REPRODUCTION, SURVIVAL, AND OCCUPIED RANGES OF SHIRAS MOOSE TRANSPLANTED TO SOUTHWESTERN COLORADO

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ABSTRACT: Moose (*Alces alces shirasi*) were released into previously unoccupied habitat in southwestern Colorado in 1991, 1992, and 1993. Nine radiocollared males and 32 radiocollared females were tracked and located approximately monthly until they died or the study terminated on December 31, 1996. Females were observed each year in July, August, or September to determine if calves were present. The females had 97 opportunities to produce calves. Fifty calves were observed resulting in an average calf to cow ratio of 52 calves per 100 cows. All radiocollars were equipped with mortality sensors and each dead animal was examined to determine cause of death. Illegal kill was the primary known cause of death followed by birth complications, winter loss, and an impacted rumen. We were unable to determine the cause of death for 9 animals. Average annual survival rates were 0.94 for males and 0.83 for females. Locations of each animal were recorded and mapped. An adaptive kernel analysis was used to create seasonal polygons of occupied habitat. By December 31, 1997 more than 5,500 km^2 were occupied by moose in the fall. The mean area occupied, over multiple years, by individual moose during all seasons was 624 km^2 for males and 772 km^2 for females. Moose numbers are increasing in the release area and we believe that range expansion will occur to favorable adjacent habitats.

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Moose apparently were never common in Colorado (Warren 1942, Bailey 1944). In 1978 and 1979 moose were released in North Park, Colorado and established a viable population (Duvall and Schoonveld 1988, Kufeld 1994). Additional habitat appeared to be available in other parts of Colorado and in 1991, 1992, and 1993 an additional 106 moose were captured in Utah, Wyoming, and North Park, Colorado and released in the upper Rio Grande river drainage in southwest Colorado (Olterman *et al.* 1994). This study was initiated to document reproductive rates, survival rates, and permanent establishment of moose in the study area. The information from our study may be useful in predicting the success of future introductions and the expansion potential of existing populations in Colorado.

STUDY AREA

Moose were released at 12 sites in the Upper Rio Grande river drainage within the boundaries of the Rio Grande National Forest in southwestern Colorado. Our study area was dictated by the area occupied by radiocollared moose and ultimately covered approximately 6,000 km^2 varying from about 2,600 m to 4,270 m in elevation. The area includes portions of Mineral, Hinsdale, Gunnison, and Archuleta counties in Colorado. Dominate vegetation includes spruce (*Picea spp.*), fir (*Abies spp.*), quaking aspen (*Populus tremuloides*), and at least 8 species of willow (*Salix spp.*). The area is described in detail by Olterman *et al.* (1994).

METHODS

In 1991, 1992, and 1993 106 moose were captured in northcentral Colorado,

northern Utah, and southwest Wyoming and transplanted to previously unoccupied moose habitat in southwestern Colorado (Olterman *et al.* 1994). The animals were released at 12 sites with a maximum straight line distance between sites of 32 km. Nine males (3 adults and 6 yearlings) and 32 females (31 adults and 1 yearling) were fitted with radio transmitters (Advanced Telemetry Systems, Isanti, MN). All radiocollars included a mortality sensor that produced a distinct signal when the transmitter became stationary for 3 hours. Each animal was tracked from a Cessna 185 fixed-wing aircraft approximately monthly until the animal died or the study terminated on December 31, 1996. A total of 1,286 locations was recorded using Loran C or Global Positioning System (GPS) receivers and verification was made visually and recorded on U.S. Forest Service 1:500,000 scale maps. No radio failures occured during the study. All females were located by ground tracking at least once each year in late July, August, or September to determine if 1 or more calves were present. Reproductive rates were calculated by dividing the number of calves observed with radiocollared females by the number of radiocollared females observed.

All mortality signals were tracked on the ground and an attempt was made to determine the cause of death. A necropsy was performed on each dead animal if the condition allowed. Only animals that survived for at least a month after the initial release were included in survival calculations. Survival estimates were calculated by dividing the number of moose alive at the end of each calendar year by the number of moose alive at the start of each calendar year.

Separate estimates were made for males and females as well as a single estimate for all adult animals. No calves were radiocollared. Capture and transportation techniques and initial capture related mortality were discussed by Olterman *et al.* (1994).

Total area occupied by the radiocollared moose was calculated using a 90% adaptive kernel analysis as described by Kie *et al.* (1996). The occupied areas represent areas that had radiocollared moose present at some point in the course of the study and do not represent annual home ranges. Occupied areas were calculated for all moose as a group in order to define total range and dispersal.

The mean area occupied for individual males and females was calculated for animals that survived long enough to be represented by at least 20 data points. The mean occupied area was calculated by dividing the sum of all occupied areas by the total number of individuals in the sample; where winter is December through February, spring is March through May, summer is June through August, and fall is September through November.

RESULTS

Radiocollared female moose had 97 opportunities to reproduce during 5 breeding seasons. A total of 50 calves was observed for an average annual reproductive rate of 52 calves per 100 cows (Table 1). Only 1 yearling female was radiocollared and was included in the 1993 observation.

Of the 41 radiocollared moose tracked, 21 died during the course of the study. Mean annual survival rates were 0.94 for adult males, 0.83 for adult females and 0.85 for all adults (Table 2). We were unable to determine the cause of death in 9 cases due to the activities of scavengers. The primary known cause of death was illegal kill by hunters licensed for other species. In the case of males all mortality was caused by illegal kill. Other mortality causes are described in Table 3.

By the conclusion of the study moose

Table 1. Reproductive rates of radiocollared moose transplanted to southwestern Colorado, 1992-96. Rates were calculated from observations of calves with females in late July, August, and September annually.

Year[1]	Number of females[2]	Number of calves observed	Calves per 100 cows
1992	13	6	46
1993	29	14	48
1994	23	14	61
1995	18	11	61
1996	14	5	36
Totals	97	50	Mean Calves/100 cows = 52

[1] January 1 - December 31

[2]Females alive in late July, August, and September.

Table 2. Survival of radiocollared moose transplanted to southwest Colorado, 1992-96.

	Males			Females		
Year[1]	Alive at Start	Mortalities	Survival Rate	Alive at Start	Mortalities	Survival Rate
1992	6	1	0.83	13	0	1.00
1993	7	1	0.85	32	6	0.81
1994	6	0	1.00	26	4	0.85
1995	6	0	1.00	22	4	0.82
1996	6	0	1.00	18	5	0.72
Mean annual male survival rate = 0.94				Mean annual female survival rate = 0.83		

[1] January 1 - December 31

occupied 5,534 km^2 of land in the fall. The largest area occupied was in the fall and the smallest area occupied was in the winter (Table 4). The area occupied by individual moose ranged from 35 km^2 to 3,537 km^2 for 2 females.

DISCUSSION

The observed average calf to cow ratio of 52 calves per 100 adult cows during the period from late July through September in our study area compared favorably with ratios observed in other populations reported to be increasing in density. Gasaway *et al.* (1977) reported that calf to cow ratios ranged between 36 and 59 calves per 100 cows during a period of population increase in interior Alaska. Baskin (1994) reported that moose populations in the Russian taiga were stable or increasing with fall calf to

Table 3. Causes of mortality for 21 radiocollared adult moose transplanted to southwest Colorado, 1992-96.

Cause of mortality	Number of males	Number of females	Totals	Percent of total mortality
Illegal kill	2	5	7	33
Birth complications	-	2	2	10
Winter loss[1]	0	2	2	10
Impacted rumen	0	1	1	5
Unknown	0	9	9	42

[1] These animals were old as determined by tooth wear and would likely not have survived for long under any circumstances.

Table 4. Total area occupied by 31 radiocollared moose transplanted to southwestern Colorado, 1992- 96 as defined by a 90% adaptive kernel analysis.

Season	Occupied Area (km^2)	Number of Locations
Summer[1]	5,032	389
Fall[2]	5,534	298
Winter[3]	3,651	248
Spring[4]	3,826	383

[1] Where summer is June, July, and August

[2] Where fall is September, October, and November

[3] Where winter is December, January, and February

[4] Where spring is March, April, and May

cow ratios of 55 calves per 100 cows and Kufeld (1994) indicated that a January calf to cow ratio of 56 calves per 100 cows was observed in a Colorado population that increased dramatically after they were transplanted in 1978 (Bowden and Kufeld 1995). Moose numbers were stable at La Verendrye Reserve, Quebec during a 7 year period when January calf to cow ratios varied between 40 and 52 calves per 100 cows (Messier and Crête 1985).

Predators present in the study area include black bears (*Ursus americanus*), mountain lions (*Felis concolor*), and coyotes (*Canis latrans*). Both bears and lions occur at relatively low densities and it is unlikely that coyotes are capable of taking moose that have survived the neonatal period. The negative influence of predators on this population is probably far less than it is where wolves and brown bears occur. No legal moose hunting is allowed in the study area.

It is important to note that, with one exception, all females were adults. Calculated calf to cow ratios based on adult females only would likely yield a higher ratio than that obtained by random observa-

tion of the population. We believe that bias is at least partially offset by the fact that 2 females, and possibly others, were isolated from males and did not have the opportunity to breed for 5 consecutive years. We conclude that reproduction and calf survival are sufficient to allow the population to increase.

Adult survival rates of 0.94 for adult male moose and 0.83 for adult females observed in this study compare favorably with reported natural adult survival rates of 0.88 in southwestern Yukon, 0.91, 1.00, and 0.76 for 3 periods on Isle Royale, and 0.80 and 0.94 in interior Alaska (Hatter and Bergerud 1991). Illegal kill was the largest known cause of death for moose in our study area. If only natural mortality were considered the survival rates increase to 1.00 for males and 0.88 for females. We conclude that adult survival rates are sufficient to allow for population increase.

Only 2 of the 41 radiocollared moose moved more than 50 km from the release site and became reproductively isolated from other moose. Both were females. One male moved 156 km from the release site during the summer following the release but returned and never left again. The remaining radiocollared animals remained within 50 km of the release sites and occupied areas that allowed interaction with other moose. The average area inhabited was 625 km^2 for adult males and 772 km^2 for adult females (Table 5). These rather large areas are the result of individual animals moving from one annual home range to a completely different home range between years and from movements between seasonal ranges. Also, some moose seemed to move about a great deal during the summer following the release, eventually establishing a home range and becoming more sedentary. Many moose without collars were reported by the public in locations that suggest the overall range occupied is larger than documented by radiotracking. Kufeld and Bowden (1997) documented seasonal areas as large as 76 km^2 for adult males and 74 km^2 for adult females and maximum distances moved between seasonal activity centers of 19 km and 21 km for males and females respectively in North Park , Colorado. We conclude that transplanted radio collared moose have become established in the study area.

MANAGEMENT IMPLICATIONS

We believe the reproductive rates, survival rates, and occupied ranges that we documented indicate that habitat in the study area is of sufficient quality and quantity to support a viable population of moose. Observations of radiocollared moose, other transplanted moose and their progeny indicate that the animals are robust and healthy.

Table 5. Mean area (km^2) occupied by radiocollared moose transplanted to southwestern Colorado, 1992-1996 as defined by a 90% adaptive kernel analysis.[1]

Season	Males (n = 7)	Females (n = 24)
Summer[2]	881 (86 locations)	678 (303 locations)
Winter[3]	102 (57 locations)	502 (191 locations)
All seasons	625 (143 locations)	772 (494 locations)

[1] Moose with 20 or more recorded locations

[2] Where summer is June, July, and August

[3] Where winter is December, January, and February

It is our opinion that densities of moose will increase in the study area and that dispersal from the area into adjacent unoccupied habitats will occur and eventually most suitable moose habitat in Colorado will be occupied. Managers should monitor riparian willow habitats in the areas where moose become established and prescribe hunter harvests that will ensure that range overuse does not occur. In addition, managers should advise land use managers about practices such as those described by Kufeld and Bowen (1997) that will ensure the long term viability of moose in Colorado. Illegal kill should be factored into recommendations for legal harvest.

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