from 29 to 44 percent. Collared moose continued to be seen in lowland areas, especially the Sterling area, throughout March and April. However, by calving season, few of these moose were seen in the areas they used during early spring. In upland areas, moose found on west-facing slopes in the winter moved back to the north-facing slopes above the Killey and Funny Rivers, where they had been seen earlier in the season. Central Peninsula moose were located at much higher elevations than northern Peninsula moose during the spring.

Southern Kenai Peninsula

During the calving period, collared moose in the southern region of the Peninsula were seen most often in riparian habitats (Table 4). Fifty-nine percent of the spring observations were in river valleys and of these, 62 percent were in the Fox River Valley and 15 percent each were in the Anchor River and Fritz Creek drainages. The Fox River calving area lies in a broad valley at the upper end of Kachemak Bay. This area, about 30 km^2 in extent and just a few meters above sea level, is very flat and is characterized by a number of tributary streams interspersed between islands of willow, alder, and cottonwood *(Populus balsamifera)*. During the calving period many of the collared moose were seen at the upper reaches of Fox River near the confluence of Clearwater Slough. Unlike the northern Peninsula, there are few extensive areas of muskeg in the southern Peninsula. Only 5 percent of our observations during calving periods were of moose in muskeg areas. Several collared moose were seen in upland habitats, usually on south-facing slopes, during May and June. Collared moose on the southern Kenai Peninsula were seen only seven times during the summers. These few observations were at equal frequencies (29%) in riparian, muskeg, and upland habitats. Some moose were seen in the flat, boggy area south of the Boxcar Hills. During two summers, only one collared moose was seen in lowland spruce-birch-aspen habitats.

Table 4. Frequency neck collared moose were seen in seasonal habitats on the southern Kenai Peninsula, 1972-1976.

	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov-Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
Habitat	N	%	N	%	N	%	N	%	N	%	N	%
Lowland. Spruce-birch-aspen	2	5	1	14	1	3	7	5	30	20	15	20
Muskeg	5	11	2	29	3	10	4	3	2	1	2	3
Upland. Timber and climax willow	11	25	2	29	17	55	93	62	39	26	11	15
Riparian. Upland and lowland	26	59	2	29	10	32	45	30	80	53	46	62
Total	44	100	7	100	31	100	149	100	151	100	74	100

Upland habitats were utilized most frequently by collared moose during the rutting period. Key rutting areas appeared to be the upper drainage of the North Fork of Deep Creek northeast of Ptarmigan Head and the south-facing slopes of the Caribou Hills. No other specific drainages that may have been were used as rutting areas were identified by observing collared moose.

After the rut, moose remained in upland areas at or near previous rutting areas. Many collared and uncollared moose were seen along the slopes of the Caribou Hills and south of Ninilchik Dome. Upland riparian habitats began to receive more use as moose concentrated in the drainages of Deep Creek, Nikolai Creek, and Cytex Creek. Lowland spruce-birch-aspen areas and muskeg were seldom used by collared moose from November through December.

As winter snows deepened, moose moved to lower elevations and began using lowland riparian or lowland spruce-birch-aspen habitats. During January and February, 53 percent of all observations of collared moose were in lowland riparian habitats. Important wintering areas were the lower lying valleys of Anchor River and Fritz Creek where 44 and 33 percent, respectively, of all observations of collared moose in riparian habitat were made. Other moose wintered near the town of Homer beside Kachemak Bay and still others wintered as far as 56 km to the north in the lowland spruce-birch-aspen habitats along Cohoe and Kalifonsky Roads.

During the spring, most collared moose continued to use the same habitats used in winters. Thus, collared moose continued to be seen in the Homer area, lower Anchor River, Fritz Creek and the Cohoe-Kalifonsky area in March and April. Despite decreasing snow cover during the spring, few moose were seen in upland habitats. This suggests that factors other than snow cover caused moose to remain in, or move into, riparian and lowland spruce-birch-aspen habitats during the spring. Like some northern Peninsula moose which left their higher wintering elevations, southern Peninsula moose may have been attracted to lowland habitats perhaps because of the availability of the season's first green plants.

Regional Differences in Seasonal Habitat Use

To obtain an index of the relative importance of each seasonal moose habitat by region, we ranked seasonal habitats according to highest intensity of use (Table 5). In the northern region, lowland habitats were most important to collared moose. Lowland spruce-birch-aspen communities were intensively used by northern Peninsula moose from November through April. If lowland muskeg habitats are included, the period in which lowland vegetation was used extended at least to June. On an average annual basis northern Peninsula moose, as indicated by our sampling methods, spent about 33 percent of the year in upland habitats and the remaining 67 percent in the lowlands. Year-to-year habitat utilization varied with winter severity; during mild winters more moose remained in the uplands instead of migrating to the lowlands.

Table 5. Key seasonal habitats used by collared moose on the Kenai Peninsula, 1968 to 1976.

Region of Reninsula	Season					
	Calving	Summer	Rut	Post-Rut	Winter	Spring
Northern	Lowland muskeg	Upland	Upland-Riparian	Lowland	Lowland	Lowland
Central	Upland and Riparian	Upland	Upland	Upland	Upland	Upland
Southern	Lowland-Riparian	Upland, Riparian and Muskeg	Upland	Upland	Lowland-Riparian	Lowland-Riparian

Since pressure on lowland and upland habitats in the northern Peninsula varied with seasonal numbers of moose, one must know the proportion of resident and migratory moose in the northern Peninsula to determine habitat use. We had no precise method of determining a captured individual's status, but through its subsequent movements we could tentatively assign it to resident or migratory status. Data presented later in this report, however, indicated that moose captured in the lowlands could not be assigned to a clearly defined status. Furthermore, we did not select moose at random during helicopter capture but purposefully selected groups known or suspected to be migratory. Our best estimates of relative proportions of lowland resident versus migratory moose were probably derived from moose captured throughout the year in fenceline traps in the lowlands at the MRC. We must assume that moose were in the lowlands during winters and that sightability was the same for all animals. If we also assume that collared moose later resighted during or immediately after the rutting period in the mountains were migratory and that those seen during or immediately after the rut in the lowlands were lowland residents, then of 52 moose, 81 percent were lowland residents. Therefore lowland residents outnumbered migratory moose about 4 to 1. If, as indicated by the annual U.S. Fish and Wildlife Service census conducted by Moose Range personnel, there were 3,782 $\pm$605 moose on the National Moose Range in March 1976, and if 81 percent were lowland residents, lowland habitats would be supporting about 1.1 moose/km^2 from November through June and 0.9 moose/km^2 the remainder of the year. Upland ranges would be supporting about 0.5 moose/km^2 from July through October. These figures are only approximations since the Moose Range population estimate includes parts of the central Peninsula where some moose remain in upland habitats all year. Nevertheless, these figures suggest lowland habitats, on an annual basis, receive about twice as much use as upland habitats.

On the central Peninsula upland habitats were used by moose more frequently than other habitats (Table 5). However, during severe winters some upland moose migrated to lowland areas and an unknown proportion of central Peninsula calves may have been born in the lowlands. Because upland communities in the central Peninsula benchland are primarily climax willow (LeResche 1972) and have not been burned recently, moose populations have not fluctuated there as much as in the northern region of the Peninsula. They may decline, however, as the area's carrying capacity decreases. The proportion of moose inhabiting the entire central Peninsula that are lowland residents is unknown.

Most collared moose in the southern region of the Kenai Peninsula utilized riparian habitats about six months of each year (winters, springs, calving and, to some extent, summers). Upland habitats were used from summer through early winter. Except for the Cohoe-Kalifonsky lowland area, which appeared to be intensively used during winters, lowland habitats did not appear to support large moose numbers. This may be attributed to the maturity of the southern Peninsula forests, which have not been burned because of moister climatic conditions.

Seasonal Elevations of Moose

One of the more obvious differences among habitats used by migratory Kenai Peninsula moose was the difference in elevations.

The mean elevations of seasonal habitats of moose revealed similar trends throughout the Peninsula (Table 6). Moose were seen at lowest elevations during the winter, spring, and calving periods. Moose collared in the central region of the Peninsula were the only exception; although they also were found at their lowest elevations in the winters and during calving periods, they characteristically moved to higher elevations during the spring. Migratory moose throughout the Peninsula were found at the highest elevations in the summer and fall.

Snow conditions, plant phenology, availability of forage and perhaps special calving habitat requirements influenced the habitats used by moose. Nasimovitch (1955) reported that moose usually moved out of areas after the first lasting snowfall, or when snow depths reached 25 to 45 cm. If snow depths of 70 cm or more persisted for long periods, moose moved to areas with less snow. However, he also reported that some moose migrated from high elevations before any snow fell and others remained behind until snow depths reached 60 to 70 cm. The influence of snow on moose movements is apparently highly variable. Rausch (1958) concluded that although snow is an influential factor, it does not cause seasonal movements.

Availability of early greening plants appeared to attract upland moose from high but habitable ranges to lowland ranges during the calving period. This downward movement, most evident among central Peninsula collared moose and to a lesser extent among northern Peninsula migratory moose, appeared unrelated to snow depth. Some moose left elevations as high as 975 m, where they had spent the winter (January and February), to use lower lying areas. Central Peninsula collared males moved from an average elevation of 514 m in the early spring (March and April) to 342 m in May and June, and females moved downward from 399 to 317 m during the same period. Since these moose were leaving areas where they had previously obtained forage, it appeared that snow was not restricting food availability at higher elevations. This movement to lower elevations and the increased use of muskeg habitats suggest that moose may have moved to lower elevations to take advantage of new plant growth.

The return of collared moose to high summer ranges appeared quite variable. Some moose seemed to be following the melting snowline up mountainous slopes, but others remained in the lowlands after the snow on the lower slopes had melted before returning to upland ranges. New plant growth in upland habitats and decreasing snow cover appeared to influence upward movements of moose. LeResche (1972) reported that migratory moose in the northern Peninsula dispersed slowly to upland summer-fall ranges beginning in June. We observed the same pattern among collared moose from the southern region of the Peninsula, but central Peninsula

Table 6. Mean seasonal elevations (meters) of collared moose on the Kenai Peninsula, 1968-1976.

Region of Peninsula	Sex	Season: Calving (May-June) N	x̄	Summer (July-Aug) N	x̄	Rut (Sept-Oct) N	x̄	Post-rut (Nov-Dec) N	x̄	Winter (Jan-Feb) N	x̄	Spring (Mar-Apr) N	x̄
Northern		M	29	103	22	531	23	586	29	474	14	118	19
		F	157	82	76	388	84	552	186	312	153	152	150
Central		M	9	342	24	437	17	457	36	655	28	472	7
		F	5	317	13	407	25	424	20	477	20	293	9
Southern		M	5	280	1	366	11	518	60	625	24	296	14
		F	41	181	4	305	21	497	89	506	125	126	60

moose displayed a slower rate of upward movement to summer ranges than either northern or southern Peninsula moose (Table 6). For all observed moose, the mean differences in elevations between calving and summer habitats ranged from 81 to 428 m (266 to 1,404 ft.). The average change in elevation was 188 m during this 60-day period or about 3 m (10 ft.) per day.

Habitats of Male and Female Moose

On the northern Kenai Peninsula, collared males were observed in certain habitats more often than were collared females. Compared to females, males were seen more often than expected in upland habitats during the calving period and more often than females in riparian habitats during summers, the rutand post-rut periods (Table 7). During these latter periods, fewer collared males than females were seen in lowland habitats. Our small sample of collared lowland males undoubtedly influenced these observations. Regardless, from May through December migratory males apparently used upland climax willow and upland riparian communities more frequently than migratory females. Migratory females used lowland habitats more often than migratory males during this period. The greatest difference in mean elevations of habitats used by all collared northern Peninsula males and females occurred during the summers and post-rutting periods. In summers, males were observed an average 143 m (470 ft.) higher than females, and during the post-rut period they were observed an average of 162 m (532 ft.) higher than females (Table 8).

Some of these apparent differences in habitat use by males and females may have resulted from the uneven proportion of collared males to females, unknown proportions of resident versus migratory moose and sightability differences. More females (154) than males (25) were collared in the lowlands at the MRC. However, if numbers of males were indicative of the proportion of males to females in the lowlands, migratory males may have been more numerous than lowland resident males at least in the vicinity of the MRC. Only 28 percent of 90 males captured in the northern Peninsula were captured in the lowlands at the MRC. The remaining 72 percent were captured elsewhere in the region by helicopter and were presumed to be migratory. Only 4 of 25 males captured at the MRC, were seen in the lowlands and none were observed in the mountains during rutting seasons, thus the proportion of lowland captured males that were lowland residents may have been as low as 16 percent. Our sample of collared males therefore may have been biased toward migratory males and the differences in elevations of habitats used by males and females may have been more apparent than real in the northern region of the Peninsula.

Male and female moose collared in the central region of the Peninsula presumably represented only two major breeding groups; no lowland residents were captured in the region. There were no significant differences in habitats used by collared males and females in the benchlands from March through October (Table 9). However, from November through February, more collared females than males were seen in lowland habitats. This

Table 7. Numbers of observations of collared male and female moose (migratory and lowland residents) in seasonal habitats, northern Kenai Peninsula. 1968-1976.

	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov-Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
Habitat	M	F	M	F	M	F	M	F	M	F	M	F
Lowland. Spruce-birch-aspen	6	43	1	33	2	51	4	77	9	122	7	89
Muskeg	22	129	-	13	1	4	-	23	2	14	11	58
Upland. Timber and climax willow	6	1	4	23	5	29	3	12	1	7	-	8
Riparian. Upland and lowland	1	37	19	32	23	46	22	51	1	28	3	21
Total	35	210	24	101	31	130	29	163	13	171	21	176
Chi-Square value	38.22[a]		22.41[a]		18.49[a]		23.13[a]		1.36		4.19	

[a] Significant at 5% level.

Table 8. Differences in mean elevations (meters) of seasonal habitats of collared male and female moose on Kenai Peninsula, 1968-1976. Sample sizes are in parenthesis

Region of Peninsula	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov-Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
	N	$\bar{x}$	M	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$
Northern	(186)	21	(98)	143	(107)	34	(215)	162	(167)	34	(169)	45
Central	(14)	25	(37)	30	(42)	33	(56)	178	(48)	179	(16)	115
Southern	(46)	99	(5)	61	(32)	21	(149)	119	(149)	170	(74)	36

Table 9. Numbers of observations of collared male and female moose in seasonal habitats, central Kenai Peninsula. 1972-1976.

	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov-Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
Habitat	M	F	M	F	M	F	M	F	M	F	M	F
Lowland. Spruce-birch-Aspen	-	2	-	-	-	-	-	3	4	10	2	5
Muskeg	3	-	-	-	-	-	1	1	-	-	-	-
Upland. Timber and climax willow	2	2	20	12	15	25	18	12	17	9	5	4
Riparian. Upland and lowland	4	1	4	1	2	-	17	4	7	1	-	-
Total	9	15	24	13	17	25	36	20	28	20	7	9
Chi-Square value	6.19		0.59		3.09		8.39[a]		8.43[a]		1.17	

[a]Significant at 5% level.

supports our observations in the northern region of the Peninsula where males, more often than females, remained in the uplands during the coldest period of the year. On an annual basis, these data suggested that most central Peninsula males and females shared the same general habitats about 67 percent of the year while most of their northern Peninsula counterparts shared the same general habitats only 33 percent of the year. Maximum separation of elevations between collared central Peninsula males and females occurred from November through February when the average difference was about 178 m (585 ft.) (Table 8).

In the southern region of the Peninsula, collared males and females were observed in the same general habitats during all seasons of the year except winters. Then fewer males were resighted in riparian habitats and more males were resighted in lowland habitats than had been expected (Table 10). Most intensive use of riparian habitats occurred during winter. Maximum elevational separation (170 m) between collared males and females also occurred during winter (Table 8).

There is little information in the literature regarding differential use of habitats by male and female moose. In sedentary resident populations males presumably use the same habitats as females, but in migratory populations males appear to be the first to leave low lying areas in spring and the last to leave upland areas in winter. At least one observation suggests that there may be differences in forage quality between upland and lowland ranges. Edwards and Ritcey (1958) noted that moose summering in upland areas in British Columbia had higher twinning and perhaps higher pregnancy rates than lowland residents.

The solitary and aggressive nature of females, especially those with calves (Houston 1968), and the tendency of males to aggregate in social groups (Peek et al. 1974) suggest that females may be dominant over males. Giest (1971) reported that some females dominated males he observed and Houston (1968) speculated that well-established or aggressive females might control areas of better habitat and force subordinate moose into marginal habitats. Houston also that noted females with calves were most aggressive toward other moose during winters when range was limited. The aggressive behavior of females could force males into other, perhaps marginal, habitats, unless winter weather dictates that both sexes share limited habitats. It was noteworthy that during winters in the southern Peninsula, collared females were observed proportionately more often than males in limited riparian habitats, and males were seen proportionately more often in lowland habitats. The comparative quality of the two habitats is unknown.

Movements

Because we were unable to locate collared moose on consecutive days, the distances recorded between observations were influenced by the intervals between resightings. However, since frequency of resightings was related to season, we assumed that distances between locations within seasons

Table 10. Numbers of observations of collared male and female moose in seasonal habitats, southern Kenai Peninsula. 1973-1976.

	Season											
	Calving (May-June)		Summer (July-Aug)		Rut (Sept-Oct)		Post-rut (Nov-Dec)		Winter (Jan-Feb)		Spring (Mar-Apr)	
Habitat	M	F	M	F	M	F	M	F	M	F	M	F
Lowland. Spruce-birch-Aspen	-	4	-	1	1	-	-	7	6	24	4	11
Muskeg	-	3	1	1	1	2	-	4	-	2	1	1
Upland. Timber and climax willow	2	9	-	2	4	13	41	61	7	32	-	11
Riparian. Upland and lowland	1	25	1	1	3	7	16	29	3	67	5	41
Total	3	41	2	5	9	22	57	101	16	125	10	64
Chi-Square value	3.19		2.31		4.2		6.97		8.65[a]		7.42	

[a]Significant at 5% level.

were comparable. The distances recorded were linear distances between relocations of individually identifiable moose and do not represent the actual distances traveled by moose between these points (Table 11).

Collared moose in the northern region of the Peninsula appeared to move greater distances in May-June and November-December than at other periods of the year. These were probably migratory movements between upland summer-fall and lowland winter-spring ranges. During other periods when moose were already on their respective summer or winter home ranges, their movements were more limited. The greatest distance between locations of a known lowland resident was 3.5 km. The greatest average distance between locations of collared female moose (3.6 km) was recorded during May and June, and the least (2.0 km) during January and February when most migratory moose were on winter ranges. The average distance between locations of collared males was equal to, or was exceeded by, those of collared females six months of the year (Table 11). The only period in which the average distance between locations of collared males greatly exceeded that of females was during calving when many collared migratory males left the Moose River Flats to return to the mountains, and the females remained behind on the calving grounds.

On the central Peninsula, the greatest average distance between locations was 13.8 km for collared females in November-December and 16.0 km for collared males in May-June. As in the northern Peninsula, these periods coincided with peak annual moose migrations; however, central Peninsula moose appeared to move greater distances during these periods than their northern Peninsula counterparts. Our data suggest that on the central Peninsula movements of males exceeded those of females during the rut, but movements of females exceeded those of males in the summer and the post-rut period.

Southern Peninsula moose appeared to travel distances within seasons comparable to those traveled by central Peninsula moose. The greatest average distance between locations of females, 6.1 km, was recorded during November-December when most females probably moved from higher to lower terrain. From September through February, the distances between locations of males generally exceeded those of females. A single recorded distance for a male during the rut (13 km), was over twice that of a female (5.0 km) for the same period. Females on the southern Peninsula appeared to move little once they were on their winter ranges. Comparable data were not obtained for males during these periods.

In general, our movement data reveal that moose moved the greatest distances during periods of annual migration and moved least often when using their summer and winter ranges. Furthermore, these data suggest that during the rut males appeared to be more mobile than females in the central and southern regions of the Peninsula, but females appeared nearly as mobile as males in the northern Peninsula. On a regional basis, moose in the central and southern regions of the Peninsula appeared to move greater distances than northern Peninsula moose from September through February.

Table 11. Linear distances in kilometers between relocations of collared moose on the Kenai Peninsula, 1968-1976.

		Season																	
		Calving (May-June)			Summer (July-Aug)			Rut (Sept-Oct)			Post-rut (Nov-Dec)			Winter (Jan-Feb)			Spring (Mar-Apr)		
Region of Peninsula	Sex	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Northern	M	(2)	7.5	±0.7	-	-	-	(2)	3.0	±1.4	(2)	1.5	±0.7	(1)	2.0	-	(1)	1.0	-
	F	(18)	3.6	±3.2	(1)	1.0	-	(11)	2.7	±2.4	(9)	3.2	±2.4	(25)	2.0	±1.8	(29)	2.1	±3.3
Central	M	(1)	16.0	-	(6)	2.5	±0.8	(3)	8.3	±7.5	(7)	5.0	±2.9	(5)	3.0	±1.4	-	-	-
	F	-	-	-	(4)	7.8	±9.6	(8)	3.9	±1 6	(4)	13.8	±12.5	(5)	2.4	±2.6	-	-	-
Southern	M	-	-	-	-	-	-	(1)	13.0	-	(25)	5.2	±4.9	(5)	5.6	±4.3	-	-	-
	F	(7)	4.1	±3.8	(1)	1.0	-	(1)	5.0	-	(30)	6.1	±5.7	(43)	3.6	±4.0	(8)	4.5	±3.3

Philips et al. (1973) reported that the mean activity radii of radio-collared male and female moose in Minnesota ranged from 1.4 to 1.9 km in the summer-fall and from 1.1 to 1.3 km in the winter, respectively. Females traveled a maximum of 1.1 km per day in June and males traveled a maximum of 1.3 km per day in September. In Quebec, the average movement of adult males from summer to fall was 7.6 km compared to 3.5 km for adult females (Roussel et al. 1975). These studies have shown that males generally travel greater distances than females and that moose are more sedentary during winter than summer.

In the central region of the Peninsula, distances between locations of collared females were greater than those of collared males from July through December (except during the rut). During the rutting period, distances between locations of males were more than double those for females. These movement patterns, the changes in average elevations and the traditional use of rutting areas by migratory moose suggest that females moved considerable distances before and after the rut but moved little during the rut. In contrast to females, males appeared to move greater distances during rather than prior to or after the rut. This suggests that migratory females moved little once they were in the vicinity of rutting areas, and males may have been attracted to these areas by the females. Assuming most female moose are bred within a period of 14 days (Edwards and Ritcey 1958) and assuming a dominance hierarchy exists among males, with the largest antlered males doing most of the breeding (Bubenik 1968), males would have little time to establish hierarchies and also breed with females during the brief time females are receptive. Furthermore, if males remain with a single female in estrus for up to seven days (Altmann 1959), a single male might be expected to breed only a few females during a two-week period. However, in areas with low bull:cow ratios males may spend less time with females or the breeding period may be prolonged. Therefore, it seems advantageous for both males and females to return to traditional rutting areas each year in order to reduce the time they spend searching for each other. As Lent (1974) speculated, and our data suggest, it appears to be the female which selects traditional rutting locations.

Two-year-old female #401 moved at least 27 km from the Moose River Flats to the Sterling area in eight days in February 1974. Another 2-year-old female (#142) moved at least 32 km from the MRC to the Mystery Creek drainage between 7 September and 27 October 1972. The maximum recorded movements in the northern and central Peninsula were by 3-year-old moose. Female #57 moved at least 60 km from the northern lowlands to the central Peninsula benchlands in four months. Male #350 moved at least 39 km from the central benchlands to the lowlands near Soldotna in six month. The greatest recorded movement in the southern Peninsula was by a 6-year-old female (#77) that moved at least 56 km from the Caribou Hills to the Cohoe-Kalifonsky lowland area in four months. Most major movements occurred during spring migrations between lowland winter and upland summer ranges. Our data suggest that younger moose were more likely to travel greater distances than older moose; certainly moose 2 to 3 years old made most of the long distance movements. In Quebec, Roussel et al. (1975) reported that movements of yearling and 2-year-old males were greater than those of adult males. Our data suggest additionally that the movements of young female moose were greater than those of adult females.

Rates of Travel

To estimate rates of travel of individual collared moose we divided the distances between locations by the appropriate time interval. This crude method of estimating travel rates of 16 moose in the lowlands indicated an average movement of 1.7 km per day. Maximum rates of travel for moose in the northern, central and southern region of the Peninsula were 3.5, 2.1 and 6.3 km per day, respectively. Migratory or dispersing moose displayed maximum rates of travel. In Minnesota, moose traveled a minimum of 0.4 to 1.9 km per day within established home ranges (Philips et al. 1973).

Migration Routes

Upland drainages appeared to be major travel routes for migrating moose on the Kenai Peninsula. In the northern region, collared moose utilized the drainages of Chickaloon River, Mystery Creek, and other smaller drainages to travel between upland summer and lowland winter ranges. Collared moose seen on the Moose River Flats in May and June were sometimes observed 5 to 10 km away, near the base of the mountains at Mystery Creek and the Chickaloon River, in July or August. From October through December they were observed farther in the mountains, often at the heads of drainages. Migration back to the lowlands in the late fall and early winter apparently was along the same routes.

Within the mountainous area of the northern Peninsula, moose appeared to follow drainages rather than cross ridges. Some moose apparently traveled up west-facing drainages and crossed over into adjacent north-and south-facing drainages by moving through American Pass and the Moose Creek area between the Chickaloon River and Big Indian Creek and the Resurrection Creek drainages, respectively. Others apparently traveled up the Chickaloon River drainage and crossed over into the Juneau Creek drainage near Swan Lake. Some moose moving up the Thurman Creek drainage probably crossed over into the Juneau Creek drainage near Trout Lake. Within the northeastern mountainous region of the study area no collared moose were sighted farther east than the upper reaches of the eastern tributaries of Juneau and Resurrection Creeks. This suggests that northern Peninsula moose seldom moved directly over mountain ridges exceeding about 1,067 m (3,500 ft) in elevation. Several collared moose seen farther east and deep within the Kenai Mountains at Summit Lake and Trail Lake probably traveled up the Kenai River Valley and its tributaries.

We were unable to document any major migration routes across the western lowlands although there were many seismic trails in the area and they may have been used by moose. Moose appeared to funnel down most mountain drainages and then disperse, in a broad front, once they reached the lowlands. This major east-west migration of moose required that all moose cross a pipeline access road which paralleled the base of the Kenai Mountains. Because of limited public access and the poor condition of this road, it did not appear to influence movements of moose.

Migration routes were less distinct in the central Peninsula. Locations of tagging sites and later resightings of collared moose suggest that the few individuals which migrated long distances may have traveled downward near the Funny River and Killey Rivers, perhaps following the streams to their confluence with the Kenai River. Although some central Peninsula collared moose were seen along Skilak Lake and north of the Kenai River, no moose collared in the central Peninsula benchlands were seen along Kalifonsky River which drains Tustumena Lake. Central Peninsula tagged moose were also absent among moose, including those collared on the southern Peninsula, observed wintering in the Cohoe-Kalifonsky lowland area. Although Tustumena Lake prevents southwestward movements of central Peninsula benchland moose, the Kalifonsky River is not a physical barrier to movements of moose. Why moose tagged on the southern Peninsula move freely northward across the Kalifonsky River to wintering areas while central Peninsula moose remain only north of the river is unknown. However, many major migrations appeared to occur within drainages and no drainages from the central Peninsula benchlands were oriented southwestward toward the Cohoe-Kalifonsky area. Instead, most drainages used by central Peninsula moose were oriented northwestward.

Collared moose on upland summer ranges in the Ninilchik Dome and Caribou Hills areas of the southern Peninsula migrated north, south and southwesterly to wintering areas. There appeared to be little movement of moose collared on the uplands directly west down drainages of Deep Creek, Clam Creek and Stariski Creek. Instead, these animals appeared to move southwesterly until they encountered Anchor River, or if moving southeasterly, they traveled directly to the Fox River. Once within the Anchor River drainage moose apparently moved downstream to lower elevations or crossed over from the Anchor River drainage into the Fritz Creek-Beaver Creek wintering areas. By following Fritz Creek downstream, some moose eventually reached the low-lying wintering areas adjacent to Kachemak Bay near the town of Homer. Moose tagged in the Caribou Hills which migrated north to winter in the Cohoe-Kalifonsky area may have traveled down the Crooked Creek drainage from the upper Deep Creek rutting and post-rutting areas.

Home Range

Sizes of home ranges of moose were estimated from areas within polygons formed by connecting outermost observation points and were probably underestimated since there were few observations per moose. Our data suggested that lowland ranges were generally smaller than upland ranges for resident moose, upland winter ranges were larger than upland summer ranges, and upland ranges were largest in the northern region of the Peninsula (Table 12).

Resident moose in the northern lowlands had an average minimum home range of 13.7 km^2 (5.3 mi^2). Most documented home ranges were near the MRC in the 1947 burn area, and 20 of 21 were those of females. In Minnesota studies using radio-telemetry, Berg (1971) and VanBallenberghe and Peek (1971) reported summer ranges varying from 4.6 to 14.3 km^2 and winter ranges averaging 2.0 km^2. Although our estimates suggested that Kenai Peninsula lowland moose had larger home ranges than Minnesota moose, these estimates included periods up to six years (Table 13) and therefore may have included year-to-year adjustments in home range.

Male moose inhabiting the central region of the Peninsula appeared to have larger upland home ranges than females. Three summer home ranges of males averaged 9.8 km^2 compared to 6.1 km^2 for four of females. Philips et al. (1973) reported smaller home ranges for males than for females in Minnesota, but Roussel et al. (1975) believed males wandered more widely than females during the summer and fall in Quebec. More extensive movements and perhaps larger home ranges of Kenai Peninsula males may be related to the low male:female ratios on the Peninsula (LeResche 1972). Our home range determinations included the rutting period when males may leave their "normal" ranges and travel through strange territory (Philips et al. 1973).

Assuming that home range size reflects differences in habitat quality, upland ranges in the northern Peninsula may be inferior to upland ranges in the central and southern regions of the Peninsula. Our data suggest that moose which remained in the uplands all year used three times as much area in the northern uplands as in the central and southern uplands. Distribution of forage and protective cover as well as characteristics of the forage during winters could influence minimum size of upland ranges. In the northern uplands, moose may be forced to use limited riparian communities during the winter, while in the central and perhaps southern uplands, moose are also able to use vegetation on snowfree, windblown ridges (Franzmann and Arneson 1973).

Upland ranges are probably incapable of supporting the year-round densities of moose supported by lowland ranges. LeResche (1974) believed that in Alaska upland ranges supported only 0.8 to 1.6 moose/km^2 while productive lowland ranges appeared to support as many as 4 to 6 moose/km^2. This implies that upland moose would have larger ranges than lowland moose. On the Kenai Peninsula, our data suggest that upland winter ranges of moose are five to seven times larger than lowland winter ranges.

<u>Distance Between Summer and Winter Ranges</u>

We estimated distances between summer and winter ranges of moose by measuring the miminum straight line distances between resightings of individuals in the summer and winter (Table 14). In the northern

Table 12. Minimum sizes of home ranges in square kilometers of Kenai Peninsula moose.

Region of Peninsula	Upland: Migratory moose: Winter range[a] N	$\bar{x}$	SD	Upland: Migratory moose: Summer range[b] N	$\bar{x}$	SD	Upland resident moose[c] N	$\bar{x}$	SD	Lowland: Migratory moose: Winter range N	$\bar{x}$	SD	Lowland: Migratory moose: Summer range[d] N	$\bar{x}$	SD	Lowland resident moose N	$\bar{x}$	SD
Northern	(1)	37.0	-	(2)	31.0	$\pm$4.2	(3)	91.2	$\pm$105.4	(14)	7.0	$\pm$3.3	(3)	4.1	$\pm$1.6[d]	(21)	13.7	$\pm$7.8
Central	(3)	16.9	$\pm$9.8	(11)	10.7	$\pm$8.9	(7)	30.4	$\pm$26.1	(3)	2.4	$\pm$0.7	-	-	-	-	-	-
Southern	-	-	-	(10)	10.4	$\pm$5.1	(3)	27.2	$\pm$7.3	(17)	5.8	$\pm$3.8	-	-	-	-	-	-

[a] Occupied from January through April

[b] Occupied from July through November

[c] Occupied from January through December and dependent on winter weather and snow conditions

[d] Probably only part of total range of lowland residents

Table 13. Sizes of home ranges of lowland resident female moose, northern Kenai Peninsula.

Number of years included in determination of home range size	Number of females	Average number of observations per female	Size of home range (km)		
			$\bar{x}$	SD	Range
1	4	4.5	17.5	±1.7	15.8-19.1
2	5	6.0	11.7	±5.1	5.3-18.9
3	3	9.3	8.9	±0.5	8.3-9.2
4	2	8.0	13.2	±4.9	9.7-16.6
5	1	6.0	14.5	-	-
6	1	9.0	5.6	-	-
Mean	-	6.7	12.6	±4.7	5.3-19.1

Table 14. Distances in kilometers between upland summer and lowland winter ranges of Kenai Peninsula moose.

Region of Peninsula	Sex of moose	Migration period: Autumn-Winter N	x̄	SD	Spring-Summer N	x̄	SD	Range of movements
Northern	M	(6)	24.2	±13.0	(21)	21.5	±16.0	16-32
	F	(11)	14.6	±8.6	(56)	18.1	±9.8	15-60
Central	M	(7)	11.7	±6.9	(10)	15.4	±11.7	1-39
	F	-	-	-	(10)	18.0	±12.2	1-35
Southern	M	(11)	23.8	±5.1	(2)	23.0	±4 2	2-56
	F	(29)	24.2	±9.4	(11)	23.8	±5.1	2-50

FINAL REPORT (RESEARCH)

State: Alaska

Cooperators: Theodore N. Bailey, Albert W. Franzmann, Paul D. Arneson, and James L. Davis

Project Nos.: W-17-3, W-17-4, W-17-5, W-17-6, W-17-7, W-17-8 and W-17-9.

Project Title: Big Game Investigations

Job No.: 1.7R

Job Title: Kenai Peninsula Moose Population Identity Study

Period Covered: July 1, 1970 through June 30, 1977.

SUMMARY

A total of 636 moose were fitted with neck collars and observed 1,775 times on the Kenai Peninsula from 1968 to 1976 to obtain information on seasonal habitats, movements and populations. Sixty percent of the observations were made from November through April when the ground was snow covered. Only 10 percent of the observations were made during summers when visibility was more limited. Seventy-three percent of the males and 68 percent of the females were resighted, but the average observation rate was only 2.8 observations per resighted moose and 36 percent of the moose were observed only once.

Migratory moose in the northern region of the study area spent about one-third of the year in upland habitats and the remainder in lowland habitats. Upland habitat use varied with severity of winters. Northern Peninsula migratory moose were usually in mountainous areas from June or July to November or December. They were in upland climax willow communities during summers, upland riparian communities in the late fall and lowland communities of birch, spruce, aspen and willow in the winters. Most collared migratory females calved in an extensive muskeg area of the Moose River Flats or in the Kenai River Valley northeast of Skilak Lake. An abundance of aquatic plants may have attracted moose to the Moose River Flats, because males as well as females were observed there. Moose resident in the northern Peninsula lowlands remained in lowland spruce-birch-aspen communities year round. Few collared lowland females calved in the Moose River Flats.

Many moose collared in the central Peninsula benchlands remained in upland areas during average winters, but others migrated to lowland areas near Skilak Lake and the Sterling Highway, especially during severe winters. Benchland moose moved from wintering areas to higher elevations briefly during the spring, then moved back down to lower elevations during the calving period before returning to high summer ranges. No major calving grounds were identified for collared central Peninsula moose, although some females calved in the Moose River Flats with northern Peninsula females.

Most moose collared in the southern Peninsula displayed migratory movements. Winters were spent in lowland riparian habitats along the Anchor River, Fritz Creek, and Fox River. Some moose overwintered up to 50 km away in lowlands near the Cohoe-Kalifonsky Road while others overwintered in lowlands near the town of Homer. The Fox River Flats was the only identified major calving area of southern Peninsula females.

Maximum seasonal movements of moose occurred in May-June and November-December when migratory moose moved from lowlands to uplands and uplands to lowlands, respectively. Movements of males generally exceeded those of females. Males moved greater distances than females during the rut. Females in the northern Peninsula moved greater distances relative to males than the females in the central and southern regions. Most maximum movements, up to 60 km, were by 2 to 3-year-old moose and maximum travel rates were up to 6.3 km per day. Mountainous migration routes often coincided with upland drainages. Average minimum winter home ranges of migratory moose varied from 2.4 to 37.0 km^2 and summer ranges varied from 4.1 to 31 km^2. Northern Peninsula lowland residents had an average minimum year-round home range of 13.7 km^2. Average distances between summer and winter ranges of migratory moose varied from 11.7 to 24.2 km throughout the three regions of the Peninsula.

Forty-one percent of the females and 24 percent of the males collared at rutting locations were observed at least once at the same rutting locations in subsequent years. Older females displayed a higher rate of return than younger females. Most of the moose initially collared at rutting locations but seen elsewhere during subsequent ruts were less than 5 years old. Nearly all rutting locations were associated with specific drainage systems. Those identified included Big Indian Creek, East Creek, American Creek, Juneau Creek, Chickaloon River, Thurman Creek, Mystery Creek, Dike Creek, upper tributaries of Funny River, Moose Creek, Deep Creek (North Fork), Cytex Creek, Falls Creek, Clam Creek, Anchor River, and Beaver Creek. Frequency of male-female encounters during the rut appeared related to sex ratios in the region. During the rutting period, only 11 percent of the observations of collared northern lowland resident females were of males with females. Sixty-four percent of the observations of collared central Peninsula females during the rut were of males and females together.

There were no significant differences in age structures between live-captured and hunter-killed females. Age structure of males differed significantly from that of females in the northern and central Peninsula. Most males were less than 5 years old and most females over 5 years old. On the southern Peninsula females over 10 years old comprised up to 34 percent of live-captured females of all ages. Females over 10 years old were seen less often with calves in the fall and winter than were younger females.

Management considerations regarding seasonal habits, movements, behavior, sex ratios and resident versus migratory modes of life of moose are discussed.

region, the average distance between winter and summer sightings of males was greater than than for females. Males traveled at least 16 to 32 km between ranges. The average distance was 21.5 km from lowland to upland in the spring and summer and 24.2 km from upland to lowland in the fall and winter. Distances between sightings of collared females averaged 14.6 and 18.1 km, respectively, for the same periods. These movement patterns suggest that males travel farther than females between their seasonal ranges. These movements and the average elevational differences between observations of males and females together suggest that males moved longer distances because their movements were further up mountain drainages and slopes than females.

In the central uplands, the average distance between summer and winter locations of collared females was greater than that for males. Here females overwintered at lower elevations than males and females apparently had to move longer distances to achieve the desired change in elevation. In the southern region, where males and females used habitats at nearly the same elevations each season, the sexes moved about equal distances, approximately 24 km, between summer and winter ranges. The distances between summer and winter ranges of moose vary greatly (LeResche 1974) and are influenced by climate, habitat and terrain. Such movements may range from 2 to 10 km (Minnesota), where moose make rapid seasonal movements (Berg 1971), to up to 170 km (Northwest Territories), where moose in the tundra move long distances along rivers with little change in elevation (Barry 1961).

Moose Populations

Characteristics of Breeding Groups

Although our data support the preliminary views of LeResche (1972) regarding the presence of distinct breeding groups of moose on the Kenai Peninsula, they have also revealed a complex situation. Less than half of the individuals collared within four groups of moose at rutting locations after LeResche's report were subsequently seen at the same rutting locations during other years (Table 15). Furthermore, more collared females than males were observed at the rutting grounds where they had been captured in other years. An average of 41 percent of females captured on rutting grounds were observed at the same rutting areas in other years compared to 24 percent of the males. Eight percent of the males and females collared at specific rutting areas were observed elsewhere during subsequent rutting periods. The remaining moose collared on rutting grounds were not observed subsequently during a rut. These individuals could have died, lost their collars or simply were not observed.

Table 15. Numbers of collared moose observed at rutting locations, 1972 to 1976.

Rutting location capture site	Total collared		Number observed in subsequent years at same rutting locations				Number observed at other locations during the rut				Number not observed during rut			
	Males	Females	Males		Females		Males		Females		Males		Females	
			N	%	N	%	N	%	N	%	N	%	N	%
Northern Peninsula: Big Indian Creek	2	10	1	50	6	60	0	-	1	10	1	50	3	30
Central Peninsula: Benchlands	19	8	7	37	5	63	1	5	0	-	11	58	3	38
Central Peninsula: Funny River	12	21	2	17	8	38	2	17	2	10	8	67	11	52
Southern Peninsula: Caribou Hills	29	25	5	17	7	28	2	7	2	8	22	76	16	64
Total	64	62	15	24	26	41	5	8	5	8	42	68	33	52

Some rutting areas had a higher rate of return of collared moose than others, and age of the animals appeared to significantly influence numbers of collared individuals returning annually to specific rutting areas. With females there was a direct relationship between the average age and the proportion returning to rutting areas (Fig. 2). More older females returned than younger females. For example, in the central Peninsula benchlands, where 63 percent of the collared females were observed in subsequent years, the average age of returning collared females was 11.3 years. In the Caribou Hills area, where only 28 percent of collared females were observed, the average age of returning collared females was 6.9 years. Low numbers of collared males that were observed at rutting areas prevented age comparisons for males.

All collared moose observed outside their initial rutting areas in subsequent years, with the exception of two collared males, were 3 to 4 years old. These males, ages 10 and 11, were killed by hunters early in the rutting period. Female #39, a 4-year-old when captured, was seen 18 km from her previous year's rutting location in the Caribou Hills, and female #25, a 3-year-old at capture, was seen 12 km from her previous year's rutting location the following rutting season. In the Big Indian Creek drainage, female #403, a 3-year-old when captured, was seen almost a year later on 6 September with two other females. She was then within her previous year's rutting area but 10 days later, she was killed by a hunter 9 km away on the opposite side of a steep mountain ridge outside the Big Indian Creek drainage. Male #51, a 3-year-old when captured, was at least 15 km from his previous year's rutting area when seen during the breeding season a year later, and male #344, another 3-year-old, was seen 16 km from his previous year's rutting location the following season. These data suggest that traditional use of a rutting location may not occur among moose less than 4 or 5 years old. However, even older moose may not return to the same rutting grounds each year.

Traditional use of winter ranges has been documented for moose in Wyoming. There, 61 percent of marked moose returned to winter ranges for at least two consecutive years, 15 percent returned only in alternate years and 24 percent failed to return within two years (Houston 1968). This is a much higher rate of traditional use than we documented for Kenai Peninsula moose.

It appears that the nucleus of breeding groups of migratory moose on the Kenai consists of older females which, when together, perhaps attract other, mostly younger, females as well as males. Perhaps some or all of the younger females are offspring of the older females. For some reason, many of these younger moose may not return or may not begin to repeatedly use a rutting area until they are older. Whether males follow the same pattern on the Kenai Peninsula is unknown. Perhaps only a few older males traditionally breed at specific rutting locations and younger subordinate males remain on the margin of breeding groups or

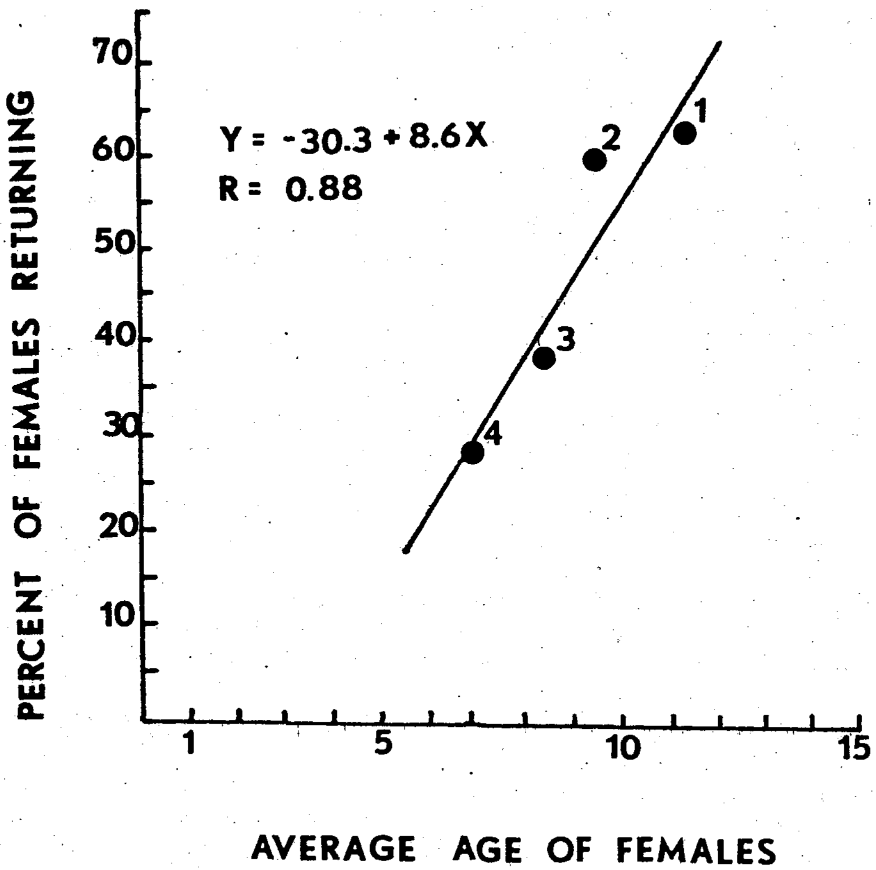

Figure 2. Percentage of rutting-grounds collared female moose returning to same rutting grounds in subsequent years in relation to age of moose. Rutting locations: 1)Timberline Lake. 2)Big Indian Creek. 3)Funny River. 4)Caribou Hills.

travel from one rutting location to another. These latter speculations are supported by the observations of Altmann (1960) and Giest (1962). Giest also reported that an adult cow drove away yearling males and females from the vicinity of an older male during the rut. These observations suggest that older moose are intolerant of younger moose during the rut and may influence the number of younger moose that use rutting areas each year.

The proportion of collared females observed alone during the rut and male:female ratios in rutting groups varied with the status of moose, terrain, and sex ratio of moose within regions (Table 16). Collared northern Peninsula lowland resident females were seen alone during the rut more often (89 percent) than collared migratory females throughout the Peninsula (average 53 percent). Central Peninsula collared females were seen alone least often (32 percent). Number of females per male was lower for lowland resident females (1.5 females per male) than for migratory females (6.4 to 9.8 females per male). Among migratory moose, the greatest disparity in numbers of females per male at rutting time was on the northern Peninsula where males were most heavily harvested by hunters. Group size during the rut was much greater in open terrain (migratory moose) than in dense cover (lowland resident). Lowland moose did not appear to aggregate during the rut.

According to Lent (1974), the size of rutting groups of moose is influenced strongly by habitat and less by the sex ratio. Because large rutting groups are usually found in open terrain, particularly in alpine areas, visibility appears critical in inducing aggregation. The influence of skewed sex ratios on rutting groups and productivity has not been investigated. In the Matanuska Valley, Alaska,during in the 1960's, extremely low male:female ratios reportedly did not influence productivity. Nevertheless, after the population declined in 1972 excessive male harvests and the resulting low proportion of males, as well as a deteriorating food supply and several severe winters, were suggested as influencing productivity (Bishop and Rausch 1974). Low bull:cow ratios could lower productivity by reducing conception rates and prolonging the conception period, which in turn may decrease overwinter survival of late-born calves.

Although a deteriorating food supply appears to be the major factor influencing productivity of the northern Kenai Peninsula moose population (Spencer and Hakala 1964, Bishop and Rausch 1974), the low bull:cow ratio which has been characteristic of the area since the 1950's may also have some influence on calf survival or productivity. In 1965, a wide range in the sizes of fetuses on the northern Peninsula suggested that the conception period had been prolonged (Rausch 1967). Of 34 females captured in the northern lowlands outside the MRC in 1972-73, 76.5 percent were pregnant (Franzmann and Arneson 1973). Pregnancy rates in other Alaskan moose populations with low bull:cow ratios were generally higher, however, ranging from 86 to 100 percent (cited in Franzmann et al. 1976). Our rutting period observations suggest that an

Table 16. Collared moose observed during the rut (September-October). Excludes moose in live traps and moose captured by helicopter during the rut.

	Region of Peninsula			
	Northern		Central	Southern
	Lowland residents	Migratory		
Observations	19	31	25[a]	22
Females alone	17 (89%)	23 (74%)	8 (32%)	10 (45%)
Females with one male	2 (11%)	6 (19%)	9 (36%)	11 (50%)
Females with more than one male	0	2 (6%)	7 (28%)	1 (5%)
Average group size: females alone	1.2 ± 0.4	1.7 ± 1.1	1.4 ± 1.1	3.8 ± 2.6
Average number of females with males	1.5 ± 0.7	9.8 ± 10.5	6.6 ± 5.3	6.4 ± 4.7
Average number of males with females	1.0 ± 0	1.5 ± 1.1	$1\ 5 \pm 0.7$	1.1 ± 0.3

[a] One male seen alone

unbalanced sex ratio in favor of females may have less influence on migratory populations than on sedentary lowland populations because migratory females characteristically aggregate in groups where one male may breed with many females. In lowland populations, where habitat and behavior of moose appear to prevent aggregations of females, a more evenly balanced sex ratio may be necessary to insure that the majority of solitary and widely dispersed females are bred.

We were unable to determine if collared lowland-resident females bred within their normal, year-round home ranges or whether they bred elsewhere in the lowlands. About 41 percent of known-status, lowland-captured females had established home ranges in the lowlands and 11 percent were overwintering migratory females. Forty-nine percent of these collared, lowland-captured females were not seen in the lowlands during or immediately after the rut nor were they seen in the uplands. These females may also have been migratory, but there were not enough observations to determine their status. Since period of initial capture of these individuals differed significantly from that of lowland residents but not from that of migratory moose, it appeared the majority were migratory since most were captured during winters (Table 17). If we can assume that increased mobility of moose in the vicinity of the MRC increased capture rates, it appears that lowland resident females were particularly active and mobile during the rut. This also suggests that females may have been leaving their normal home ranges in search of males and perhaps were attracted to the males in our enclosures. Females were sometimes seen opposite the fence from enclosed males suggesting this may have been the case. The density of males at the MRC was probably considerably greater than anywhere else on the northern Peninsula lowlands. Response of nearby free-roaming collared females to this artificial concentration of enclosed males during the rut suggests the disproportionate number of males in the northern lowland population may have influenced rutting behavior of females and perhaps the productivity of moose in the area.

In a largely lowland resident population in Minnesota, Philips et al. (1973) reported increased activity and movements of males and decreased movements of females during the rut. Increased movements of males during the rut were also reported by Houston (1968) and VanBallenberghe and Peek (1971). We recorded increased movements of males or greater movements of males than females during the rut among collared moose on the Kenai Peninsula except in the northern region (Table 11). These movements of females and the aggregation behavior of Kenai Peninsula (mainly northern Peninsula) females (Peek et al. 1974) appear unusual compared to other moose populations in which sex ratios are more balanced.

Numbers and Locations of Breeding Groups

We did not attempt to identify all breeding groups of moose in our study areas. From the segregation of collared moose, locations of aggregations of rutting groups, and return of collared moose to specific rutting locations, we identified 18 breeding groups of moose on the Peninsula

Table 17. Period moose were captured at the Moose Research Center, 1968-1976. Includes only moose which were subsequently observed.

Status of moose	No.	Period of capture			
		Rut		Other	
		N	%	N	%
Lowland resident	42	22	52	20	48
Migratory	10	2	20	8	80
Unknown status	52	1	2	51	98

Period of capture:

lowland residents versus moose of unknown status, $X^2 = 31.99$, df = 1 $P < 0.005$

Period of capture:

migratory moose versus moose of unknown status, $X^2 = 6.00$, df = 1, $P > 0.010$

(Fig 3), however. Excluding northern lowland residents, each group characteristically assembled in specific benchland or mountain drainages or near some other distinct feature in open terrain. It is likely that other unidentified groups of moose assembled during the rut and that an unknown, but smaller, proportion of central and southern Peninsula moose also were lowland residents. Moose from these localized breeding groups commonly shared winter ranges with each other and with lowland residents (LeResche 1972). During the summer and fall these moose were usually observed within or near the same drainages where they aggregated for the rut.

Northern Kenai Peninsula - At least eight breeding groups of migratory moose were recognized in this region. During the rut, collared moose aggregated in the drainages of Big Indian Creek, East Creek, American Creek, Juneau Creek, Chickaloon River, Thurman Creek, Mystery Creek, and Dike Creek. Depending upon winter severity, these migratory moose left their upland ranges in December or January to overwinter in the adjacent lowlands or in the Kenai River valley. Migratory females remained behind in the lowlands to calve while males returned to the uplands. By late August or early September, most migratory moose appeared to be on their upland ranges where they assembled for the rut. The movement patterns of several collared moose inhabiting this region illustrate the difference in movements between lowland residents and migratory individuals (Fig. 4).

Central Kenai Peninsula - We recognized two, possibly three, breeding groups of moose in the central region and speculate that a lowland resident population also exists in the region. Two conspicuous breeding groups were evident during tagging operations near the lower Funny River airstrip and in the benchlands to the north, southwest of Timberline Lake. A third breeding group, based on later resightings of collared moose, was seen in the Moose Creek drainage. It is likely that other breeding groups of moose were present but not observed. Most collared upland moose remained in the upland areas or moved only short distances during average winters. During severe winters, some upland moose wintered in the lowlands near Kenai River and the Sterling Highway and west of Skilak Lake (Bottenintnin Lake). Some upland females calved in the Moose River Flats and others were thought to have calved in the lowlands of the central region. Figure 5 depicts the movements of two collared moose from this region and illustrates movements of migrating moose and moose remaining in the uplands.

Southern Kenai Peninsula - At least seven breeding groups of moose were recognized in the southern region of the Peninsula, and it is likely that a lowland resident population exists in the lowlands between the Kasilof and Anchor Rivers. Groups of moose gathered in the upper drainages of the North Fork of Deep Creek, Cytex Creek, Falls Creek, Clam Creek, Anchor River and Beaver Creek. Moose from these breeding groups displayed complex seasonal movement patterns. For example, some moose breeding in

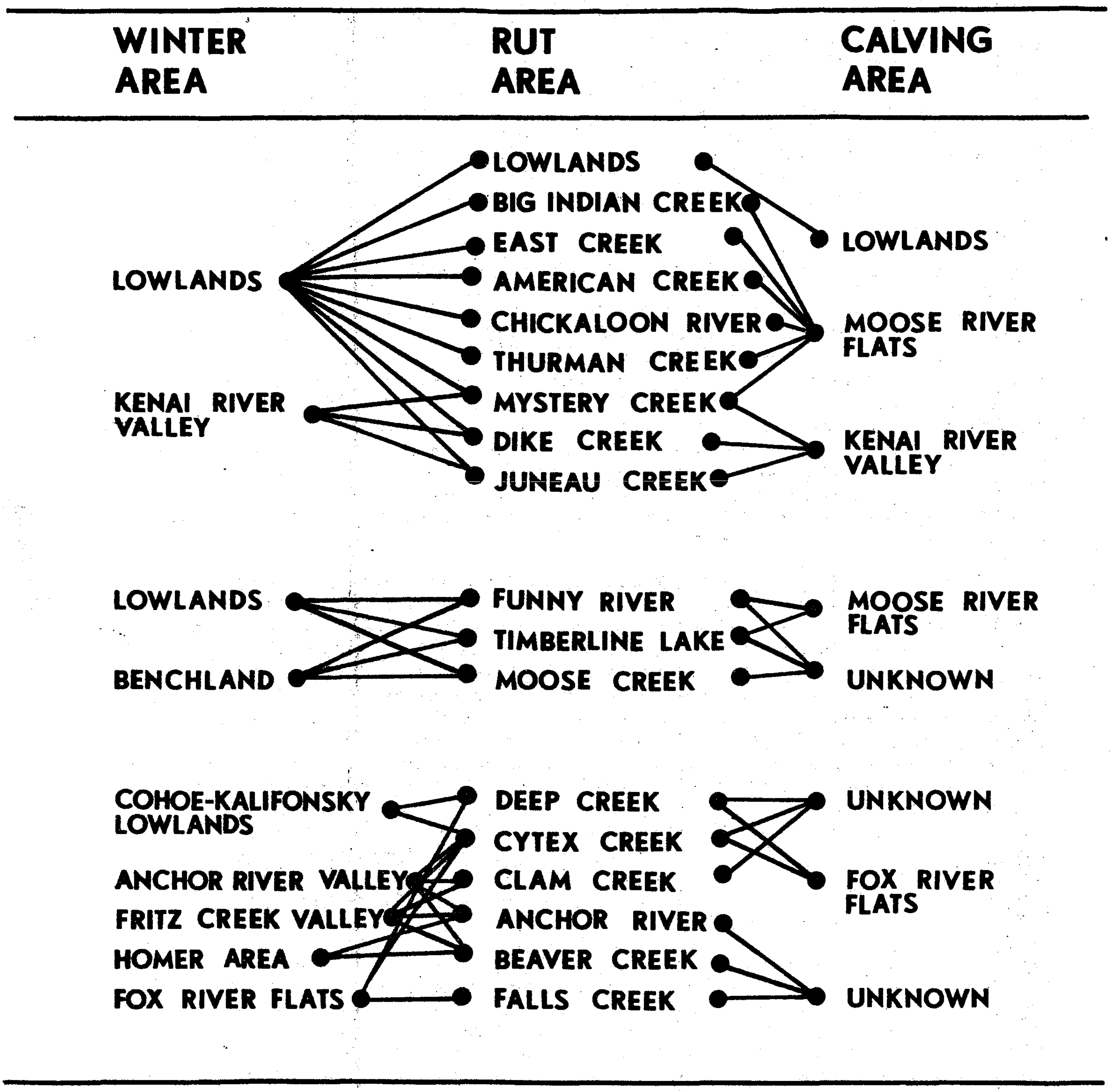

Figure 3. Relationships between moose at winter, rutting and calving locations on Kenai Peninsula.

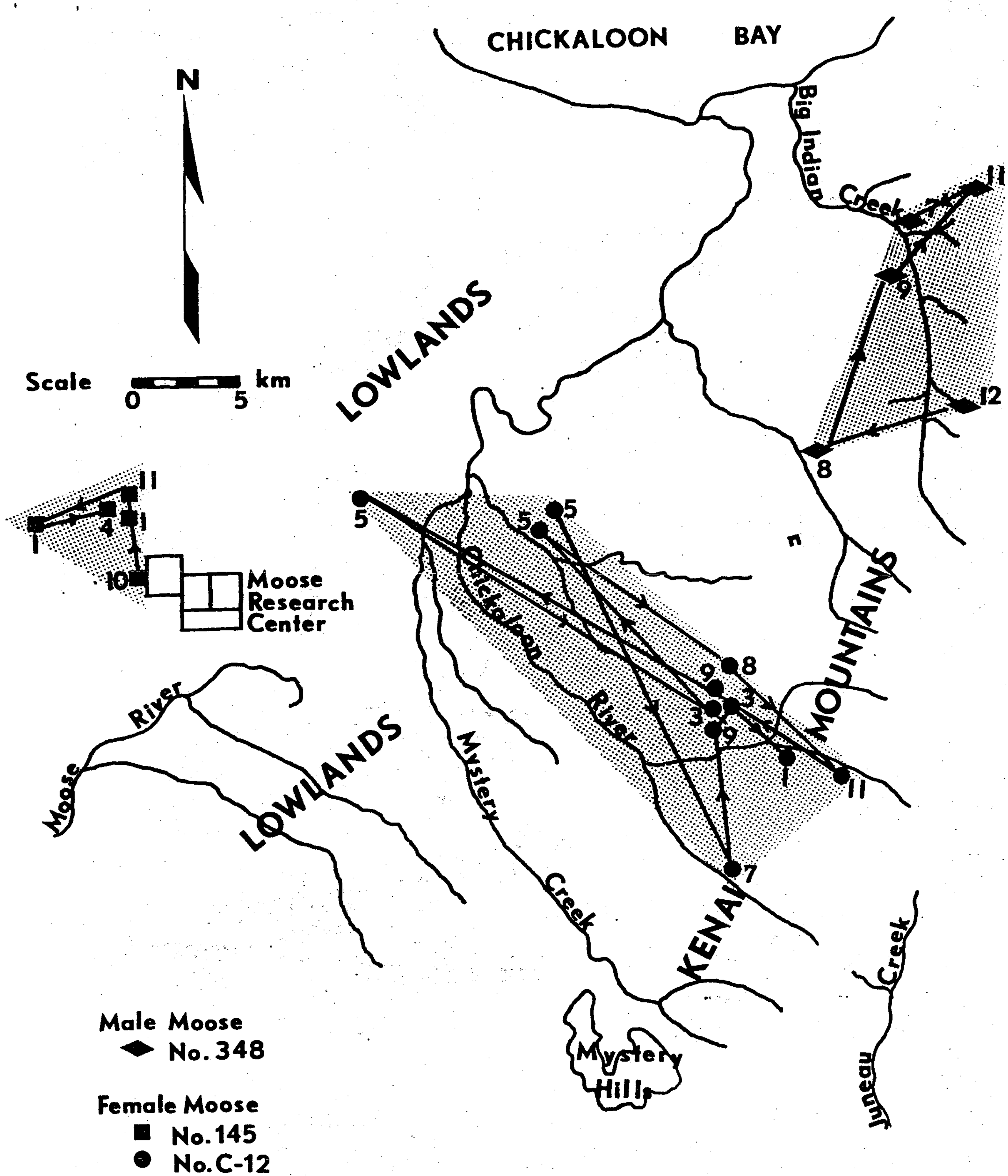

Figure 4. Movement patterns of collared moose in northern region of Kenai Peninsula. Numbers indicate month of observation.

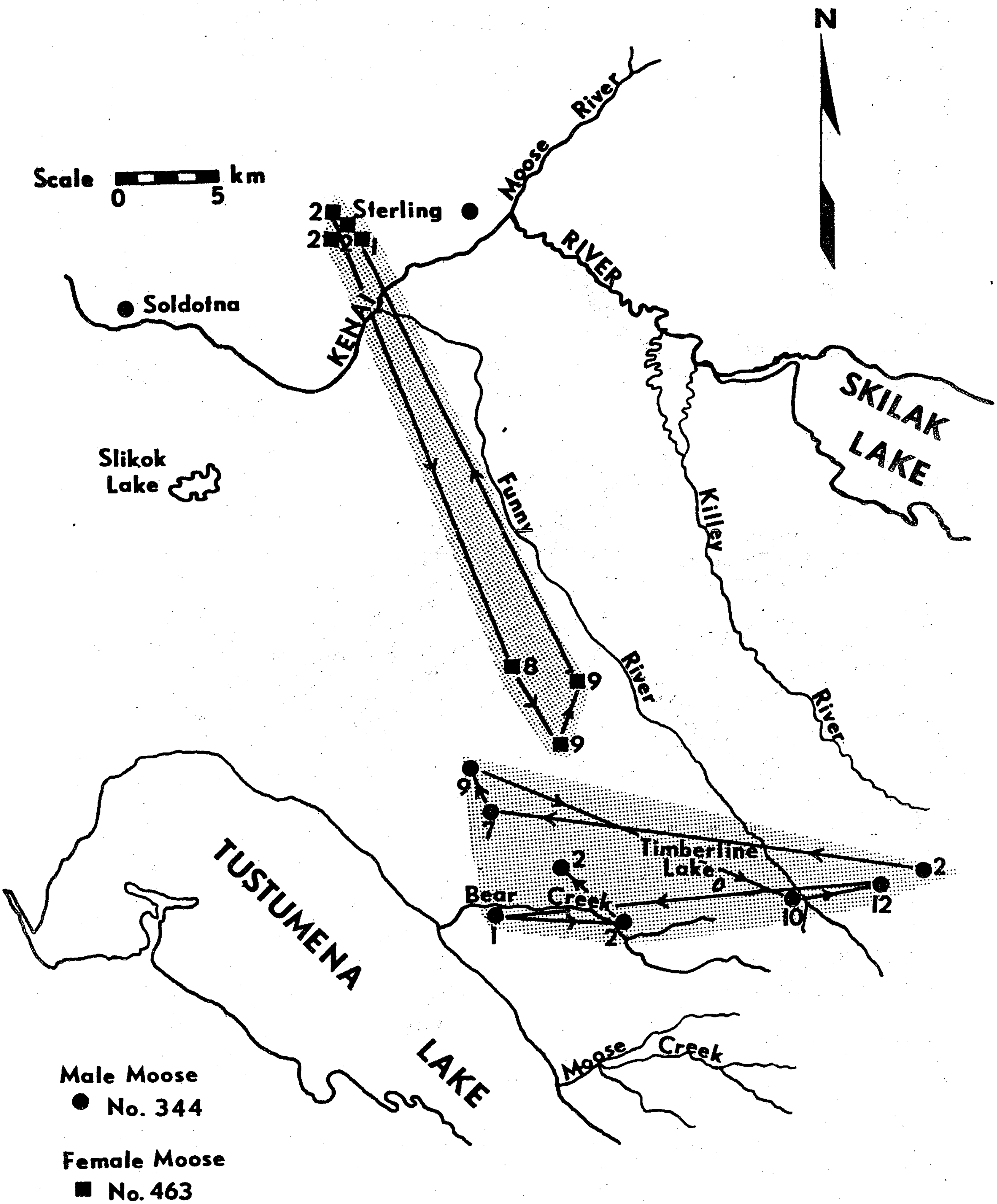

Figure 5. Movement patterns of collared moose in central region of Kenai Peninsula. Numbers indicate month of observation.

the Deep Creek drainage migrated south to overwinter in the Fox River valley. Others from the same group migrated north to overwinter in the Cohoe-Kalifonsky lowland area and still others overwintered along the Anchor River to the west (Fig. 6). Some moose from the same group apparently remained in the Caribou Hills area throughout the winter. The rutting locations of a number of moose which overwintered in the Fritz Creek, Homer, and Anchor River areas were not identified.

There was no obvious intermixing of moose collared on the northern or central Peninsula with those collared on the southern Peninsula at any season of year. Some northern and central Peninsula populations shared winter and calving areas in the northern lowlands, particularly at Bottenintnin Lake and the Moose River Flats. No moose collared in the central or northern Peninsula were observed south of the Kasilof River. No southern Peninsula- tagged moose were observed north of the Kenai River although one individual was once seen just south of the river near Soldotna.

Ages of Moose

It was initially assumed that the techniques utilized to capture moose for collaring would result in biased age ratios. When moose were captured by helicopter, yearlings and calves were avoided because of the risk of drug overdose. Drug dosage necessary for immobilization varied with condition of the moose (Franzmann et al. 1974), and darting may have been selective for weaker, and perhaps older, moose. Moose captured in fenceline traps at the MRC presumably were not subject to these biases. To determine if our capture techniques were age selective, we compared ages of captured female moose over 1 year old with those of hunter-killed moose from the same regions and during the same periods but found no significant differences in age structure (Table 18). This suggested either that drug dosage did not significantly influence the age distribution of captured moose or, less likely, that darting and hunting were equally age selective.

The age distribution of captured male moose differed significantly from that of captured females in two of three regions of the Peninsula. Seventy-three percent and 64 percent of northern and southern Peninsula captured males, respectively, were less than 6 years old, compared to only 33 and 29 percent of the females from the same regions. Although only 6 to 7 percent of the males were older than 10 years, 28 to 34 percent of the females were older than 10 years. Age distributions of captured males and females from the central Peninsula were not significantly different (Table 19).

The skewed age distribution of males reflects the heavy hunting pressure to which males were subjected in the more easily accessible northern and southern regions of the Peninsula. In the more remote central region, where access and hunting methods were more restricted, proportionately fewer males were killed and hence more survived to older ages. The

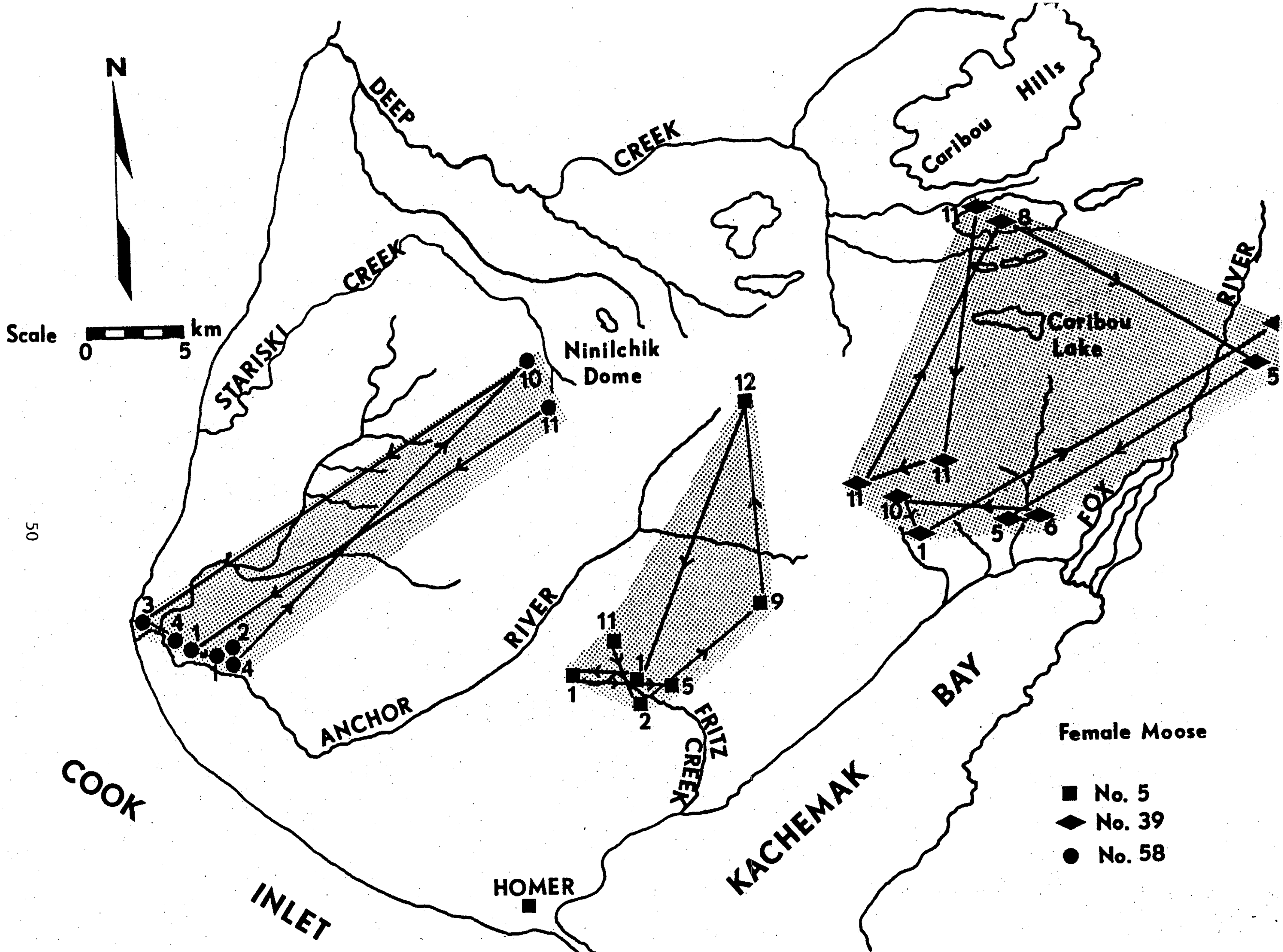

Figure 6. Movement patterns of collared moose in southern region of Kenai Peninsula. Numbers indicate month of observation.

Table 18. Ages of female moose killed by hunters and captured alive on the Kenai Peninsula, 1968 to 1975.

Age	Northern Peninsula		Central Peninsula		Southern Peninsula	
	Hunter[a] killed	Live[b] captured	Hunter killed	Live captured	Hunter killed	Live captured
Calves	108	–	20	–	8	–
1	95	8	30	–	47	4
2	76	30	22	3	24	8
3	57	22	16	2	6	3
4	52	20	13	1	29	8
5	50	22	13	4	23	10
6	40	13	4	3	22	15
7	37	26	12	1	14	10
8	34	26	9	4	4	5
9	39	17	9	2	10	3
10	30	21	8	–	10	10
11	26	20	10	1	10	6
12	28	16	6	3	9	10
13	18	15	7	2	7	8
14	14	4	6	1	5	5
15	6	4	4	–	3	4
16	2	1	2	–	3	3
17	3	1	1	–	–	1
18	–	–	–	–	1	2
Total	715	266	192	27	235	115

[a] Northern Peninsula, 1970 and 1972; Central Peninsula, 1970 and 1971; Southern Peninsula, 1973 and 1974 (Alaska Department of Fish and Game, unpublished data).

[b] Northern Peninsula, 1968 through 1975; Central Peninsula, 1972; Southern Peninsula, 1973 through 1975.

Table 19. Ages of live captured moose on the Kenai Peninsula, 1968-1975.

Region of Peninsula	Status	Sex	Number	Age in years																		Average age
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Northern	Lowland	M	4	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5
	residents	F	37	2	3	6	2	2	1	4	3	3	2	1	2	3	1	2	-	-	-	7.2
	Migratory	M	45	1	13	8	6	4	5	2	-	3	-	1	2	-	-	-	-	-	-	4.5
		F	128	2	15	9	7	8	8	12	11	9	13	11	10	8	3	1	-	1	-	7.6
	Sub-total	M	49	2	13	11	6	4	5	2	-	3	-	1	2	-	-	-	-	-	-	4.3
		F	165	4	18	15	9	10	9	16	14	12	15	12	12	11	4	3	-	1	-	7.6
Central	Upland residents	M	28	-	3	5	5	2	3	1	3	1	4	1	-	-	-	-	-	-	-	5.7
	and migratory	F	27	-	3	2	1	4	3	1	4	2	-	1	3	2	1	-	-	-	-	7.0
Southern	Majority	M	33	4	3	4	3	7	5	1	1	3	-	-	1	-	1	-	-	-	-	5.1
	migratory	F	115	4	8	3	8	10	15	10	5	3	10	6	10	8	5	4	3	1	2	8.3
Total	-	-	417	14	48	40	32	37	40	31	27	24	29	21	28	21	11	7	3	2	2	6.9

proportion of males in Kenai Peninsula moose populations was already severely depressed from hunting as early as 1962 (Bishop and Rausch 1974). Numbers of males per 100 females averaged 15.2, 31.9 and 17.8 from 1968 to 1974 in the northern, central and southern regions of the Peninsula, respectively (Alaska Department of Fish and Game, unpublished data). The lowest ratio during this period, 1.5 males per 100 females, occurred in the northern Peninsula in 1973.

There were proportionately more females over 10 years old in the southern region of the Peninsula than the northern and central regions. Thirty-four percent of the known-age, captured females in the southern region were over 10 years old compared to 26 percent of females captured elsewhere on the Peninsula. There were also fewer females (29 percent) less than 6 years old in the southern region than in the other two regions of the Peninsula (Table 19). There were no significant age differences among males captured throughout the Peninsula; however, most males were less than six years old. None of the captured males classified as northern Peninsula lowland residents were over 5 years old.

Ages of moose captured in the northern lowlands varied significantly. The difference in age distribution between sexes in migratory moose was much greater than that for lowland residents. Although sample size was small, it appeared that lowland males were generally younger than migratory males. The average age of lowland males was 2.5 years and that of migratory males was 4.5 years. Although migratory females were also older than lowland resident females, the difference was not significant. There were no significant age differences among females captured at various tagging sites, although females captured during the rut in the Kenai Mountains at Mystery Creek and Big Indian Creek were generally older than females captured in the lowlands throughout the year (Table 20). The fact that migratory females captured at the MRC were considerably younger, on the average, than migratory females captured at rutting areas in the mountains, also suggests that a proportion of younger migratory females did not traditionally return to the same rutting areas each year, as did older females.

Age of Females and Calf Survival

To determine if age of females was related to calf survival, we recorded, when possible, if collared females were accompanied by calves. Because most of these observations were made late in the fall or winter, they provided information on calf birth and survival until fall rather than births alone. These observations probably provided a minimum estimate of survival since some females with calves may have been alone at the time they were observed. This information suggested that age of females in the northern and central regions of the Peninsula was not significantly related to calf survival. However, in the southern region of the Peninsula, collared females 6 to 10 years old were seen with calves more often than females over 10 years old. We do not know whether to attribute this to increased survival of calves of the younger females or to possible

Table 20. Ages of female moose captured at various tagging sites, northern Kenai Peninsula, 1968-1975.

Tagging site	Period of captures	Number	Age in years																	Average age
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Mystery Creek	Rut	13	-	-	1	-	1	2	4	1	-	2	-	-	-	-	-	-	1	8.1
Skilak Lake Area	Late winter	47	-	6	1	3	4	2	2	4	4	2	9	3	6	1	-	-	-	8.3
Moose River Flats	Calving	81	3	14	7	5	4	4	12	7	6	6	3	5	1	2	2	-	-	6.6
Big Indian Creek	Rut	10	-	1	1	-	-	1	-	1	-	4	-	1	1	-	-	-	-	8.4
MRC-Migratory	Throughout year	11	-	1	2	2	1	-	1	-	1	1	-	2	-	-	-	-	-	6.5
MRC-Lowland Residents	Throughout year	37	2	3	6	2	2	1	4	3	3	2	1	2	3	1	2	-	-	7.2

decreased calf survival or lower productivity of older females. Throughout the Peninsula more calves were seen with collared females 6 to 10 years of age than with younger or older females. Females over 10 years old were seen with calves the least often (Table 21). Yearling moose are known to have lower fertility rates than older moose (Simkin 1965, Houston 1968) and, in Sweden, full maturity apparently does not occur until females are between the ages of 5 or 6 to 10 or 11 (Markgren 1969). In Sweden, females 6 to 11 years old had significantly more twins than did other females. Six of seven sets of twins that we observed were accompanying collared females over 5 years old.

Observations of known-age females during two consecutive years also suggested that females over 10 years old reared proportionately fewer calves than females 6 to 10 years old (Table 22). Of 42 collared females seen with calves only one of two consecutive years, only one year of two years, or without calves two consecutive years, 48 percent were over 10 years old, 29 percent were between 6 and 10 years old and 24 percent were 5 years old or less. Fifty-seven percent of the females observed without calves two consecutive years were over 10 years old. The oldest collared female observed with a calf was 19 years old. Houston (1968) reported that females 18 and 22 years old appeared senile. Because pregnancy rates among moose are usually over 75 percent and more commonly around 90 percent (Pimlott 1959, Simkin 1965, Edwards and Ritcey 1958, Rausch and Bratlie 1965), calf survival appears to be more significant than initial birth rates to population maintenance of moose.

Mortality

Winter mortality of calves on overutilized and limited winter range was suggested as being the greatest factor influencing moose numbers on the Kenai Peninsula (Bishop and Rausch 1974). Overwinter calf mortality varied from 41 to 95 percent between 1970 and 1975 in the study areas (Table 23). The highest rate of calf mortality occurred during the severe winters of 1971-72 and 1974-75 when an estimated 80.6 to 95 percent of the calves died. Observations of calves with collared females earlier in the year supported the above observations and also suggested that calf mortality was greatest in the southern region of the Peninsula and least in the northern region. Percentages of collared females observed with calves during the fall and winters were 59, 45 and 33 in the northern, central and southern regions, respectively. If overwinter mortality of moose calves is, indeed, influenced by condition of winter range as well as average snow depths and duration of snow cover, winter range in the 1947 burn area of the northern lowlands still appears superior to that in the central Peninsula uplands and the river bottoms and lowlands of the southern Peninsula.

If, as our data suggest, calf survival was related to age of females, productivity may be lower in areas having high proportions of females over 10 years old. Such a condition appeared to exist in the southern

Table 21. Occurrence of calves with known-age collared female moose. Each observation represents one year per female.

Region of Peninsula	Status	Calf Present	Age in years: 0-5 N	0-5 Percent of age group	6-10 N	6-10 Percent of age group	11+ N	11+ Percent of age group	Total N	Total Percent
Northern	Lowland residents	Yes	10	45	15	75	7	39	32	53
		No	12	55	5	25	11	61	28	47
	Unknown status	Yes	13	72	10	71	15	60	38	68
		No	5	28	4	29	10	40	19	32
	Migratory[a]	Yes	3	19	5	36	1	20	9	26
		No	13	81	9	64	4	57	13	76
	Migratory[b]	Yes	6	100	3	75	4	57	13	76
		No	0	-	1	25	3	43	4	24

(continued)

(continued)

Table 21. Occurrence of calves with known-age collared female moose. Each observation represents one year per female.

Region of Peninsula	Status	Calf Present	0-5 N	0-5 Percent of age group	6-10 N	6-10 Percent of age group	11+ N	11+ Percent of age group	Total N	Total Percent
	Sub-total	Yes	32	60	30	68	27	49	89	59
		No	21	40	14	32	28	51	63	41
Central	Upland residents and migratory	Yes	2	33	11	58	2	25	15	45
		No	4	67	8	42	6	75	18	55
Southern	Majority migratory	Yes	9	29	19	53	5	16	33	33
		No	22	71	17	47	27	84	66	67

[a] Captured on Moose River Flats, 1970 and 1971.

[b] Captured at Moose Research Center, 1968 to 1975.

Table 22. Occurrence of calves with known-age females during two consecutive years.

Observation	Age in years					
	0–5		6–10		11+	
	N	%	N	%	N	%
Calf observed with female only one of two consecutive years	7	26	10	37	10	37
Calf observed with female two consecutive years	7	41	6	35	4	24
No calf observed with female for two consecutive years	6	35	3	18	8	47

Table 23. Percent of calves dying during winters on the Kenai Peninsula (Alaska Department of Fish and Game, unpublished data).

Winter	Severity Index[a]	Percent Mortality[b] Northern Peninsula	Central Peninsula	Southern Peninsula
1969-70	5	44.8	ND	ND
1970-71	20	50.2	ND	ND
1971-72	110	80.6	ND	92.0
1972-73	45	71.5	4.1	14.0
1973-74	62	74.4	21.3	ND
1974-75	100	86.9	85.5	95.0

[a] One point each day snow depths exceed 30 cm, two points each day snow depths exceed 60 cm. Weather data from Kenai F.A.A.

[b] Based on aerial fall and spring survival counts.

ND = No Data.

region of the Kenai Peninsula where 43 percent of the captured females were over 10 years old. Here calves were seen with older (10+ years) females only on 16 percent of our observations compared to 42 percent for younger females. Wolf predation probably has not had a significant impact on recent Kenai Peninsula moose numbers (Bishop and Rausch 1974), at least from the mid-1960's to early 1970's. Wolf predation has been shown to be selective for young and old moose (Mech 1970, Petersen and Allen 1974), while intensive hunting pressure over a number of years usually selects the more vulnerable younger age classes (Cumming 1974). Although this may not be true for the Kenai Peninsula because of its limited antlerless hunting seasons, current wolf predation should remove a high proportion of older females compared to other moose populations long subjected to wolf predation. By removing old females, wolf predation may permit more of the younger females to successfully bring their young through winters by reducing competition with older, perhaps more aggressive, females. Reducing numbers by harvesting old females in populations where wolf predation has been negligible is another method, but antlerless seasons throughout Alaska have characteristically met with public opposition (Rausch et al. 1974).

Management Considerations

Based on differences in their seasonal habitats, movements, behavior and sex and age composition, at least two types of moose populations can be distinguished for management purposes on the Kenai Peninsula: lowland residents and migratory moose. The migratory population is comprised of a number of discrete interbreeding groups which characteristically aggregate within most of the larger mountain drainages during the rutting season, but intermix with each other and lowland residents during the winter and spring. Lowland residents and migratory moose should not be considered members of one homogenous population from which new individuals originate and fill vacant niches left by moose dying of natural or unnatural causes. Although some interchange between lowland resident and migratory moose probably occurs, the extent, timing and relative significance of this interchange is unknown. There also appears to be some interchange between breeding groups of migratory moose, but its significance is also unknown. Movements and return of marked individuals to rutting locations suggest that the interchange between breeding groups and lowland residents mainly occurs among moose less than 6 years old.

The relative proportions of lowland residents and migratory moose are unknown on the Kenai Peninsula. Lowland residents are probably most numerous in the northern Peninsula where they may comprise 40 to 80 percent of that region's moose numbers. Lowland residents are probably also found in the more limited central and southern Peninsula lowlands; however, in these regions, most moose appear to be migratory. Some moose apparently remain in the uplands during mild winters especially in the central Peninsula benchlands. LeResche (1974) estimated that about 10 to 20 percent of the moose on the Kenai Peninsula were of this type.

On the Kenai Peninsula, lowland residents are characterized by their relatively sedentary habits, high population densities, small home ranges, solitary behavior and a low proportion of males in the population. Most of these characteristics are adaptations to a closed environment which has an abundance of forage on a year-round basis. This mode of life is apparently common for moose living in transient habitats created by local disturbances, usually fire (Giest 1971). The present low proportion of males in the population and perhaps a high proportion of females over 10 years old is a result of the intensive hunting pressure on males and lack of antlerless hunting seasons, respectively. Negligible wolf predation on moose in the 1960's and perhaps differential survival of older females during severe winters also may have contributed to the observed high proportion of older females in the lowland resident population of the northern Peninsula.

Migratory moose on the Kenai Peninsula are characterized by their long movements between seasonal ranges, lower population densities, larger home ranges during the summers, seasonally greagarious habits, a low proportion of males, and perhaps a high proportion of females over 10 years old. Most of these characteristics are adaptations to seasonally limited upland ranges and open terrain. The skewed sex ratio is largely a result of hunting pressures on males and perhaps differential survival of older females.

The relationships between lowland resident and migratory moose, when they occur in the same area, are not well understood. Giest (1971) speculated that the most stable and permanent habitats of moose are limited to small areas which are kept by various modes from developing into climax situations unfavorable for moose. Most often permanent moose habitats are found along watercourses and in river deltas. Some permanent moose habitat is also found above timberline. Giest speculated that moose from these small isolated populations expand into newly created transient (seral) habitats until such habitats again become unfavorable. In Europe, Pulliainen (1974) believed that the migratory habit of moose was a result of increased population densities in favorable habitats. He reported that moose in eastern Europe did not begin to demonstrate seasonal migrations until an upper threshold density of moose was reached in the 1950's. LeResche (1974) viewed seasonal migrations in terms of reproductive success and stressed the importance of survival in relation to energy balance during winters. It is likely that all these factors--stability of habitat, population density, and reproductive success--are responsible in determining the relative advantages of a sedentary versus migratory mode of life. One can visualize small, isolated populations of moose expanding into new habitats and then, after densities in the transient habitat exceed a threshold level, dispersing back into more marginal habitats that are favorable only during certain periods of the year.

On the Kenai Peninsula, where both transient habitat (lowland) and permanent habitats (watercourses and above timberline) occur adjacent to each other, the proportion of lowland residents and migratory moose can be expected to vary with time. Because of the declining productivity of transient lowland habitats which have been created by fires, one cannot expect lowland areas to maintain the high moose densities characteristic of earlier successional stages (Spencer and Hakala 1964). To maintain such high densities of moose in the lowlands, considerable effort must be made to set back plant succession, and the economic advantages and disadvantages must be evaluated. Potential management options to influence habitat include controlled burning, logging and mechanical tree crushing. Unless advanced stages of plant succession are set back to earlier stages, lowland habitats will be unable to support the current densities of lowland residents and overwintering densities of migratory moose.

Movement patterns of resident and migratory moose must be considered when burning, logging or crushing trees to improve habitat. Movement data suggest that if such areas are distant from current overwintering areas of migratory moose, only local lowland residents may immediately benefit. For example, 7 of 8 collared moose of known status observed in a 1-to 2-year-old, mechanically rehabilitated area near Willow Lake on the Kenai National Moose Range were lowland residents from nearby habitats. Only one was a collared migratory moose. No collared migratory moose have been observed in the 1969 burn area 40 km from the Kenai Mountains up to four years after the fire. These observations suggest that older migratory moose may be slow to discover new, distant habitats. Long distance movements of lowland residents into such areas may also be limited. Therefore, the farther rehabilitated areas are from traditional wintering grounds, the less immediate benefit they may have for migratory moose. Only local lowland residents with home ranges adjacent to disturbed areas may benefit from immediate forage advantages.

Because it appears that younger moose are the ones which discover and make immediate use of new habitats, the overall success of managed areas in increasing moose productivity and survival may depend on a slow build-up of the local population if the area is not used by migratory moose. Survival of young will therefore be an important factor in population response. Among lowland populations on the Peninsula, overwinter mortality of calves is great during severe winters. Among migratory moose, calf survival elsewhere than on winter range may also limit population response. The potential benefits of increased winter forage production and survival could be negated if calves are lost on calving or summer ranges. This may be especially true for migratory moose calving on the Moose River Flats where only 26 percent of the collared females were later seen with calves compared to 53 percent for collared lowland resident females.

Other management considerations regarding migratory moose have been discussed in general by LeResche (1974). In applying them to Kenai Peninsula migratory moose, several considerations become important. In the southern region, where most migratory moose overwinter in riparian or lowland habitats, key winter range may be lost to human settlement. Elimination of winter habitat in the Fritz Creek, lower Anchor River, Cohoe-Kalifonsky lowlands, Homer area, and Fox River Flats would seriously reduce winter range carrying capacity. With the exception of the Fox River Flats, all critical wintering areas of moose in this region already lie in or near areas of increasing human populations. Reduction of moose numbers supported by winter range in these areas will influence numbers of moose spending the summer and fall in the Caribou Hills. Winter range for central Peninsula moose is more secure becuase during most winters migratory moose winter in remote or protected areas. During severe winters, increased highway mortalities may be expected along the Sterling Highway because central Peninsula moose cross the Kenai River and overwinter in areas near Robinson Loop and Sterling. Similar highway mortalities may be expected during severe winters in the southern region of the Peninsula as migrating moose from the Caribou Hills cross the highway to overwinter near the Cohoe-Kalifonsky area and lower Anchor River. Winter range of northern Peninsula moose is most secure from human disturbance although winter range in this area is deteriorating because of plant succession. However, some of this area is currently being mechanically rehabilitated in experimental blocks to assess the potential of this procedure for providing forage for moose (Oldemeyer 1977).

Because of the remoteness of the mountainous areas on the Kenai Peninsula, most rutting locations of migratory moose are secure from human disturbance. Traditional use of such areas by rutting moose demands that these areas receive continued protection if viable migratory populations are to be maintained. With the exception of the Moose River, Kenai River Valley, and Fox River calving grounds, there do not appear to be any major calving grounds where disturbance may seriously influence moose numbers. At the present time, the Moose River and Fox River calving areas are remote and probably free of human disturbance. Any alteration or blockage of migration routes to or from these calving areas could influence the area's moose productivity, however. The Kenai River Valley calving area lies adjacent to a highway, but the impact of nearby traffic on the calving area is unknown.

The impact of hunting on lowland resident and migratory moose on the Kenai Peninsula is difficult to assess. The area has a long history of bulls-only hunting and antlerless seasons have been difficult to establish (Rausch et al. 1974). Because most hunting probably occurs along road systems in the lowlands, when seasons are early, likely more lowland residents than migratory moose are harvested. If seasons were held later in the year, migratory moose could outnumber lowland residents in the harvest because migratory moose move into the lowlands. It is likely that along roads in the lowlands, most older, lowland resident males that have been removed are replaced by young, dispersing males instead of by older moose moving from nearby adjacent areas. Goddard

(1960) reported little influx of older tagged moose into heavily harvested areas in Ontario. Cumming (1974) reported that yearlings sometimes comprised over 40 percent of the harvest from this same region and attributed the influx of yearlings into such areas as a possible indication of excessive harvesting. On the Kenai Peninsula, poor overwinter calf survival may limit the rate at which young moose can fill empty niches caused by hunting.

If migratory moose are harvested after they leave their upland ranges and intermingle with other overwintering migratory groups, the impact of the harvest on specific breeding groups will be difficult to assess. More control over the harvest of migratory moose could be attained if known numbers are harvested within specific drainages. Similarly, overharvest of moose in the lowlands after migration has occurred may have a lesser impact on the lowland resident population.

Because migratory moose often concentrate in local areas during the winter, even a short late season may expose a large number of moose from several populations to hunters. In contrast, a long, early season on lowland residents may have little impact on numbers because lowland residents are widely dispersed and inhabit dense cover in inaccessible areas. By properly timing seasons of appropriate duration in relation to the movement patterns and degree of dispersion of lowland and migratory moose, one could attain the desired harvest ratio.

The influence of sex ratios favoring males on moose production is unknown (Cumming 1974). Bubenik (1972) expressed concern that an unbalanced sex ratio might interfere with moose social behavior. In Sweden, where bulls and cows have been intensively hunted for many years, a nearly equal sex ratio is maintained in the population (Lykke 1974). Markgren (1974) reported that in regions of northern Sweden with low moose densities, more than two females per male reduced production. In the Matanuska Valley, Alaska, pregnancy rates in a dense migratory population were about 90 percent despite male:female ratios of 4 to 20:100 (Bishop and Rausch 1974). These apparent differences in response of moose to an unbalanced sex ratio may reflect differences in population composition, density and moose behavior.

In the Matanuska Valley most moose appear to be migratory, but in Europe many areas appear to have only resident populations (Pulliainen (1974). Because of their solitary behavior, especially during the rut, lowland residents may be impacted more heavily by a scarcity of males than migratory moose which characteristically aggregate during the rut. In migratory populations, one adult male may have little difficulty locating and breeding with a number of females, especially when the females traditionally use the same rutting grounds year after year. However, in resident populations, where both females and males remain widely dispersed during the rut, fewer females may be bred, especially during their first estrus, if there is a scarcity of males in the population. If this is true, it may be desirable to maintain a more balanced sex ratio in resident populations inhabiting dense cover. Among migratory moose aggregating in open terrain during the rut, as few as 20 or 30 bulls per 100 cows may be sufficient to maintain a desirable pregnancy rate. To properly answer this question, pregnancy rates of known lowland resident versus migratory females would have to be compared under varying sex ratios.

Moose populations throughout the Kenai Peninsula may contain a high proportion of females over 10 years old. These old females may be contributing little to the populations' productivity. Our visibility-limited observations of females with calves later in the fall and winter suggest that calves of 6- to 10-year-old females have a higher survival rate than do calves of older or younger females. Predation on calves of older migratory females might be greater, especially if older females traditionally calve in the same areas year after year and predators become familiar with these areas. It appears that under present conditions some older females could be removed from the population without seriously reducing productivity. It is unlikely that hunting can be used to reduce present numbers of old females on the Peninsula (Rausch et al. 1974), but wolf predation, which appears to be selective for old moose (Mech 1970, Petersen and Allen 1974), may lower the number of older females.

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APPENDIX

RESIGHTING NECK-COLLARED MOOSE[1]

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Abstract: Of 636 moose *(Alces alces)* fitted with neck collars on the Kenai Peninsula from 1968 to 1975, 438 were observed 1,775 times to determine moose movements and ranges and identify populations. Within three regions of the Peninsula, up to 94 percent of the observations were from aircraft, 37 percent from public resightings and 3 percent from hunter kills. Most public resightings of moose were near roads. Sightings during reconnaissance flights averaged 2.3 collared moose per hour, the average flight lasted 2.7 hours and the average air charter cost per observation was $19.72. Proportion of collared moose later resighted varied from 45 percent for those wearing painted-on numbered collars to 72 percent for those wearing sewn-on numbered collars. An average of 73 percent of all males and 68 percent of all females were observed at least once. Although the mean observation rate was 2.8 per moose, 36 percent of the moose were seen only once. Sixty percent of all resightings were from November through April when the ground was covered with snow and deciduous trees were leafless. Few collared moose were seen during summers. Limitations of data are discussed.

Several investigators (Goddard 1970, Phillips et al. 1973, Roussel et al. 1975) have collared moose to study their movements and population dynamics. They reported that a high proportion of neck-collared individuals were not resighted or were observed infrequently. Phillips et al. (1973) concluded that visual observations of collared moose were so limited and biased by habitat type that they could not be used for analysis of moose movements and home range. In contrast when VanBallenberghe and Peek (1971) and Phillips et al. (1973) placed radio collars on moose to delimit home ranges and monitor movements, they were able to obtain detailed information.

In this study we evaluated the success of resighting 636 neck-collared moose, the frequency of resightings and the average number of observations per moose. Method of observation, sex of moose, style of collar and seasonal variability were considered in resighting success. Moose were collared as part of a long range study to determine movements, calving and breeding sites, populations and interactions between populations in order to establish management policies for moose on the Kenai Peninsula

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(LeResche 1972). LeResche also summarized the project up to 1972.

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STUDY AREA

The Kenai Peninsula is located between Prince William Sound and the Cook Inlet in southcentral Alaska. Physiographically, about 60 percent (14,000 km^2) of the Peninsula consists of mountains rising to 914 meters, and the remaining 40 percent (9,300 km^2) is rolling lowland. Numerous small and several large streams drain the eastern mountains and the western lowlands are dotted with hundreds of small to medium-sized lakes.

Vegetation in the lowlands is primarily white and black spruce *(Picea glauca* and *P. mariana)*, birch *(Betula papyrifera)* and aspen *(Populus tremuloides)*, with climax willow *(Salix spp.)* communities dominating above the timberline in the mountains (LeResche et al. 1974). Fire-created seral communities have provided willow and birch forage for moose in the lowlands especially after a wildfire in 1947 burned about 40 percent of the northern lowlands. Another wildfire (360 km^2) in 1969 has not yet produced optimum forage conditions for moose.

A warm, rainy, maritime climate influences the eastern, Prince William Sound-facing side, and the southern tip of the Peninsula. The northern and western regions of the Peninsula have a colder, drier continental climate. Annual precipitation is 43 to 51 cm and average temperature is about 1°C (Spencer and Hakala 1964).

METHODS

Moose were captured in fence-line traps (LeResche and Lynch 1973) at the Moose Research Center in the northern lowlands, and from helicopters in other regions of the Peninsula. Moose were immobilized by intramuscular injections of succinylcholine chloride or etorphine (M-99). A variety of collars were used to identify moose. Braided polyethylene ropes with numbered pendants were used at the beginning of the study as well as monocolor, quadricolor, and striped canvas-web collars. However, canvas-web collars 15.3 cm wide with sewn-on numbers 12.7 cm high were found most effective in identifying moose from low flying aircraft (Franzmann et al. 1974). Collared moose were also marked with metal ear tags and colored flagging in one or both ears. To locate collared moose, a reconnaissance flight was attempted once weekly in a Piper PA-18 aircraft. Locations of collared moose were plotted on 1:250,000 topographic maps from which a general habitat type was later assessed.

Moose were first collared in 1968 in the northern region of the Peninsula at the Moose Research Center and in the Mystery Creek drainage. Later, groups of moose were collared near the western end of Skilak Lake (1970), Moose River Flats (1970 and 1971) and Big Indian Creek (1972). Emphasis was then progressively focused on other regions of the Peninsula. Moose were collared in the central and southern regions of the Peninsula from 1972 to 1975 (Table 1). Moose were captured and collared year round at the Moose Research Center from 1968 to 1975.

RESULTS AND DISCUSSION

Method of Observation

In the southern region of the Peninsula, 61 percent of 458 resightings were from aircraft occupied by Department of Fish and Game personnel, 37 percent were reported by the public and 2 percent were reported as hunter kills. In the central region, 94 percent of 213 resightings were aerial observations. Comparable data were not available for the northern Peninsula because of early data recording methods. In general, fewer observations were reported by the public in the northern and central regions of the Peninsula because of limited public awareness of the project at the beginning of the study, early collar design, and the remoteness of the region.

The peak period for public reports occurred from December through February when moose wintered in areas adjacent to roads. Although public resightings provided information on movements of collared moose between tagging sites and wintering locations, they provided little information on the locations of collared moose throughout most of the year. Public observations were also biased by area because areas where moose were seen comprised only about 10 percent of the region's total area. Similar trends in public reported sightings applied to the remainder of the Peninsula.

Hunter kills provided 3, 3, and 2 percent of the total observations of collared males in the northern, central and southern regions of the Peninsula, respectively. The extent of illegal shooting of moose was unknown although at least 2 of 419 collared moose in the northern Peninsula were taken illegally. Collars and ear tags from carcasses of moose found in the field and along highways were sometimes returned by the public and it is possible that some may have been killed illegally. In the northern Peninsula such returns accounted for only 1 percent of that

Table 1. Moose collared on the Kenai Peninsula, 1968-1975.

Region	Tagging Site	Year	Males	Females	Total
Northern	Mystery Creek	1968	11	17	28
	Skilak Lake	1970	15	54	69
	Moose River Flats	1970, 1971	37	94	131
	Big Indian Creek	1972	2	10	12
	Moose Research Center	1968-75	25	154	179
	Subtotal		90	329	419
Central	Funny River	1972	12	21	33
	Benchland	1972	19	8	27
	Subtotal		31	29	60
Southern	Caribou Hills	1973	29	25	54
	SW Caribou Hills	1973	3	9	12
	Eagle Lake	1974	-	10	10
	Headwater Hills	1974	6	19	25
	Bald Mountain	1974	2	22	24
	Deep Creek	1975	-	5	5
	Ninilchik River	1975	1	4	5
	Clearwater Slough	1975	-	12	12
	Fox River Flats	1975	-	10	10
	Subtotal		41	116	157
	Total		162	474	636

region's observations. The extent to which hunters avoided legally killing collared moose was also unknown but probably negligible.

The effectiveness and cost of charter flights to relocate collared moose were evaluated on a yearly basis. Success and cost of flying to locate moose were complicated by the fact that collared moose were also seen during flights designed to estimate moose numbers in the Kenai National Moose Range and to determine composition and survival of moose populations throughout the Peninsula. Therefore only the flights solely devoted to searching for collared moose were considered.

The average air charter cost per collared moose observation was $19.72, an average of 1.9 collared moose were seen each flight hour, and each flight averaged 2.6 hours (Table 2). Yearly variations in cost per observation were due to the varying success of flights and increased costs of flying. Success of aerial observations was probably dependent on weather conditions, experience of observers (LeResche and Rausch 1974), area searched and season of year. For example, moose were seen more readily when there was snow cover and moose above timberline were seen more readily than moose in timber. Higher rates of resighting were sometimes common soon after tagging because observers tended to return to areas where most moose were previously seen rather than searching areas uniformly.

Observation Success

Early in the study, collared moose were seldom identified as individuals because all moose from specific tagging sites wore identical monocolor neck collars. Individual identification was possible only from tag returns from hunter kills, recognition of individual characteristics (antler shape), or extremely close observation. Because of fading colors and difficulty in distinguishing color combinations from the air, some moose wearing improved quadricolor neck collars also could not be identified as individuals. At least 300 observations were disregarded because the animal could not be individually identified or assigned to a specific tagging site.

Collar design had an impact on number of collared moose later identified as individuals. As expected, moose with monocolored collars were difficult to identify since ear markers or other obvious physical clues (antler size, shape, etc.) had to be used to identify individuals. Hunter kills and ear tag returns accounted for a large proportion of observations of moose marked with such collars. Few moose marked with painted number collars were later identified as individuals probably because the paint ("magic marker") rapidly wore off (Table 3). Moose wearing quadricolor type collars were more difficult to identify as individuals than moose with numbered collars. Some color combinations

Table 2. Success and cost of reconnaissance flights to relocate collared moose on Kenai Peninsula, 1970-1975.

Year	Number of flights	Hours per flight	Number of Moose[1]	Moose per hour	Cost per hour	Cost per observation
1970	33	2.3	164	2.2	35.00	15.91
1971	14	1.9	103	3.9	35.00	8.97
1972	19	3.2	113	1.9	35.00	18.83
1973	42	2.9	297	2.4	45.00	18.75
1974	29	2.9	118	1.4	45.00	32.07
1975	15	3.1	96	2.1	50.00	23.81
Mean	25	2.7	149	2.3	40.83	19.72

Table 3. Influence of collar design on individual recognition of collared moose.

Collar Type	Males			Females		
	Number Tagged	Number Relocated	Percent Relocated	Number Tagged	Number Relocated	Percent Relocated
Plain	42	26	62	110	54	49
Striped	10	6	60	50	34	68
Quadricolor	9	4	44	67	52	78
Numbered[1]	14	5	36	53	25	47
Numbered[2]	13	8	62	58	43	74
Mean	88	49	53	338	208	63

[1]Painted-on numbers

[2]Sewn-on numbers

(pink and yellow) and the rapid fading of colors made individual recognition difficult from the air. Nonexistent color combinations were sometimes reported. To distinguish individual moose, the most effective combination we discovered was a number sewn on a contrasting color on a single colored neck band. In our area, blue numbers on a yellow background and yellow numbers on a blue background were readily distinguished from aircraft.

Despite these problems, the majority of collared moose were later resighted and identified as individuals at least once. Only slightly more collared males (73 percent) were relocated than collared females (68 percent) but the proportion of collared moose that were relocated varied with tagging area (Table 4). These differences were probably related to visibility, intensity of effort to relocate collared moose, collar design, natural and hunter-caused mortality and perhaps differences in moose behavior. In Canada, Roussel et al. (1975) and Goddard (1970) reported 44 and 18 percent, respectively, of the moose they tagged were later observed.

Collared moose inhabiting the central Peninsula, where they were easily seen above timberline or against a background of snow, were relocated at the highest rate. Collared moose were seen less often in the northern Peninsula where they apparently spent much time in timbered areas. This was especially true for collared moose resident in the lowland areas surrounding the Moose Research Center and Skilak Lake. Sparse to dense spruce-birch forest covered most of this area. Many female moose collared on the Moose River Flats were relocated because they used the open muskegs of the Flats during the calving periods when other moose were in timbered areas and hence difficult to observe. Many collared moose in the Big Indian Creek drainage remained in high country during the comparatively mild winter of 1972-73. These individuals were responsible for the high observation success of moose tagged at that site. Different habitats used by collared moose probably were responsible for the differences in observational success in the southern Peninsula. In the southern region most collared moose were seen in the winter when snow cover increased visibility. Here, many collared moose were seen in small relatively open areas. These factors plus an intensive flying effort and good cooperation from the public increased the probability that most collared moose in this region were relocated.

Observation per Moose

The mean number of observations per collared moose was 2.8 throughout the Kenai Peninsula (Table 5). Collared moose in the central Peninsula were probably seen more often (3.6 per moose) than moose in the northern and southern regions of the Peninsula (3.3 and 2.5 per moose) because of the region's more open terrain. Our data suggested males were most conspicuous in the central Peninsula and the least conspicuous in the northern Peninsula. In the northern Peninsula, males inhabiting the mountainous areas from summer through early winter were seen often

Table 4. Percentage of collared moose resighted on Kenai Peninsula, 1968-1976.

Tagging Area	Males No. Marked	Males Percent Relocated	Females No. Marked	Females Percent Relocated
NORTHERN				
Mystery Creek	11	37	17	35
Skilak Lake	15	36	54	47
Moose River Flats	37	69	94	63
Big Indian Creek	2	50	10	90
Moose Research Center	25	56	154	69
Subtotal	90	54	329	63
CENTRAL				
Funny River	12	100	21	81
Benchland	19	100	8	100
Subtotal	31	100	29	86
SOUTHERN				
Caribou Hills	32	88	34	85
Eagle Lake	0	--	10	56
Headwater Hills	6	100	19	84
Bald Mountain	2	100	22	91
Deep Creek	0	--	5	60
Ninilchik River	1	100	4	75
Clearwater Slough	0	--	12	67
Fox River Flats	0	--	10	80
Subtotal	41	90	116	80
TOTAL	162	73	474	68

Table 5. Average number of resightings per moose.

Tagging Area	Moose Tagged	Resightings per Moose		
		Males	Females	Average
Northern Peninsula				
Mystery Creek	28	2.7	7.1	5.4
Skilak Lake	69	1.1	2.4	2.1
Moose River Flats	131	1.9	3.1	2.7
Big Indian Creek	12	2.5	4.0	3.8
Moose Research Center	179	1.2	2.4	2.3
Subtotal	419	2.5	3.8	2.6
Central Peninsula				
Funny River	33	4.7	2.4	3.2
Benchland	27	3.4	5.1	3.9
Subtotal	60	4.1	3.8	3.6
Southern Peninsula				
Caribou Hills	54	3.3	3.4	3.3
SW of Caribou Hills	12	2.3	2.9	2.8
Eagle Lake	10	0	1.3	1.3
Headwater Hills	25	2.3	3.7	3.4
Bald Mountain	24	2.5	4.0	2.1
Deep Creek	5	0	1.4	1.4
Ninilchik River	5	2.0	1.3	1.4
Clearwater Slough	12	0	1.8	1.8
Fox River Flats	10	0	2.0	2.0
Subtotal	157	3.0	2.9	2.9
TOTAL	636	2.5	2.9	2.8

(average 2.1 per moose) but males inhabiting the lower, more heavily timbered, areas during the same period were observed less often (average 1.2 per moose). Although collared females were seen more frequently than males this probably was due to observational bias in the northern Peninsula. At the Moose Research Center we often captured several collared females in our fenceline traps and frequently observed several collared females near our cabins. If this bias is eliminated, females were seen less often than males. These data suggested males were slightly more conspicuous or used open habitats more often than females.

The low number and seasonal bias of observations per moose prohibited detailed assessment of individual movement and home range characteristics. In other studies of home range and movements of ungulates the average number of observations per radio-collared moose have ranged from 42 to 56 (Phillips et al. 1973) and for radio-collared elk *(Cervus canadensis)* 69 to 122 (Craighead et al. 1973). This is 14 to 42 times the number of observations we obtained using visual collars and suggests that despite an intensive and expensive effort to relocate collared moose, the technique had limitations.

The frequency distribution of resightings revealed that many collared moose were seen but once and that most were seen less than four times (Table 6). Of those seen five times or more, most were seen during the winter or spring or were lowland residents seen throughout the year in the one particular area. For example, a female moose tagged at Headwater Hills in the southern Peninsula was seen at least 24 times from December to March 1975 and 1976 along a 2.7 mile section of highway. This contributed to 96 percent of the observations, yet revealed little about her whereabouts at other times of the year. Moose collared at the Moose Research Center were periodically seen throughout the study period but usually near the trap where they were initially captured.

Seasonal and Annual Variations in Observation Success

Most collared moose were seen after the ground was covered by snow. Sixty percent of all observations were from November through April. Few collared moose were seen in the summer (July and August) and early fall (September and October) (Table 7). Seasonal observations varied with region. Many collared moose were seen during the calving period in the northern Peninsula because moose calved in the relatively open Moose River Flats. Similarly, many collared moose in the southern Peninsula calved in the open Fox River Flats. Few collared moose were seen in the central Peninsula during calving because moose there apparently calved throughout the lower timbered regions instead of localized open areas. The high proportion of sightings during the spring in the southern Peninsula was a result of habitat usage adjacent to the road systems. The low resighting success in the southern region during summers was probably related to the distribution and density of vegetation in the summer habitat of moose. Compared to the other regions, there was less available above-timberline summer habitat for moose where visibility was best.

Table 6. Frequency distribution of sighting of collared moose, Kenai Peninsula, 1968-1976.

Tagging Area	Number of Times Moose Observed					Total
	1	2	3	4	5+	
NORTHERN						
Mystery Creek	9	1	0	0	0	10
Skilak Lake	26	4	0	0	0	30
Moose River Flats	38	24	7	7	7	83
Big Indian Creek	2	4	1	1	1	10
Moose Research Center	52	27	12	8	24	123
Subtotal	127	60	20	16	33	256
Percentage	50	23	8	6	13	100
CENTRAL						
Funny River	1	7	5	4	11	28
Benchland	1	8	3	2	11	25
Subtotal	2	15	8	6	22	53
Percentage	4	28	15	11	42	100
SOUTHERN						
Caribou Hills	10	9	10	10	18	57
Eagle Lake	0	4	0	0	1	5
Headwater Hills	7	4	2	3	6	22
Bald Mountain	3	3	3	5	8	22
Deep Creek	1	1	0	0	1	3
Ninilchik River	2	0	2	0	0	4
Clearwater Slough	3	1	1	2	1	8
Fox River Flats	2	3	1	1	1	8
Subtotal	28	25	19	21	36	129
Percentage	22	19	15	16	28	100
TOTAL	157	100	47	43	91	438
Percentage of total	36	23	11	10	21	100

Table 7. Seasonal distribution of resightings of collared moose, Kenai Peninsula 1968-1976.

	Season						
	May-June	July-Aug	Sept-Oct	Nov-Dec	Jan-Feb	Mar-Apr	
Region	(Calving)	(Summer)	(Rut)	(Early Winter)	(Winter)	(Spring)	Total
Northern	245	125	161	192	184	197	1104
Central	14	37	42	56	48	16	213
Southern	44	7	31	148	151	74	455[1]
Total	303	169	234	396	383	287	1772
Percentage of total	17	10	13	22	22	16	

Male and female collared moose were observed in relation to their relative abundance and habitat usage. During the calving period, collared females were seen more often than collared males, because females often calved in open swampy areas or river bottoms. Males were seen more often than collared females during the rutting period. Their greater visibility may have been influenced by their increased boldness and the open habitats characteristic of several rutting areas.

Efforts to relocate collared moose in different regions of the Peninsula varied throughout the study. In the northern Peninsula, most collared moose were seen in 1970 and 1973 two to five years after the study began.

Thereafter, collared moose seen per year declined as emphasis on tagging and relocating moose shifted to the central and southern regions of the Peninsula. From 1973 to 1976, most flights were assigned to locate moose in the central and southern regions of the Peninsula.

CONCLUSION

Our data revealed that information based on resightings of collared moose were biased by season, habitat, behavior of moose, and area accessibility. Aerial observers also may have tended to search areas where observational success was high rather than search areas uniformly. Although the majority of collared moose were relocated, many were seen only once. The low number of observations per moose, seasonal bias, and the effort and charter costs required to obtain that information limited this technique for determining seasonal movements, home ranges and migration paths of moose.

The probability of observing a particular neck-banded moose during a given flight was extremely low in comparison to the success of radio-tracking studies of ungulates. Craighead et al. (1973) were successful locating radio-collared elk on 78 percent of 474 attempted days throughout the year, and 96 percent of 246 attempts to visually observe elk were successful. Although many collared moose often inhabited dense cover, radio-tracking studies (Phillips et al. 1973 and VanBallenberghe and Peek 1971) of moose in dense vegetation have demonstrated that technique's effectiveness in studying movements of moose. They reported mean observation rates of 48 and 33 per moose, respectively, compared to our mean rate of 2.8 per moose. In another study (Didrickson and Cornelius, 1976, P-R Job Prog. Rpt., Proj. W-17-8, Alaska Dept. Fish and Game, Juneau) 24 moose were located 386 times by radio-tracking but 21 moose with visual collars were seen only 74 times in the same area during the same period. These investigators reported it was extremely difficult and at times impossible, to see a radio-collared moose even though its general location was known.

Using radio-telemetry, one can eliminate many of the biases associated with visibility-limited techniques and increase the frequency of observations per moose. For example, home range studies of moose based on visual observations generally underestimated home range size because of limited observations (Phillips et al. 1973). Our data provided useful information on fall through early spring habitat use by moose, but we were unable to determine the whereabouts of most collared moose during the late spring through summer period, their actual migration routes, timing of movements, rate and extent of movements and seasonal or annual home range size.

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