MOOSE DISTRIBUTION RELATIVE TO HUMAN DEVELOPMENT IN A NATIONAL PARK

Jerrold L. Belant[1,2], Jonathan A. Paynter[1], Kenneth E. Stahlnecker[1,3], and Victor Van Ballenberghe[4]

[1]National Park Service, Denali National Park and Preserve, P.O. Box 9, Denali Park, AK 99755, USA; [4]U.S. Forest Service, Pacific Northwest Research Station, 3301 C Street, Suite 200, Anchorage, AK 99503, USA

ABSTRACT: The potential influence of human development on distribution of moose (*Alces alces*) within Denali National Park and Preserve, Alaska, was investigated during May-September 1995-1997. Univariate and multivariate analyses were conducted to evaluate seasonal habitat use and distances to the park road and developed areas. Moose exhibited avoidance of spruce habitat during summer and spruce, shrub, and deciduous habitats during autumn. Results from univariate analyses indicated moose were closer to the park road than expected during summer and autumn and further than expected from developed areas during autumn. However, multivariate logistic regression models including habitat types revealed that distances moose were located from roads were similar to expected during each season. Logistic regression models also indicated that moose were further from developed areas in autumn. Moose movement away from developed areas during autumn was likely because developed areas were located predominantly (69%) in forest and shrub habitats; moose appeared to select more open areas in autumn for rutting activities. Distribution of moose did not appear strongly influenced by human development. That moose did not overall avoid the park road or developed areas appears a consequence of habituation (i.e., indifference) to human activity from no positive or negative reinforcement.

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Annual visitation to Denali National Park and Preserve (DNPP) has increased from < 45,000 people before 1972 (Dalle-Molle and Van Horn 1989) to the current level of > 350,000 people (DNPP, unpublished data). A large part of the popularity of DNPP is the relative ease of viewing moose (*Alces alces*), caribou (*Rangifer tarandus*), grizzly bear (*Ursus arctos*), and Dall's sheep (*Ovis dalli*) from the park road. The National Park Service's mandate is to protect park resources while providing access and viewing opportunities for the public. Balancing these needs becomes more difficult as visitation increases. Because of the potential effect of increased visitation and associated traffic on wildlife (Knight and Gutzwiller 1995), DNPP limited vehicle access beyond the first 24 km of the park road, while there are no restrictions on the number of vehicles along the first 24 km of road.

Several studies have been conducted at DNPP to determine large mammal abundance along the park road corridor and their behavior in response to traffic (Tracy 1977, Singer and Beattie 1986, Burson et al. 2000). None of these studies, however, evaluated whether

[2]Present address: National Park Service, Pictured Rocks Science Center, P.O. Box 40, Munising, MI 49862, USA

[3]Present address: National Park Service, Black Canyon of the Gunnison National Monument/Curecanti National Recreation Area, 102 Elk Creek, Gunnison, CO 81230, USA

large mammals exhibited selection or avoidance of the park road. In addition, no previous study has focused on the effects of human development and associated human activity on wildlife along the unrestricted portion of the park road. Our objective was to determine if moose distribution was affected by human development along a 24 km section of road with unrestricted vehicle access and the associated developed areas in DNPP.

STUDY AREA

DNPP is located in the interior of Alaska about 225 km north of Anchorage. The southern half of the park is composed of the Alaska Range, containing numerous mountain peaks > 3,000 m. The northeast is characterized by lower mountains and glacial valleys. Spruce (*Picea* spp.) lowlands predominate the northwest part of the park. Areas below 800 m contain spruce forests, tussock tundra, and riparian spruce/willow (*Salix* spp.). Elevations between 800-2,400 m are characterized by alpine sedge (*Carex* spp.) and low shrub (*Salix* spp. and *Betula* spp.) tundra; permanent snow and ice occur at elevations > 2,400 m.

DNPP has a subarctic montane climate, with temperatures ranging from –47 to +37°C. Mean annual precipitation is 38 cm, which includes about 200 cm of snowfall. Monthly mean high and low temperatures during the study (May-September 1995-1997) were 21 and –3°C, respectively; monthly precipitation ranged from 1.8-8.9 cm during this period.

The 158-km^2 study area (63° 42' N, 149° 00' W) was located along the eastern boundary of the park. This area is bisected by the park road and flanked to the south and north by the Alaska and Outer Ranges; elevations varied from 440-1,890 m. The study area contained the first 24 km of the road, which is paved and has unrestricted vehicle access when passable. The eastern portion of the study area is generally lower in elevation and more heavily vegetated than the more open western portion of the study area. We limited the study from May-September, as the road is typically passable to vehicles during this period. In addition, > 95% of visitor use is estimated to occur during May-September (S. Carwile, DNPP, personal communication).

METHODS

Adult moose were immobilized (Van Ballenberghe 1989) and fitted with radio transmitters as a part of long-term ecological studies (Risenhoover 1986; Van Ballenberghe and Miquelle 1990, 1993; Miquelle et al. 1992). Moose were captured within the study area, typically within 1.6 km of the road. Previous research indicated that collared moose were representative of the population (Miquelle et al. 1992). Moose were relocated opportunistically between 0700-1700 hours during May-September 1995-1997 using standard aerial telemetry techniques (Mech 1983).

Moose locations across years were pooled and compared to 1,000 random locations used to describe habitat availability (Design I; Manly et al. 1993). Habitat data were obtained from a land cover map with 50 m resolution developed from 1981 Thematic Mapper imagery (K. Winterberger, U.S. Forest Service, unpublished data). No large-scale habitat alteration such as fire occurred within the study area after the imagery was acquired. Over-storey habitat was characterized as spruce, deciduous, shrub, herbaceous, and bare ground/gravel. The spruce habitat included all areas with a spruce over-storey component; shrubs (e.g., willow) occurred frequently within portions of this habitat. Elevations were derived from 1:63,360 U.S. Geological Survey Digital Elevation Models. Habitat > 1,219 m elevation was considered unsuitable for moose and excluded from analyses.

Seventeen developed areas in the study area were delineated, which included campgrounds, DNPP office buildings and employee residences, park concessions, and similar areas of frequent human activity. Developed areas were predominantly clustered along the eastern 5 km of road. Developed areas and the park road were digitized from aerial photographs and verified by ground reconnaissance. For analyses, the park road was considered linear whereas a 50-m buffer was incorporated around developed areas. The buffer was incorporated around developed areas to include yards and other disturbed sites directly associated with the developments.

An aerial telemetry error of 80 m was incorporated into the digital map using a GIS Focal Majority routine (ARC/INFO 1998; Environmental Systems Research Institute, Redmond, California, USA). The dominant habitat within each error polygon was used for analyses. Telemetry error was estimated by obtaining aerial Global Positioning System coordinates from 10 known locations in the study area visible from the aircraft. There was no need to estimate telemetry error using concealed radio transmitters, as 82% of moose locations obtained were determined from direct observations.

Seasons were characterized as spring (1 May-15 June), summer (16 June-15 August), and autumn (16 August-30 September). Spring and autumn coincided approximately with calving and the rut, respectively. Daily visitation to DNPP was about twice as high during summer than during spring and autumn (DNPP, unpublished data). Seasonal mean elevations and distances to the road and developed areas were compared using Student *t*-tests. Chi-square analyses were used to assess seasonal habitat use. For multivariate analyses, stepwise logistic regression (PROC LOGISTIC, SAS Institute 1988) was used. Categorical variables (i.e., habitat types) were assigned 0-1 indicator variables to facilitate analyses (Hosmer and Lemeshow 1989). As moose have been reported to exhibit sexual segregation, preliminary analyses were conducted using sex as a categorical variable. Sex of moose did not enter these initial models ($P > 0.050$), therefore location data for males and females were pooled for subsequent analyses. In addition, because Burson et al. (2000) observed fewer moose within 100 m of the park road than did Tracy (1977), we also incorporated whether moose were present within 200 m of the road as an additional categorical variable in the logistic regression models rather than 100 m because of telemetry error (80 m). Statistical significance for all tests was $P < 0.050$.

RESULTS

Twenty-one moose (15 females, 6 males) were located within the study area 271 times; 72% of locations were of females and locations were recorded during spring (17%), summer (44%), and autumn (40%).

Most of the road occurred within shrub (65%), followed by spruce (17%), deciduous (10%), and herbaceous (7%) habitats. Developed areas were predominantly in spruce (38%), followed by shrub (22%), herbaceous (18%), bare ground/gravel (13%), and deciduous (9%) habitats.

Univariate Analyses of Resource Selection

The mean distance moose were located from the road was similar ($t = 1.34$; 1,038 df; $P = 0.191$) to random during spring; however, moose were located closer to the road during summer ($t = 2.43$; 1,111 df; $P = 0.015$) and autumn ($t = 2.29$; 1,101 df; $P = 0.022$) (Table 1). Mean distances moose were located from developed areas was similar to mean random distance during spring ($t = 0.53$; 1,038 df; $P = 0.597$) and summer ($t = 0.48$; 1,111 df; $P = 0.632$), but moose were located farther from developed areas during autumn ($t = 2.38$; 1,101 df; $P = 0.018$). The mean elevation at which moose were located was similar to random during spring ($t = 0.90$; 1,038 df; $P = 0.371$) and autumn ($t = 1.83$; 1,101 df; $P = 0.068$) but was lower than random during summer ($t = 2.39$; 1,111 df; $P = 0.017$).

Habitats available to moose were primarily

Table 1. Availability and seasonal use of habitat types and distances to road and developed areas for moose, Denali National Park and Preserve, Alaska, 1995-1997.

Availability and Use	% Availability and Use of Habitat					Distance (m) to:				Elevation (m)	
	Spruce	Deciduous	Shrub	Herbaceous	Bare Ground/ Gravel	Road		Developed areas			
						$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Available	16	10	62	8	5	1,670	1,203	3,382	1,892	886	162
Spring use	18	11	62	7	2	1,431	1,041	3,536	2,285	862	162
Summer use	29	10	58	3	1	1,389	1,060	3,471	1,970	846	140
Autumn use	32	15	53	1	0	1,393	1,095	3,837	1,863	854	115

shrub (62%), followed by spruce (16%) and deciduous (10%) (Table 1). Moose used habitat types similar to that available during spring (χ^2 = 1.17, 4 df, P = 0.882) and summer (χ^2 = 8.99, 4 df, P = 0.061). However, moose used the spruce habitat more than expected during autumn (χ^2 = 17.19, 4 df, P = 0.002).

Multivariate Analyses of Resource Selection

None of the variables entered the stepwise logistic regression model for spring, indicating no selection for habitat types or influence of human development on moose. During summer, moose demonstrated some avoidance of spruce habitat (P < 0.001; Table 2); no other variables entered the model. During autumn, moose exhibited stronger avoidance of spruce habitat and also avoided shrub and deciduous habitats (P < 0.015). Similar to univariate analyses, moose avoided (P < 0.001) developed areas. The effect of developed areas, however, appeared minimal as indicated by the small coefficient estimate (< 0.01). Moose did not display avoidance or selection of the road during any season.

DISCUSSION

Based on broad habitat classes, moose in DNPP generally used habitats relative to their availability during spring and summer. Moose typically moved to traditional rutting areas in the western portion of the study area during autumn (V. Van Ballenberghe, unpublished data). Why moose during autumn appeared to prefer spruce habitat using a univariate approach and avoided spruce based on our multivariate approach is likely a consequence of their concentrated use of a small proportion of the study area containing limited spruce over-storey. This is also the portion of the study area with fewest human developments. That moose avoided developed areas during autumn is probably an artifact of their selection for this more open spruce habitat during the rut; 69% of developed areas occurred in denser forest or shrub habitats. Also, the daily number of visitors during autumn is only about half the daily number of visitors during summer (DNPP, unpublished data), suggesting that visitation was not causing avoidance.

The number of moose observed from the park road has declined considerably since 1973 (Singer and Beattie 1986, Burson et al. 2000). Singer and Beattie (1986) attributed the decline in the number of moose observed from the road in part to human disturbance. Overall, data from this study does not support their conclusion. In addition, Burson et al. (2000) determined that about 50% of the reduction in the number of moose observed from the road was a consequence of the reduction in the moose population. Reduced visibility from vegetative growth along the park road may also have contributed to lower numbers of moose observed (Burson et al. 2000).

Numerous studies have evaluated the effects of human disturbance on ungulates

(Johnson and Todd 1977, Van Ballenberghe 1978, Morrison et al. 1995, Cole et al. 1997), however, few have been conducted on unharvested populations (Schultz and Bailey 1978). Moose have not been legally harvested in this portion of DNPP since the park was established in 1917. Hunting has been suggested to cause negative conditioning in animals (McCullough 1982) whereas ungulates frequently habituate to disturbances if they do not receive negative reinforcement (Belant et al. 1996, 1998). Thus, that moose overall did not avoid the park road or developed areas during this study appears a consequence of habituation to human activity from no positive or negative stimuli.

The range of human activities that occur in our study area at DNPP is restricted compared to many other areas containing moose. The majority of activities included camping, limited hiking on established trails, use of the park road, and administrative activities. The number of people hiking off-trail within our study area was low compared to the number of people using the area. Thus, although the number of people present on a given day from spring to autumn varies markedly, their distribution and activities are generally predictable. Telemetry data suggest that moose remained within the study area and would not be exposed to additional human activities that could occur outside DNPP (e.g., hunting). Predictable and controlled human activity increases the likelihood for habituation in animals (Mace and Waller 1996). That overall predictable and controlled human activity occurred within our study area would facilitate habituation by moose.

It is suggested that most moose occurring in this portion of DNPP are habituated (i.e., indifferent) to humans. Moose did not appear to distribute themselves in response to human development. Previous studies have suggested that human activities within our study area have resulted in fewer moose being observed near the park road (Tracy 1977, Singer and Beattie 1986). However, a more comprehensive analysis suggested that the primary factor explaining the reduction in moose observations in the road corridor was an overall reduction of moose in the study area (Burson et al. 2000). Habituation of ungulates to forms of human-induced stimuli is frequently not immediate (e.g., Belant et al. 1996); moose may initially have avoided developed areas and vehicle traffic in DNPP. The time required for moose to habituate to various recreational activities is unknown; it is possible that moose demonstrated avoidance of these developed areas for years. However, our data suggest that avoidance of the road and developed areas by moose no longer occurs.

Because of limited and predictable human activity and a lack of positive or negative reinforcement, it is suggested that moose have habituated to humans in this portion of DNPP. Modest increases in visitation to DNPP with activity patterns similar to current recreationists should at most have a short-term adverse effect on moose. However, it is possible that continued increases in existing

Table 2. Stepwise logistic regression coefficient estimates (Est) describing moose habitat selection by season, Denali National Park and Preserve, Alaska, 1995-1997.

Variable	Summer				Autumn			
	Est	SE	χ^2	*P*	Est	SE	χ^2	*P*
Intercept	2.3	0.11	403.48	< 0.001	5.9	0.32	31.84	< 0.001
Spruce habitat	-0.78	0.22	12.49	< 0.001	-3.68	1.03	12.77	<0.001
Shrub habitat					-2.48	1.02	5.98	0.015
Deciduous habitat					-0.55	1.05	11.4	0.001
Distance to developed areas					-0.01	< 0.01	17.46	<0.001

human activities could alter moose behavior and result in avoidance of certain areas. Additionally, changes in distribution of humans or types of human activities, particularly those that result in negative stimuli toward moose (e.g., increased development, harvest), could adversely affect moose distribution.

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