Population Identity and Movements of Moose in the Togiak, Kulukak, and Goodnews River Drainages, Southwest Alaska

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Progress Report

Andy Aderman and Jim Woolington

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U.S. Fish and Wildlife Service
Togiak National Wildlife Refuge
P.O. Box 270
Dillingham, AK 99576

and

Alaska Department of Fish and Game
P.O. Box 1030
Dillingham, AK 99576

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SUMMARY

Twenty-four moose (18 females and 6 males) radiocollared in 1998 and 10 (females) in 2000 were monitored from 3 April, 2000 to 25 April, 2001, primarily within Game Management Unit 17A. Radiotracking flights were conducted monthly for all moose and weekly for females during the calving period. Calf production and recruitment in 2000 was 157.1 and 84.6 per 100 females, respectively. Calf production and recruitment during 1998 - 2000 averaged 128.2 and 66.7 per 100 females, respectively. Twinning rate in 2000 was 59.3%, slightly higher than the 1998 - 2000 average of 57.1%. The annual mortality rate of radiocollared moose during 2000 - 2001 was 0.121. Between April 1998 and April 2001, annual adult mortality rate averaged 0.152. Population surveys conducted 18-22 February, 2001, indicated a minimum of 471 moose in Unit 17A, an 11.6% increase from the 2000 estimate of 422. Annual home range sizes for females and males averaged 297.1 km^2 (114.7 mi^2) and 374.8 km^2 (144.7 mi^2), respectively. Seventy-one percent of females and 88.9% of males are resident, with the remainder being migratory.

BACKGROUND

Moose *(Alces alces gigas)* are relative newcomers to southwest Alaska, and in Unit 17A aerial surveys conducted in the 1980's and early 1990's often revealed less than 10 moose. Subsequent surveys revealed an increase from 84 moose in 1994 to 511 moose in 1999. The dramatic increase in numbers is attributed to: 1) continued immigration from neighboring Unit 17C; 2) regulation changes implemented by the Alaska Board of Game; 3) an apparent reduction of illegal harvests as a result of poor travel conditions and changing attitudes of local residents; 4) availability of the expanding Mulchatna Caribou (*Rangifer tarandus*) Herd in Units 17 and 18 for subsistence; and, 5) good productivity and survival of Unit 17A moose due to mild winters, few predators, and pristine habitat. Along with the increasing moose population has come several regulatory requests to open/liberalize hunting seasons. Hunters reported taking 15, 10 and 10 moose during State registration permit hunts in 1997, 1998 and 1999, respectively. Because little was known regarding movements, immigration and population parameters of moose in Unit 17A, a 5-year study (see Aderman et al. 1998) was initiated in 1998 to address these and other factors. Aderman et al. (1998, 1999, 2000) provides summaries of the initial capture and radiocollaring of 36 moose and subsequent first 2 years of radiotracking data and habitat assessment.

STUDY AREA

The primary study area is on Togiak National Wildlife Refuge, in Unit 17A, and includes the drainages between Cape Newenham and Cape Constantine (Fig.1). Adjacent areas, western Unit 17C and southern Unit 18, also are in the study area. The Wood River and Ahklun mountains begin at the southern boundary (coastline) and rise to over 1,500 m in the northern portion of the study area. Numerous rivers and creeks, bordered by willows *(Salix spp.)* and cottonwoods

(Populus balsamifera), begin in alpine tundra and alder *(Alnus spp.)* covered slopes and drain though wet and dry tundra uplands. Most of the study area is designated as Wilderness Area. Petersen et al. (1991) and USDI (1986) provide further detail of the study area.

METHODS

Capture and Radiocollaring

We used a Cessna 185 to locate moose and monitor darted individuals. Female moose, $\geq$ 34 months old, were pursued with a Robinson 44 helicopter and darted with a mixture of 4.5 mg carfentanil and 150 mg xylazine fired from a CO_2 pistol (Valkenburg et al. 1999). We collected standard measurements and blood samples and fitted immobilized moose with a VHF radiocollar (Telonics Model 600). Moose body condition was evaluated based on criteria established by Franzmann (1977). Naltrexone (450 mg) was administered intramuscularly as a reversal.

Blood samples were kept unfrozen and were centrifuged the same day collected. Whole blood, plasma and serum samples were transferred to labeled 1.8 ml cryovials and frozen. Samples were sent to the Alaska Wildlife Serum Bank in Fairbanks for storage and future analysis.

Radiotracking

We attempted to locate all moose on a monthly basis, radiotracking from fixed-winged aircraft. During the calving period females were monitored weekly. An index of fall recruitment was determined in November, based on the number of collared females still accompanied by their calves. We determined moose locations by onboard GPS and recorded activity, habitat type and association with other moose.

Population Estimate

We attempted to estimate moose numbers following Gasaway et al. (1986) and were successful in stratifying Unit 17A east of the Matogak River drainage and north of the Nushagak Peninsula. Due to weather delays and movement of moose we decided against conducting standard and intensive searches of selected sample units (SUs) and opted instead to repeat the stratification using varying search intensities. Generally, SUs identified as low density (0 - 4 moose) during the first stratification were searched using a Cessna 185 with one observer. Medium and high density SUs were searched with either a Piper PA18 or Aviat Husky with one observer. In all SUs the pilot acted as a secondary observer. We recorded obvious age (calf or adult) and sex (males with antlers or females with calves), however, we did not attempt to classify every moose.

Distribution, Home Range and Movements

Annual and seasonal home ranges of individual collared moose were calculated using the 100% minimum convex polygon (MCP) technique (Mohr 1947). Individuals with <12 locations were excluded from analysis. The Animal Movement Analysis extension for ArcView was used to estimate home range size and distances moved between relocations (Hooge and Eichenlaub 1997). For seasonal home range analysis, winter was defined as November - April and summer as May - October, which corresponded to shrub phenology, i.e., leaf abscission - dormancy and leaf - flower bud break - maturation, respectively. For migratory status, we define migratory moose as having distinct summer and winter home ranges (<50% overlap), and nonmigratory moose as having >50% overlap of summer and winter ranges (MacCracken et al. 1997). For seasonal movement analysis, winter was defined as November - April, spring (calving) as May - June, summer as July - August and fall (rut) as September - October.

RESULTS AND DISCUSSION

Capture and Radiocollaring

During 3 and 5 April, 2000 we radiocollared 10 adult (≥ 34 months old) females within Unit 17A. Capture operations went well and we were able to obtain measurements and sera samples from most drugged moose (Table 1). Body condition scores averaged 5.3 (range 4 - 7). The CO_2 pistol worked well for dart delivery. No mortalities related to the capture operation occurred.

Radiotracking

Forty-six radiocollared moose were located 1,236 times from 30 March, 1998 - 24 April, 2001. Moose were visually observed 86.6% of the time and were seen more often in winter (96.3%) than summer (77.2%). Locations per animal averaged 30 for those captured in 1998 and 15 for those captured in 2000 (range 3 to 44).

Calf Production, Chronology and Survival

In 2000, 27 of 28 radiocollared cows produced a minimum of 44 calves, suggesting a production rate of 157.1 calves per 100 females (Table 2). Minimum twinning rate was 59.3 percent (16 of 27), including one set of triplets.

Minimum calf production averaged 128.2 per 100 females during 1998 - 2000 and minimum twinning rate averaged 57.1 percent (Table 2). Over the same time period, pregnancy rate averaged 81.7 percent. Production, twinning and pregnancy rates are minimum estimates as some calves might not have been observed. Blood samples taken from 25 females captured in 1998 indicated all were pregnant (T. Stephenson, ADF&G pers. comm.), yet only 18 (72.0%) were observed with ≥ 1 calf. Gasaway et al. (1992) showed that, in populations below carrying capacity, twin births range from 25 to 90 percent of all births for females older than 29 months. Twinning rates in populations near carrying capacity range from approximately 5 to 25 percent, whereas twinning occurred less than 5 percent in populations above carrying capacity. Thus, our observed twinning rates suggest this population is below carrying capacity.

Calving generally begins in mid-May and is nearly complete by early June. During 2000, 5 (18.5%) radiocollared females gave birth to 9 (20.5%) calves by 21 May; 11 (40.7%) females had 19 (43.2%) calves by 23 May; 22 (81.5%) females had 35 (79.5%) calves by 31 May; and

26 (96.3%) females had 43 (97.7%) calves by 8 June. Pooling calving chronology from 1998 - 2000 indicates 12 (20.7%) radiocollared females gave birth to 21 (23.1%) calves by 21 May; 44 (75.9%) females had 72 (79.1%) calves by 31 May; 52 (89.7%) females had 84 (92.3%) calves by 8 June; and 6 (10.3%) females had 7 (7.7%) calves after 8 June. Interestingly, one radiocollared female (TM17b) gave birth to a single calf after 18 July 2000. When observed on 22 August, the calf appeared ≤ 2 weeks old. Capture notes and measurements indicate TM17b as a "small" bodied female. Based on a gestation period of 231 days (Schwartz and Hundertmark 1993), conception probably occurred in early to mid-December 1999.

Calf survival rate to late November 2000 was 0.524. In arriving at this estimate we censured TM38's two calves as her fate is unknown (last relocated 25 September) and we assumed TM30's two calves perished as she died before 20 June. Calf survival rates from birth to fall have been similar since 1998 and averaged 0.517 (Table 2.). As some calves may have been born and died between observation periods, actual calf survival may be lower. Sources of calf mortality were not determined, but likely include predation, inclement weather, and accidents. Fall 2000 calf recruitment was 84.6 calves per 100 females. Average (1998 - 2000) fall calf recruitment was 66.7 calves per 100 females (Table 2).

<u>**Sex and Age Composition**</u>

Little inference can be made from our fall composition data collected thus far as adequate snow cover has not been present before males begin to lose their antlers. Despite inadequate snow cover, we classified all moose observed during October and November radiotracking flights, 1998 - 2000. Ratios of males and calves per 100 females ranged from 83 - 127 and 32 - 68, respectively (Table 3).

Because males have antlers and form groups after the rut, they are more easily detected than females or females with calves. Thus, there were likely higher proportions of females and calves and lower proportions of males than was observed. Radiotracking flights were biased towards females (and calves associated with radiocollared females).

Elsewhere in Alaska, fall composition counts reveal highly variable moose sex and age ratios. Antlered males and calves per 100 females ranged from 4 - 189 and 0 - 70, respectively (Stephenson 1998, Whitman 1998), however the numbers of moose classified were less than 90 in each instance.

Age composition data collected during February 2001 moose surveys, revealed a minimum of 12.5 percent calves. Previous surveys conducted during March 1999 and 2000 indicated 9.2 and 14.2 percent calves, respectively.

<u>**Adult Mortality**</u>

Between 14 April, 2000 and 24 April, 2001, mortality rate of radiocollared adult moose was 0.121 (Table 4). Predation by brown bears (*Ursus arctos*) is believed to be the cause of death for 3 females and 1 male during this period (Table 5). Based on midpoints between dates last

known alive and first known dead, 1 female died in early June and 2 females and 1 male died in mid-April.

Between April 1998 and April 2001, annual adult mortality rate averaged 0.152. Cause of death was determined for 15 radiocollared adult moose during this period; 53.3% were killed by brown bears, 33.3% were harvested illegally, and 13.3% died from locked antlers (Table 5). Males experienced a slightly higher mortality rate (0.167) than females (0.147), however, females had a higher rate of loss due to predation (63.6%) and illegal harvest (36.4%) than males (25.0% lost to predation, 25.0% illegally harvested). With the exception of the 2 males that locked antlers in early fall, all other deaths occurred during late winter - early spring. Only one female was predated during the calving period. The small number of radiocollared males (n = 9) in this study may not be representative of the male population at large.

Despite the closure (1981 to 1997) of moose hunting season in Unit 17A, local residents continued to harvest moose. Both males and females were taken, with an estimated annual illegal harvest of 15 to 25 moose, although probably lower in recent years. Moose were taken primarily during late winter and spring when daylight increased and conditions for traveling by snowmachine were generally excellent.

With the advent of a legal fall (August 20 - September 15, 1 bull) hunt in 1997, hunters reported taking 15 moose (Table 6). Annual reported and estimated illegal harvest from 1997 - 2000 averaged 11.3 and 3.3 moose, respectively. Estimates of illegal harvest are derived primarily from aerial observations during winter radiotracking and population surveys. We do not have an estimate of unreported or illegal harvest during fall.

Population Estimate

From 12 - 13 February, 2001 we stratified most of mainland Unit 17A east of the Matogak River drainage and north of the Nushagak Peninsula (Figure 1). We observed a total of 374 moose in 14.2 survey hours (26.4 moose/hour). A total of 101 of 110 SUs were stratified, of which no moose were observed in over half (60). We began standard searches on 14 February, however, we were "weathered out" after completing only 2 SUs. Mixed snow and rain precluded surveys until 18 February. Due to the likelihood of moose movements since the stratification, we decided to survey the entire area again as described under the methods section.

From 18 - 22 February, 2001 we searched all 110 SUs and observed a total of 471 moose during 27.0 survey hours (17.4 moose/hour). Disregarding the 9 SUs not stratified in our first effort would give an estimate of 460 moose observed during 25.7 survey hours (17.9 moose/hour). No moose were observed in 63 (57.3%) SUs during this second effort.

Survey conditions in 2001 were similar to 2000 and ranged from poor to excellent. Patchy snow cover in the southern part of the survey area made moose difficult to see. Disregarding counts from SUs surveyed in 2001 but not in 2000 would give an estimate of 465 moose observed in 22.6 survey hours (20.6 moose/hour). The apparent increase from the 2000 survey (422 moose observed in 14.0 survey hours or 30.2 moose/hour) is likely due to the increased search effort in 2001. Search effort in 2001 was approximately 2.1 km^2/minute (0.8 mi^2/minute) compared to 3.5 km^2/minute (1.4 mi^2/minute) in 2000. Search effort varied among SUs dependent on the amount and type of habitat and the number of moose encountered. Population surveys of adjacent areas were not conducted, however, 4 of 32 (12.5%) radiocollared moose were located in Unit 17C during Unit 17A surveys.

The Alaska Department of Fish and Game (ADF&G) started moose surveys in Unit 17 in 1971 (Faro 1973). In 1981, the first major survey of Unit 17A was conducted and only three moose were observed. Additional surveys were conducted by ADF&G and TNWR in 1982, 1984 and 1987 with similar results. In 1989, in an effort to determine factors contributing to low moose densities, ADF&G/TNWR biologists radiocollared 30 moose in western Unit 17C. Subsequent radiotracking flights from 1989 to 1992 indicated movement of only one moose from the western part of Unit 17C into Unit 17A (Jemison 1994). However, the moose population in western Unit 17C showed an apparent increase since the study, and it is possible younger, non-collared moose, with less home range affinity, began dispersing to Unit 17A.

Surveys conducted during the 1990's indicated an increase in moose in Unit 17A (Figure 2). In January 1994, 84 moose were observed. A more thorough survey technique (Gasaway et al. 1986) was conducted for moose in Units 17A and 17C in February 1995. Survey results and extrapolation of the survey data indicated a population of 136 moose in Unit 17A (Aderman et al. 1995). During this survey, movement of 29 moose from Unit 17C into Unit 17A was documented. Surveys conducted in late February and early March 1997 indicated a minimum of 234 moose in Unit 17A. Subsequently, surveys conducted in February 1998, revealed a minimum Unit 17A population of 429 moose. The dramatic growth and expansion of moose in Unit 17A parallels that of western Unit 17C during the 1980's and early 1990's.

<u>**Habitat Use and Activity**</u>

From April 1998 to April 2001, we obtained 873 and 241 observations of habitat use by radiocollared females and males, respectively. Of the 9 habitat types used, >86% of all observations occurred in 3 habitats (Tables 7 and 8). For both females and males, willow, cottonwood and alder habitats were used the most. Willow habitats were used the most during winter by both males and females. Birch and gravel bars were used least by both females and males. Overall use of cottonwoods was greater than use of alders, however, alders were used more than any other habitat during July and August by both females and males. Grass or herbaceous habitats were primarily used by both sexes during July, August and September. Use of tundra was sporadic except by males during October when it was the second most used habitat. October use of tundra by males is likely related to the rut.

From April 1998 to April 2001, we obtained 752 and 216 observations of activity by radiocollared females and males, respectively. Of the 4 types of activity recorded, moose were most often observed lying or bedded (Tables 9 and 10). Observations of lying moose are likely biased low for two reasons. The first is moose response to survey aircraft. Bedded moose have been observed changing their activity (to standing) when approached or circled by low level aircraft. Secondly, a bedded moose presents less of a visual target than when upright and it is possible a higher proportion of moose not observed were of bedded moose. On the other hand, all of our observations were during daylight hours, presumably during the period when maximum daily temperatures occur. Moose tend to rest during warmer temperatures. During May to October, both sexes were observed more often in a non-resting (standing, walking, running) position, whereas during November to April both sexes were most often observed resting. During winter, when moose consume a diet of coarse, relatively poor quality woody vegetation, they must spend many hours ruminating (Renecker and Schwartz 1998). Additionally, during periods of colder temperatures moose may conserve energy by bedding in snow (Schwartz and Renecker 1998).

<u>Distribution, Home Range and Movements</u>

Telemetry data from 17 April, 1998 to 24 April, 2001 indicated 17 of 46 (37%) radiocollared moose moving outside Unit 17A. Three females and 1 male have been observed in Unit 18 and 9 females and 4 males observed in Unit 17C. Of the 4 radiocollared moose observed in Unit 18, 2 females were killed there illegally in late winter, 1999; 1 female gave birth to twin calves in June 2000 and all had returned to Unit 17A by mid-July; and the 1 male remains in Unit 18. Of the 13 radiocollared moose observed in Unit 17C all except 2 females and 2 males had returned to Unit 17A by 24 April, 2001. Of 1,236 relocations of radiocollared moose, 1,111 (89.9%) were in Unit 17A, 107 (8.7%) were in Unit 17C and 18 (1.4%) were in Unit 18. This indicates the majority of radiocollared moose are staying in Unit 17A.

In recent years, moose have been observed throughout most of the willow and cottonwood dominated habitats in mainland Unit 17A. Generally, these habitats occur along the waterways. Moose are more dispersed during summer months and tend to aggregate in winter (Figure 3).

Annual home range sizes for females (n = 35) and males (n = 9) with $\geq$ 12 relocations averaged 297.1 km^2 (114.7 mi^2) and 374.8 km^2 (144.7 mi^2), respectively (Tables 11 and 12). Home range sizes ranged from 10.0 - 1187.1 km^2 (3.9 - 458.3 mi^2) for cows and from 56.3 - 915.2 km^2 (21.7 - 353.4 mi^2) for bulls. Annual home range sizes for females with 12 - 18 relocations (n = 17) averaged 224.9 km^2 (86.8 mi^2) while those with 29 - 44 relocations (n = 18) averaged 365.2 km^2 (141.0 mi^2). Annual home range sizes for males with 17 - 23 relocations (n = 3) averaged 316.2 km^2 (122.1 mi^2) while those with 31 - 37 relocations (n = 6) averaged 404.1 km^2 (156.0 mi^2). On average, males had bigger summer and winter home ranges than females. Mean winter home range sizes for both sexes were larger (4.6% for females, 11.8% for males) than their summer home ranges.

Using the MCP method, it is likely our moose home ranges will increase as more relocations are obtained. Median relocations (and ranges) for females and males in this study are 29 (12 - 44) and 35 (17 - 37), respectively. Ballard et al. (1991), using MCPs, determined estimated size of home range of Alaskan moose began to level off after 60 to 90 relocations had been obtained for an individual animal. In a review of North American moose seasonal home ranges, Hundertmark (1998) concluded that below 60 degrees north latitude, seasonal home range sizes did not exceed 51.2 km^2 (20 mi^2). During this study 1,236 relocations ranged between 58° 51.49' and 60° 15.33', with only 10 (0.8%) being above 60 degrees north latitude. Seasonal home range sizes for females and males in this study (Tables 11 and 12) are more than triple and quadruple, respectively, expected at this latitude range.

Ten of 35 (28.6%) collared females exhibited migratory movement patterns, having distinct summer and winter home ranges (<50% overlap) with areas of overlap ranging from 4.6 - 92.7 km^2. One of nine (11.1%) males was migratory. The other collared animals, 25 (71.4%) females and 8 (88.9%) males, were considered nonmigratory or resident with >50% overlap of summer and winter home ranges.

Distances moved between relocations averaged 6.59 and 7.50 km for females and males, respectively (Table 13). Females moved most during summer (7.05 km) and least during spring (6.18 km), whereas, males moved most during the fall (12.47 km) and least during summer (5.36 km). By month, females moved most during February (8.79 km) and least during September (4.75 km). Males moved most during September (15.27 km) and least during August (3.97 km). Longest straight-line distance moved by a female was 80.2 km in 30 days (2.67 km/day). Longest straight-line distance moved by a male was 37.1 km in 27 days (1.37 km/day).

Management Implications

Evidence from available literature and local knowledge suggests moose were absent, or nearly so, from this area during most of the last 200 years. Recently, moose have established themselves within Unit 17A in sufficient numbers to allow limited fall hunting. Some local residents feel the current moose population (500 - 550) is large enough and greatly desire increased hunting opportunities, especially in the form of a winter hunt.

Unit 17A contains a mixture of federal, state and private lands. Despite differing mandates, management agencies and land owners have worked together in developing a draft moose management plan. Major objectives of the draft plan include increasing the population to 1,100 - 1,750 moose; allowing fall hunting when the population exceeds 300 moose; and allowing limited winter hunting when the population exceeds 600 moose.

Despite above average production and recruitment of moose calves, the population has not increased over the last two years. The proportion of males appears to equal that of females. Mortality of adult females, due to brown bear predation and illegal hunting, continues to be high. Incidental evidence suggest numbers of brown bears and wolves (*Canis lupus*) are increasing in the same area. With the eventual decline of Mulchatna caribou and increasing human population in southwest Alaska, we expect increased demands on this recently established moose population.

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Table 1. Data collected from adult female moose (n = 10) captured in southwest Alaska, April 2000.

Moose ID	Estimated Age	Condition score	Measurements (cm) Length	Girth	Neck	Hindfoot	Calves at heel	Date Collared
1b	3+	5	287	180	69	83	0	04/05/2000
17b	5	5	290	168	79	86	0	04/05/2000
25b	6-7	5	298	200	84	86	1	04/05/2000
26b	3+	5	302	202	99.5	82	1	04/05/2000
33b	3+	7	290	206	79	90	1	04/05/2000
37b	5-6	6	304	182	98.4	75	0	04/03/2000
42	4-5	5	293	182	77.5	87	0	04/03/2000
52	6-7	5	304	184	88	87	0	04/03/2000
62	3-4	4	302	188	72	86	1	04/03/2000
72	3+	6	302	194	101	90.5	1	04/03/2000
average		5.3	297.2	188.6	84.74	85.25		

Table 2. Production and recruitment of moose calves by radiocollared females, southwest Alaska, 1998 - 2000.

Year	Radioed females	Production: calves/100 females	Twinning %	% Survival to Nov	Recruitment: calves/100 females
1998	25	88.0	25.0	54.5	48.0
1999	18	138.8	92.3	48.0	66.7
2000	28	157.1	59.3	52.4	84.6
average	23.7	128.2	57.1	51.7	66.7

Table 3. Moose sex and age composition observed during October and November radiotracking flights, southwest Alaska, 1998 - 2001.

			# Classified			
Year	Males per 100 Females	Calves per 100 Females	Females	Males	Calves	Total
1998	107.1	31.6	98	105	31	234
1999	83.0	39.6	53	44	21	118
2000	127.0	68.3	63	80	43	186

Table 4. Observed mortality rates of radiocollared male and female moose, southwest Alaska, April 1998 - April 2001.

	# Mortalities/#Radiocollared (%)		
Monitoring Period	Males	Females	Total
4/98 - 4/99	0/9 (0.000)	4/26 (0.154)	4/35 (0.114)
4/99 - 4/00	3/9 (0.333)	4/22 (0.182)	7/31 (0.223)
4/00 - 4/01	1/6 (0.167)	3/27 (0.111)	4/33 (0.121)
Total	4/24 (0.167)	11/75 (0.147)	15/99 (0.152)

Table 5. Timing and causes of mortalities of radiocollared moose, southwest Alaska, 1998 - 2001.

Record	TM	Sex	Date last known live	Date first known dead	Mid-Point	Cause	Location
1	18	F	04/17/1998	05/19/1998	2 May	br bear	Ongivinuck L. trib
2	12	F	01/28/1999	03/05/1999	14 Feb	shot	Kwethluk/Crooked Cr.
3	26	F	01/26/1999	03/05/1999	13 Feb	shot	lower Kukakthlik R.
4	33	F	03/05/1999	04/14/1999	24 Mar	shot	mid-Kulukak R.
5	17	F	04/14/1999	05/18/1999	30 Apr	br bear	upper Ongivinuck R. trib.
6	25	F	04/14/1999	05/18/1999	30 Apr	br bear	mid-Togiak R.
7	1	F	04/14/1999	05/19/1999	1 May	br bear	upper Togiak valley
8	37	F	04/14/1999	05/19/1999	1 May	shot	mid-Kulukak R.
9	11	M	08/24/1999	09/27/1999	9 Sep	fighting	lower Kemuk R.
10	23	M	08/24/1999	09/27/1999	9 Sep	fighting	lower Kemuk R.
11	6	M	03/13/2000	04/14/2000	28 Mar	shot	upper Togiak R.
12	30	F	05/23/2000	06/20/2000	6 Jun	br bear	lower Kulukak R.
13	2	F	03/29/2001	04/24/2001	15 Apr	br bear	lower Togiak L. (east)
14	34	M	03/29/2001	04/24/2001	15 Apr	br bear	lower Izavieknik R.
15	10	F	03/29/2001	04/24/2001	15 Apr	br bear	Trail Creek

Table 5. Timing and causes of mortalities of radiocollared moose, southwest Alaska, 1998 - 2001.

Record	TM	Sex	Date last known live	Date first known dead	Mid-Point	Cause	Location
1	18	F	04/17/1998	05/19/1998	2 May	br bear	Ongivinuck L. trib
2	12	F	01/28/1999	03/05/1999	14 Feb	shot	Kwethluk/Crooked Cr.
3	26	F	01/26/1999	03/05/1999	13 Feb	shot	lower Kukakthlik R.
4	33	F	03/05/1999	04/14/1999	24 Mar	shot	mid-Kulukak R.
5	17	F	04/14/1999	05/18/1999	30 Apr	br bear	upper Ongivinuck R. trib.
6	25	F	04/14/1999	05/18/1999	30 Apr	br bear	mid-Togiak R.
7	1	F	04/14/1999	05/19/1999	1 May	br bear	upper Togiak valley
8	37	F	04/14/1999	05/19/1999	1 May	shot	mid-Kulukak R.
9	11	M	08/24/1999	09/27/1999	9 Sep	fighting	lower Kemuk R.
10	23	M	08/24/1999	09/27/1999	9 Sep	fighting	lower Kemuk R.
11	6	M	03/13/2000	04/14/2000	28 Mar	shot	upper Togiak R.
12	30	F	05/23/2000	06/20/2000	6 Jun	br bear	lower Kulukak R.
13	2	F	03/29/2001	04/24/2001	15 Apr	br bear	lower Togiak L. (east)
14	34	M	03/29/2001	04/24/2001	15 Apr	br bear	lower Izavieknik R.
15	10	F	03/29/2001	04/24/2001	15 Apr	br bear	Trail Creek

Table 7. Observed habitat associations by radiocollared female moose (n = 37) from aerial relocations (n = 873), southwest Alaska, April 1998 - April 2001.

	Predominant Species/Cover Type									Number of
Month	Alder	Willow	Birch	Cottonwood	Spruce	Tundra	Grass	Gravel Bar	Water	Relocations
Jan	17.0	45.3	1.9	26.4	3.8	1.9	- -	1.9	1.9	28
Feb	- -	34.1	- -	47.7	- -	- -	- -	2.3	4.5	19
Mar	- -	66.2	- -	23.5	4.4	- -	- -	2.9	1.5	40
Apr	2.0	53.1	3.1	31.6	1.0	2.0	- -	5.1	2.0	67
May	17.1	40.0	3.6	29.3	- -	4.3	4.3	- -	- -	79
Jun	23.9	51.1	- -	14.1	- -	3.3	2.2	- -	5.4	67
Jul	33.8	27.9	- -	17.6	- -	- -	14.7	- -	- -	42
Aug	37.9	22.4	1.7	12.1	- -	- -	24.1	- -	1.7	34
Sep	21.8	44.9	- -	14.1	- -	2.6	15.4	1.3	- -	53
Oct	27.4	43.5	1.6	14.5	- -	- -	11.3	- -	- -	36
Nov	37.5	43.8	- -	16.7	- -	- -	- -	- -	- -	25
Dec	12.5	40.6	- -	39.1	3.1	- -	- -	- -	- -	39
Average	19.1	43.5	1.5	23.8	0.9	1.9	6.0	1.4	1.8	44.1

Table 8. Observed habitat associations by radiocollared male moose (n = 9) from aerial relocations (n = 241), southwest Alaska, April 1998 - April 2001.

	Predominant Species/Cover Type									Number of
Month	Alder	Willow	Birch	Cottonwood	Spruce	Tundra	Grass	Gravel Bar	Water	Relocations
Jan	18.8	68.8	12.5	- -	- -	- -	- -	- -	- -	11
Feb	- -	70.0	- -	20.0	- -	- -	- -	- -	- -	7
Mar	8.7	56.5	- -	26.1	- -	- -	- -	- -	- -	16
Apr	3.3	73.3	- -	16.7	- -	- -	- -	- -	6.7	24
May	11.5	46.2	- -	34.6	- -	7.7	- -	- -	- -	19
Jun	22.2	33.3	- -	33.3	- -	5.6	- -	- -	- -	16
Jul	41.7	20.8	- -	16.7	- -	- -	20.8	- -	- -	18
Aug	47.6	9.5	4.8	14.3	- -	- -	23.8	- -	- -	15
Sep	26.1	39.1	- -	17.4	- -	- -	13.0	- -	- -	17
Oct	15.0	45.0	- -	5.0	10.0	25.0	- -	- -	- -	14
Nov	8.3	50.0	- -	16.7	- -	- -	- -	- -	- -	8
Dec	16.7	38.9	- -	33.3	- -	5.6	- -	- -	- -	13
Average	19.5	45.2	1.2	19.9	2.1	5.0	6.2	0.0	0.8	14.8

Table 6. Unit 17A moose hunter residency, participation and reported harvest data, 1997 - 2000.

	Permits Issued			Permittees Reported Hunting			Moose Reported Harvested		
Regulatory Year	Local Resident	Nonlocal Resident	Total Permits	Local Resident	Nonlocal Resident	Total Hunters	Local Resident	Nonlocal Resident	Total Moose
1997	44	0	44	39	0	39	15	0	15
1998	48	0	48	43	0	43	10	0	10
1999	55	2	57	39	2	41	10	0	10
2000	54	2	56	48	1	49	10	0	10

Table 7. Observed habitat associations by radiocollared female moose (n = 37) from aerial relocations (n = 873), southwest Alaska, April 1998 - April 2001.

	Predominant Species/Cover Type									Number of
Month	Alder	Willow	Birch	Cottonwood	Spruce	Tundra	Grass	Gravel Bar	Water	Relocations
Jan	17.0	45.3	1.9	26.4	3.8	1.9	--	1.9	1.9	28
Feb	--	34.1	--	47.7	--	--	--	2.3	4.5	19
Mar	--	66.2	--	23.5	4.4	--	--	2.9	1.5	40
Apr	2.0	53.1	3.1	31.6	1.0	2.0	--	5.1	2.0	67
May	17.1	40.0	3.6	29.3	--	4.3	4.3	--	--	79
Jun	23.9	51.1	--	14.1	--	3.3	2.2	--	5.4	67
Jul	33.8	27.9	--	17.6	--	--	14.7	--	--	42
Aug	37.9	22.4	1.7	12.1	--	--	24.1	--	1.7	34
Sep	21.8	44.9	--	14.1	--	2.6	15.4	1.3	--	53
Oct	27.4	43.5	1.6	14.5	--	--	11.3	--	--	36
Nov	37.5	43.8	--	16.7	--	--	--	--	--	25
Dec	12.5	40.6	--	39.1	3.1	--	--	--	--	39
Average	19.1	43.5	1.5	23.8	0.9	1.9	6.0	1.4	1.8	44.1

Table 8. Observed habitat associations by radiocollared male moose (n = 9) from aerial relocations (n = 241), southwest Alaska, April 1998 - April 2001.

	Predominant Species/Cover Type									Number of
Month	Alder	Willow	Birch	Cottonwood	Spruce	Tundra	Grass	Gravel Bar	Water	Relocations
Jan	18.8	68.8	12.5	--	--	--	--	--	--	11
Feb	--	70.0	--	20.0	--	--	--	--	--	7
Mar	8.7	56.5	--	26.1	--	--	--	--	--	16
Apr	3.3	73.3	--	16.7	--	--	--	--	6.7	24
May	11.5	46.2	--	34.6	--	7.7	--	--	--	19
Jun	22.2	33.3	--	33.3	--	5.6	--	--	--	16
Jul	41.7	20.8	--	16.7	--	--	20.8	--	--	18
Aug	47.6	9.5	4.8	14.3	--	--	23.8	--	--	15
Sep	26.1	39.1	--	17.4	--	--	13.0	--	--	17
Oct	15.0	45.0	--	5.0	10.0	25.0	--	--	--	14
Nov	8.3	50.0	--	16.7	--	--	--	--	--	8
Dec	16.7	38.9	--	33.3	--	5.6	--	--	--	13
Average	19.5	45.2	1.2	19.9	2.1	5.0	6.2	0.0	0.8	14.8

Table 9. Observed activity of radiocollared female moose (n = 37), from aerial relocations (n = 752), southwest Alaska, April 1998 - April 2001.

Month	% Activity				Visual	Total
	Lying	Standing	Walking	Running	Relocations	Relocations
Jan	77.0	19.7	3.3	- -	61	68
Feb	69.8	23.3	- -	- -	43	46
Mar	76.1	19.4	4.5	- -	67	69
Apr	64.0	30.7	5.3	- -	75	102
May	52.3	43.2	3.8	0.8	132	143
Jun	33.3	61.3	4.0	- -	75	103
Jul	21.2	69.7	9.1	- -	33	69
Aug	36.4	60.6	- -	- -	33	58
Sep	46.0	44.4	9.5	- -	63	79
Oct	68.3	31.7	- -	- -	60	64
Nov	66.0	31.9	2.1	- -	47	51
Dec	63.5	31.7	3.2	1.6	63	68
Average	57.2	38.0	4.4	0.4	62.7	76.7

Table 10. Observed activity of radiocollared male moose (n = 9), from aerial relocations (n = 216), southwest Alaska, April 1998 - April 2001.

Month	% Activity				Visual	Total
	Lying	Standing	Walking	Running	Relocations	Relocations
Jan	76.5	23.5	- -	- -	17	21
Feb	70.0	30.0	- -	- -	10	11
Mar	63.6	31.8	4.5	- -	22	23
Apr	80.8	19.2	- -	- -	26	30
May	39.1	60.9	- -	- -	23	26
Jun	33.3	60.0	- -	- -	15	22
Jul	33.3	66.7	- -	- -	18	24
Aug	50.0	42.9	7.1	- -	14	21
Sep	41.2	58.8	- -	- -	17	23
Oct	50.0	50.0	- -	- -	20	20
Nov	50.0	50.0	- -	- -	12	14
Dec	63.6	36.4	- -	- -	22	22
Average	55.1	43.5	1.4	0.0	18.0	21.4

Table 11. Annual, summer (May - Oct) and winter (Nov - Apr) home range sizes (Minimum Convex Polygon), percent summer/ winter home range overlap and migratory status of radiocollared female moose (n = 35), southwest Alaska, March 1998 - April 2001

Togiak	Annual			Summer			Winter			%	Migratory
Moose	n	sq km	sq mi	n	sq km	sq mi	n	sq km	sq mi	Overlap	Status
1	16	248.58	95.98	9	123.32	47.61	7	164.99	63.70	48.10	M
2	40	401.63	155.07	22	187.96	72.57	18	256.45	99.02	49.34	M
3	41	70.35	27.16	23	37.38	14.43	18	16.67	6.44	61.19	N
5	44	333.57	128.79	26	205.96	79.52	18	184.46	71.22	56.60	N
7	36	261.77	101.07	13	70.90	27.37	17	216.79	83.70	68.00	N
10	42	73.94	28.55	23	44.76	17.28	19	35.48	13.70	48.25	M
12	12	414.34	159.98	6	150.37	58.06	6	80.41	31.05	15.91	M
14	38	824.39	318.30	21	692.61	267.42	17	271.53	104.84	58.67	N
16	39	612.90	236.64	21	210.81	81.39	18	428.37	165.39	60.66	N
17	16	9.99	3.86	9	8.00	3.09	7	1.54	0.59	81.17	N
19	39	125.60	48.49	21	112.58	43.47	18	56.03	21.63	88.35	N
21	41	351.75	135.81	23	259.91	100.35	18	170.04	65.65	69.51	N
22	41	173.08	66.83	23	58.85	22.72	18	167.03	64.49	97.71	N
25	16	116.09	44.82	9	68.50	26.45	7	78.59	30.34	71.55	N
26	12	816.14	315.11	6	231.57	89.41	6	294.38	113.66	26.04	M
27	38	1187.08	458.33	20	1071.71	413.79	18	282.63	109.12	79.29	N
29	39	150.89	58.26	21	95.10	36.72	18	117.02	45.18	79.20	N
30	29	121.27	46.82	17	25.32	9.78	12	119.16	46.01	97.20	N
31	39	59.77	23.08	21	44.37	17.13	18	29.81	11.51	72.66	N
33	17	53.78	20.77	9	20.23	7.81	8	42.05	16.24	66.14	N
36	41	942.14	363.76	22	200.60	77.45	19	759.11	293.09	31.40	M
37	16	215.67	83.27	9	21.11	8.15	7	169.29	65.36	53.39	N
38	32	549.80	212.28	21	258.56	99.83	11	367.15	141.76	75.58	N
39	42	112.48	43.43	24	24.32	9.39	18	100.18	38.68	89.39	N
41	39	221.34	85.46	19	91.74	35.42	20	173.94	67.16	86.08	N
42	15	86.56	33.42	7	37.49	14.47	8	50.67	19.56	34.22	M
52	14	58.38	22.54	6	29.42	11.36	8	38.27	14.78	59.59	N
62	16	81.67	31.53	8	55.76	21.53	8	56.40	21.78	78.25	N
72	15	187.56	72.42	7	43.22	16.69	8	154.37	59.60	70.92	N
17b	18	153.41	59.23	10	118.79	45.86	8	102.96	39.75	78.03	N
1b	12	109.01	42.09	4	9.80	3.78	8	80.33	31.02	47.35	M
25b	15	120.76	46.63	7	85.88	33.16	8	69.66	26.90	81.25	N
26b	16	253.20	97.76	8	22.37	8.64	8	206.07	79.56	83.91	N
33b	17	130.10	50.23	9	70.26	27.13	8	32.15	12.41	30.45	M
37b	14	768.45	296.70	6	542.86	209.60	8	204.03	78.78	10.41	M
ave	29	297.07	114.70	13	152.35	58.82	11	159.37	61.53	63.02	71.4N/28.6M

n = number of relocations
ave = median (n), arithmetic mean (sq km, sq mi)
M = migratory, N = nonmigratory

Table 12. Annual, summer (May - Oct) and winter (Nov - Apr) home range sizes (Minimum Convex Polygon), percent summer/ winter home range overlap and migratory status of radiocollared male moose (n = 9), southwest Alaska, March 1998 - April 2001.

Togiak	Annual			Summer			Winter			%	Migratory
Moose	n	sq km	sq mi	n	sq km	sq mi	n	sq km	sq mi	Overlap	Status
23	17	422.05	162.95	10	75.64	29.20	7	186.05	71.83	17.29	M
11	18	85.52	33.02	11	65.33	25.22	7	26.43	10.20	71.62	N
6	23	441.06	170.29	11	419.48	161.96	12	195.32	75.41	92.04	N
4	31	389.42	150.36	15	142.26	54.93	16	257.13	99.28	57.21	N
32	35	248.07	95.78	18	205.83	79.47	17	153.54	59.28	83.80	N
34	36	56.31	21.74	18	29.08	11.23	18	42.70	16.49	75.17	N
8	37	191.00	73.75	19	110.00	42.47	18	109.58	42.31	54.50	N
35	37	624.74	241.21	18	497.49	192.08	19	349.62	134.99	80.60	N
40	37	915.18	353.35	19	275.36	106.32	18	715.55	276.27	86.07	N
ave	35	374.82	144.72	18	202.27	78.10	17	226.21	87.34	68.70	88.9N/11.1M

n = number of relocations

ave = median (n), arithmetic mean (sq km, sq mi)

M = migratory, N = nonmigratory

Table 13. Average monthly and seasonal movements of radiocollared moose, southwest Alaska, April 1998 - April 2001.

	Average Distance Moved (km)	
Month/Season	Females	Males
May	6.21	6.54
Jun/Spring	6.12/6.18	8.63/7.50
Jul	8.14	6.75
Aug/Summer	5.93/7.05	3.97/5.36
Sep	4.75	15.27
Oct/Fall	8.36/6.50	9.26/12.47
Nov	7.75	7.13
Dec	7.72	6.52
Jan	5.71	6.61
Feb	8.79	9.23
Mar	4.93	4.55
Apr/Winter	5.16/6.72	5.21/6.59
Average	6.59	7.50

Season: Spring=May-Jun; Summer=Jul-Aug; Fall=Sep-Oct; Winter=Nov-Apr

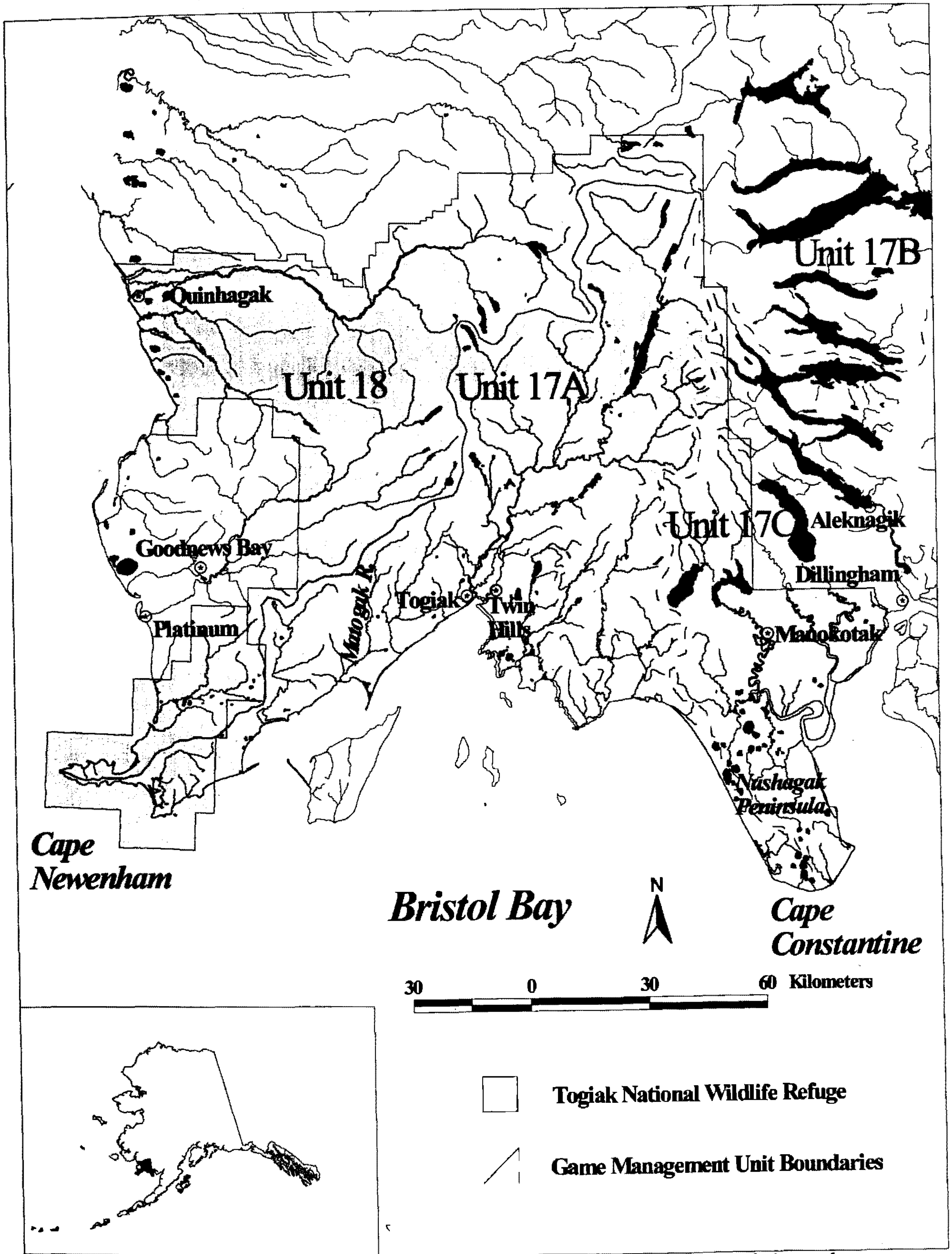

Figure 1. Location of the primary study area on Togiak National Wildlife Refuge (the drainages between Cape Newenham and Cape Constantine), southwest Alaska.

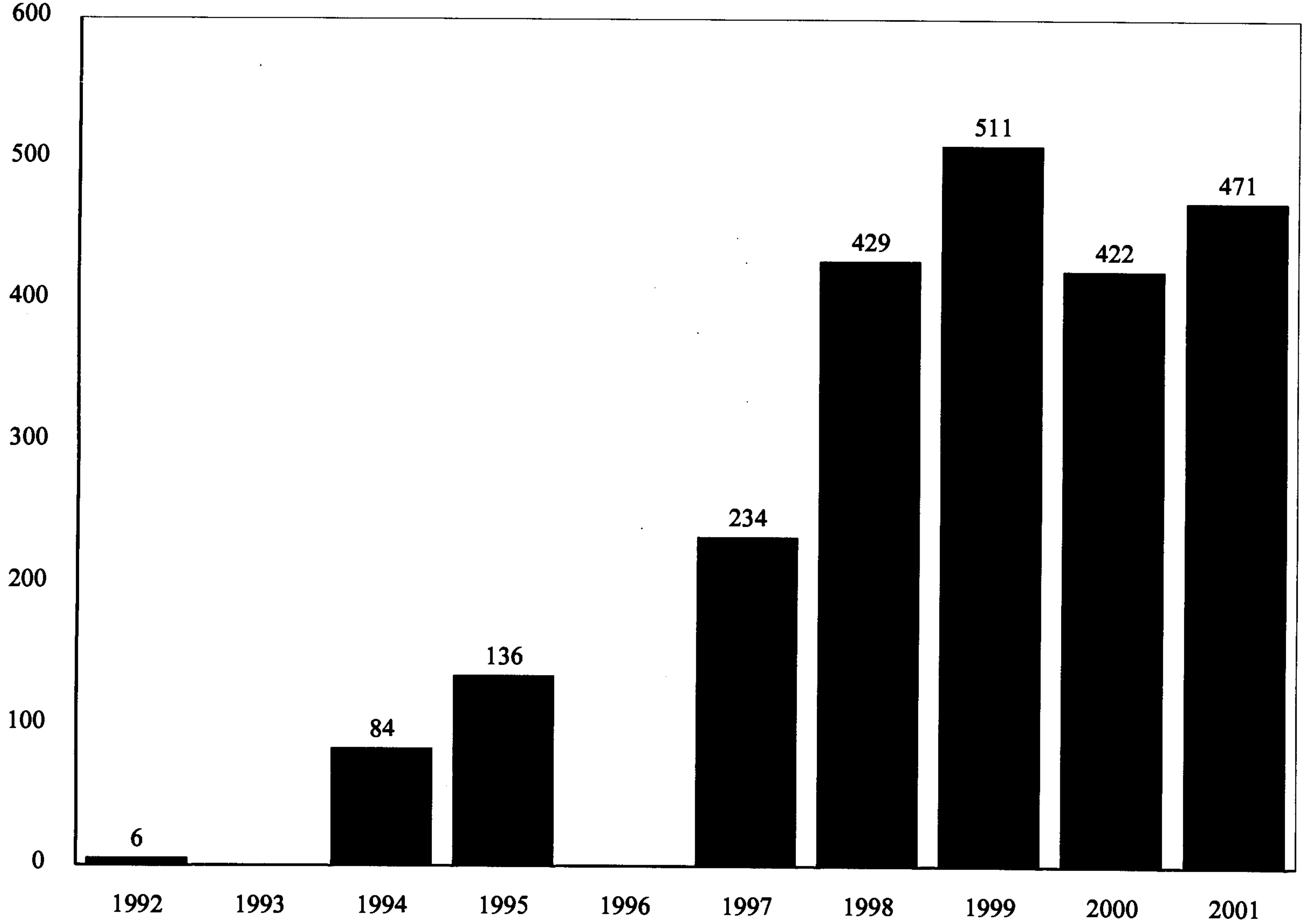

Figure 2. Number of moose observed during winter aerial surveys of Unit 17A, southwest Alaska, 1992 - 2001.

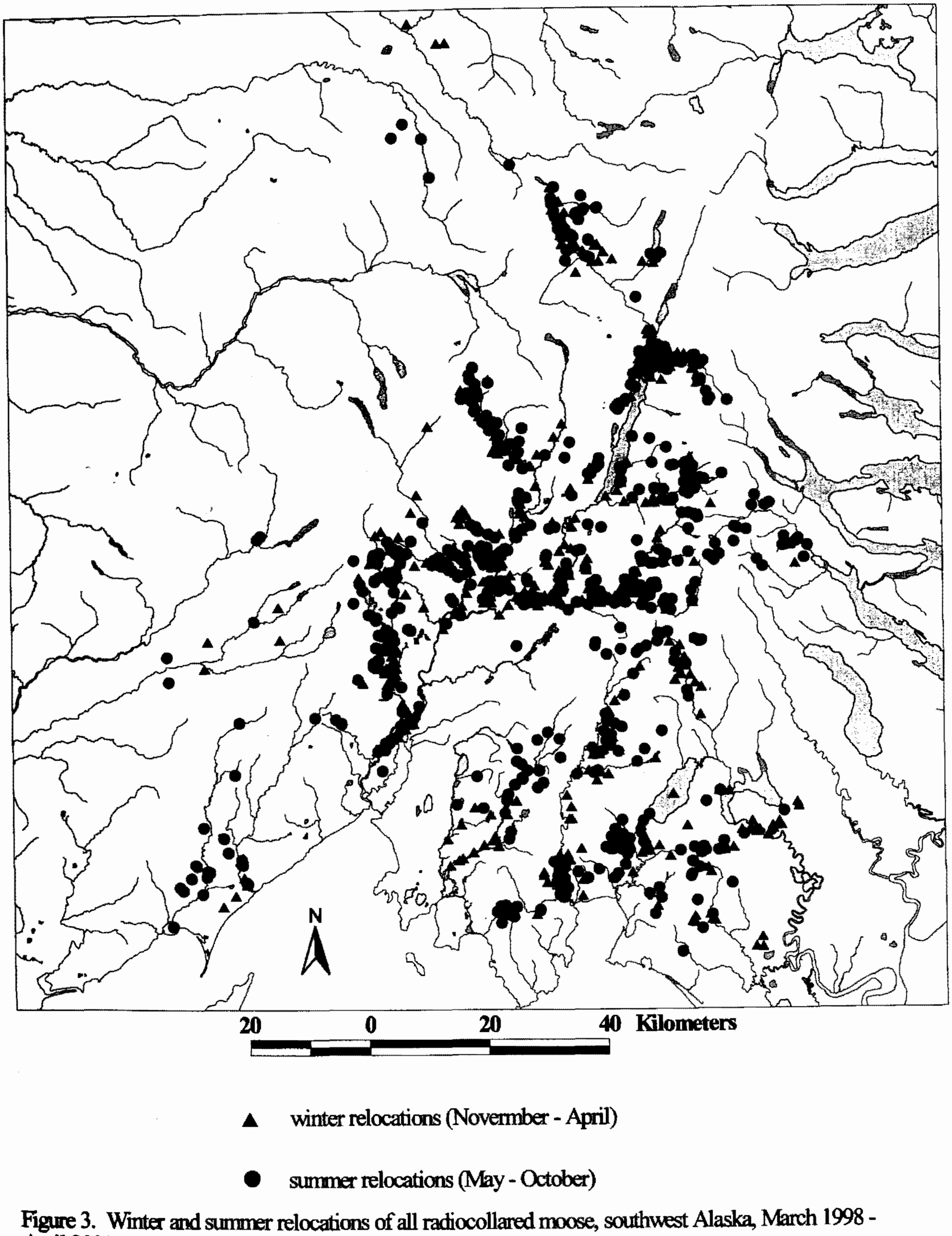

Figure 3. Winter and summer relocations of all radiocollared moose, southwest Alaska, March 1998 - April 2001.