Gray Wolf Response to Refuge Boundaries and Roads in Alaska

Author(s): Joanne M. Thurber, Rolf O. Peterson, Thomas D. Drummer and Scott A. Thomasma

Source: *Wildlife Society Bulletin (1973-2006)*, Spring, 1994, Vol. 22, No. 1 (Spring, 1994), pp. 61-68

Published by: Wiley on behalf of the Wildlife Society

Stable URL: https://www.jstor.org/stable/3783224

animal removal program San Clemente Island. Nat. Resour. Off., San Diego, Calif. 86pp.
VITOUSEK, P. M. 1988. Diversity and biological invasions of oceanic islands. Pages 181–189 *in* E. O. Wilson, ed. Biodiversity. Natl. Acad. Press, Washington, D.C.
YOCUM, C. F. 1967. Ecology of feral goats in Haleakala National Parks, Maui, Hawaii. Am. Midl. Nat. 77:418–451.

Received 24 June 1992.
Accepted 28 May 1993.
Associate Editor: Swihart.

***Wildl. Soc. Bull.* 22:61–68, 1994**

GRAY WOLF RESPONSE TO REFUGE BOUNDARIES AND ROADS IN ALASKA

JOANNE M. THURBER,[1] ***School of Forestry and Wood Products, Michigan Technological University, Houghton, MI 49931***

ROLF O. PETERSON, ***School of Forestry and Wood Products, Michigan Technological University, Houghton, MI 49931***

THOMAS D. DRUMMER, ***Department of Mathematics, Michigan Technological University, Houghton, MI 49931***

SCOTT A. THOMASMA,[2] ***School of Forestry and Wood Products, Michigan Technological University, Houghton, MI 49931***

Key words: Alaska, behavior, *Canis lupus*, gray wolf, Kenai Peninsula, refuge boundaries, roads

Road density in Minnesota and Wisconsin has been shown to influence wolf (*Canis lupus*) distribution and thus may be used to predict the suitability of areas to sustain breeding populations of wolves. Three studies (Thiel 1985, Jensen et al. 1986, Mech et al. 1988) were in general agreement that wolf packs did not persist where road density exceeded approximately 0.6 km/km^2. Low-density wolf populations may be supported at greater road densities when adjacent areas have either no roads or low road densities (Mech 1989). Management plans to benefit wolves may include reduction of roads and seasonal or permanent gating of roads to reduce human access (Land and Resour. Manage. Plan, Ottawa Natl. For. 1986, State of Minn. For.—Wildl. Hab. Manage. Guidelines, St. Paul, 1988 update).

Although it is generally assumed that road access increases human-caused mortality of wolves (Mech 1989), other factors such as avoidance by wolves of roads used by humans also may contribute to the road-density effect. Wolf response to human habitation and roads closed to human access has not been evaluated. A better understanding of wolf behavior in relation to human presence may help facilitate wolf-human coexistence in areas of proposed development or wolf recovery.

We examined wolf response to road types (highway, secondary road, and gated road) and to human presence at the boundaries of Kenai National Wildlife Refuge (KNWR), Alaska. Our purpose was to better characterize the influence of human settlement on wolf distribution.

[1] Present address: Ottawa National Forest, 801 Adams, Iron River, MI 49935.
[2] Present address: Lockheed Engineering and Sciences Company, Spatial Analysis Laboratory, 1050 Flamingo Road, Las Vegas, NV 89119.

STUDY AREA

The KNWR (7,972 km^2) is located on the Kenai Peninsula (60°N, 150°W) in south-central Alaska (Fig. 1). The forested northern half of KNWR was used for this study. Chugach National Forest lies to the east of the study area. The human population of the Kenai Peninsula (26,000 km^2) in 1980 was 25,282, with more than half living near the west-central boundary of the refuge. Three heavily settled townships (280 km^2) are almost surrounded by the KNWR and contain the cities of Kenai and Soldotna with populations in 1980 of 4,324 and 2,320, respectively (Fig. 1). Three smaller settlements and associated roads connecting adjacent rural residences also occur outside the western boundary. Most land adjacent to the refuge is divided into small (<10 ha) parcels that are privately owned by rural residents.

The KNWR included 4 road types used in this study: gravel (secondary) roads open to public use but left unplowed in winter, a gas pipeline access road (gravel) that was closed to vehicle access except during moose (*Alces alces*) hunting season (approx 3 weeks in Sep), portions of a heavily-used paved state highway, and a gravel access road associated with an active oilfield. The oilfield access road was open to the public year-round except for minor gated portions around active oil wells and had considerable traffic, but less than the highway. Approximately 5 km^2 encompassed the actual oilfield and housing for oilfield workers. Speed limit on the state highway was 88 kph (55 mph); all other roads had a 56 kph (35 mph) limit.

All the roads we studied were in a single physiographic area near sea level (the Kenai Lowlands), containing gently rolling terrain with forest vegetation dominated by paper birch (*Betula papyrifera*) and white spruce (*Picea glauca*). National forest lands lying east of the study area were mountainous with maximum elevations of 2,000 m.

Aside from the developed oilfield, there were no permanent human habitations on the refuge. Outside the western boundary of KNWR, both urban and rural settlements were present. Subsistence agriculture was present in small, cleared areas; developed areas were largely forested. There was no abrupt change in vegetation at refuge boundaries, although beyond the eastern KNWR boundary the land was more mountainous.

Wolves were protected on the Kenai Peninsula during a period of reestablishment from 1961 to 1974, after which hunting (1974) and trapping (1975) seasons were initiated. During the study, wolf hunting and trapping seasons were 10 August–30 April and 10 November–31 March, respectively.

METHODS

Sixty-four wolves were radiocollared within the KNWR during 1976–1980 as part of a study of wolf ecology and wolf-moose relationships (Peterson et al. 1984). All packs within the study area were radiocollared with the possible exception of a small pack that was later radiocollared in the southwestern portion of the study area (T. N. Bailey, KNWR, pers. commun., 1981). We located wolves by aircraft 1–2 times weekly in summer and almost daily in winter. Resulting wolf locations ($n = 2,064$, 70% during Nov–Apr) for the 4 years were digitized and registered on a 1:250,000 topographic map of the Kenai Peninsula (updated to 1974) using software from Earth Resources Data Analysis Systems (ERDAS, Inc., Atlanta, Ga.). The map and locations were then converted to geographic information system raster format. The frequency of wolf locations was computed for successive 100-m wide bands parallel to roads, up to 5 km. We made similar calculations for portions of the eastern and western boundaries of the refuge that included ≥5 km of land on both sides (Fig. 1). For each 100-m distance category within each data set, the relative use (Y) was defined as the number of wolf locations/number of available pixels (pixel size = 100 m^2). This variable was used as an index of wolf use and to estimate the functional relationship between wolf use and distance from the road or boundary.

For each of the 4 road data sets, 2 nonlinear regression models were fit; a parametric 2-phase model (Seber 1989:433) and a nonparametric smoothing spline (Eubank 1988:189). The parametric model assumed a monotonic behavioral response by wolves to roads and enabled estimates to be made of road impact (see below) on wolf habitat selection. For the first phase of the 2-phase model, it was assumed that the impact (positive or negative) of the road on relative wolf use declined as distance from the road increased. As this distance grew large, it was assumed that relative use was constant (phase 2), representing relative use for nonroad habitat. The model used was

$$Y = B_0 + B_1X + B_2X^2 \qquad \text{for } X < X_0,$$

and

$$Y = C \qquad \text{for } X > X_0,$$

where Y = relative use as previously defined and X is the distance from the road (km). The parameter X_0 is the changepoint, and represents the distance from the road where impact of the road is 0. Beyond distance X_0, expected relative use is assumed to be equal to the constant C.

The parameters B_0, B_1, and B_2 represent standard regression parameters. Two additional model assumptions were: (1) equality between the 2 phases at the changepoint X_0, or that $B_0 + B_1X_0 + B_2X_0^2 = C$; and (2) to ensure smoothness, the first derivatives of each of the 2 functions with respect to X were equal at the changepoint, implying that $B_1 + 2B_2X_0 = 0$. Solving simultaneous equations stated in assumptions (1) and (2) for X_0 and C yields (i) $X_0 = -B_1/2B_2$ and (ii) $C = B_0 - (B_1^2/4B_2)$.

Road impact was defined as the ratio of relative use at distance 0 from the road to nonroad relative use, C. Thus, impact = B_0/C, and substitution for C yields impact = $4B_0B_2/(4B_0B_2 - B_1^2)$. A value of impact >1.0 implied that wolves were attracted to the road, a value of impact <1.0 implied that wolves avoided the road, and a value of impact = 1.0 implied wolf use of the road was no different than for nonroad areas. We expressed impact as a percent deviation by computing (impact − 1.0)100%.

Models for each road type were fit with PROC NLIN in the SAS package (SAS Inst. Inc. 1985:575–606) and we substituted estimates of B_0, B_1, and B_2 to estimate the changepoint X_0 and road impact. The delta method (Seber 1982:8) was used to obtain standard errors for estimates of X_0 and road impact. We used a 2-tailed Z-test to determine significance of road impact.

The nonparametric second order smoothing splines also were fit to the road data sets, using a procedure developed by Craven and Wahba (1979). This model was free of behavioral response assumptions, and the fit was determined only by the data. However, only visual impact estimates could be made from this model, e.g., if the curve turned upward (more locations) near the road, attraction was assumed. We visually compared the results of both models to determine the reliability of the assumptions of the parametric model.

We used the midpoints of the 100-m-wide distance intervals for the values of X, resulting in 51 data points for each data set. Model adequacy was determined via residual plots and we computed $(1 - SSE/SS_{total})100\%$ to further assess model fit.

Wolf use inside and outside the refuge along the eastern and western boundaries was compared by matching relative use for each distance interval. We used the large-sample approximation of the sign test (Conover 1971:123) to determine if there was a difference in relative use between refuge and adjacent nonrefuge areas.

Cause of mortality was determined for radio collared wolves that died while their collars were transmitting. The distribution of reported wolf harvest was obtained from an Alaska Department of Fish and Game mandatory reporting program (Peterson et al. 1984).

RESULTS

The smoothing spline and 2-phase models were in best agreement for the oilfield data (Fig. 2). The estimated impact of the oilfield road was −43% ($P = 0.001$, Table 1), implying that wolves used habitat near the oilfield road 43% less than adjacent nonroad areas. The estimated changepoint, beyond which wolf behavior was unaffected by the oilfield road, was 2.1 km (SE = 0.9).

For the remaining data sets, the parametric and nonparametric models exhibited greater discrepancies (Fig. 2), so the estimated impact and changepoints were not as reliable. Both models indicated preference for the pipe-

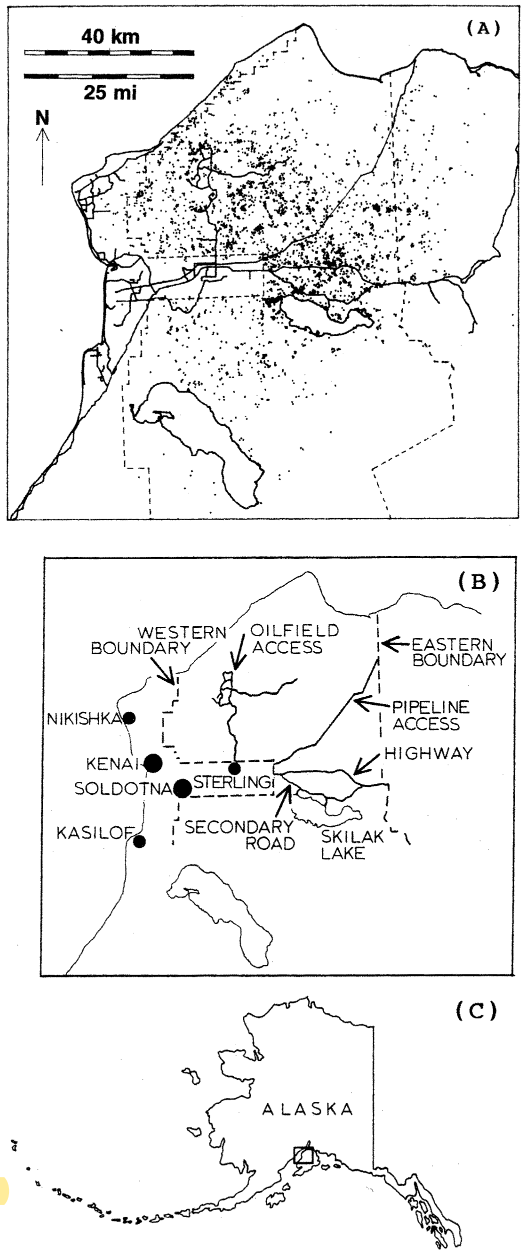

Fig. 1. (A) Wolf locations in relation to roads (solid lines) and boundaries (dashed lines) of Kenai National Wildlife Refuge, Alaska, 1976–1980; (B) roads and boundaries (as in Fig. 1A) studied in the refuge; and (C) location of study area in Alaska.

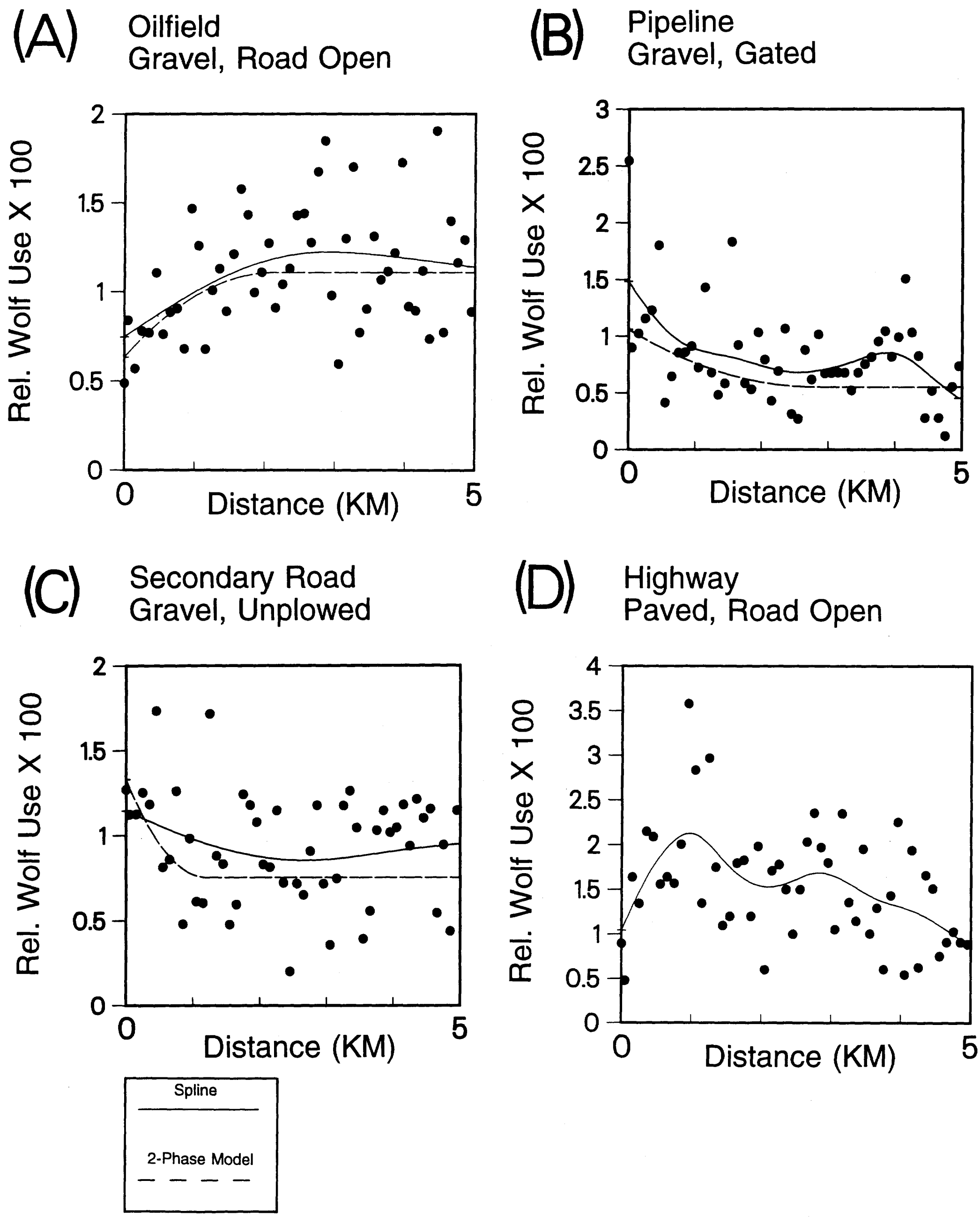

Fig. 2. Relative wolf use of different road types in Kenai National Wildlife Refuge, Alaska, 1976–1980.

line road (P = 0.013, impact = +93%), but the spline indicated increased use at approximately 3–4 km. Both models also indicated preference for the secondary road (P = 0.048, impact = +77%) and were in close agreement near the origin. However, the smoothing spline indicated a smaller decline in relative use as X increased, thereby indicating that the im-

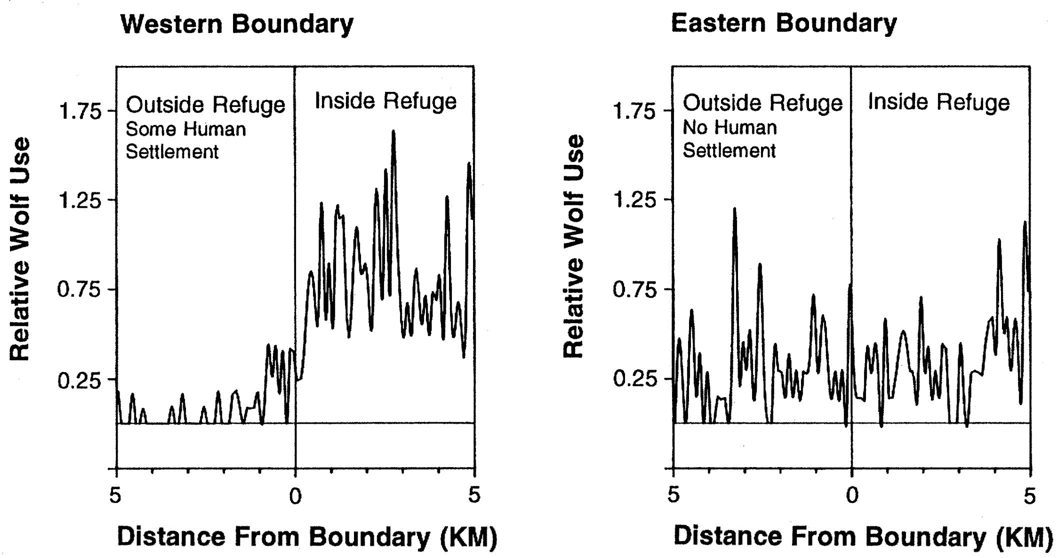

Fig. 3. Relative wolf use of western and eastern boundaries, inside and outside of Kenai National Wildlife Refuge, Alaska, 1976–1980.

pact could be overestimated. We could not fit the 2-phase model to the highway data set because relative use was not a monotonic function of distance from the road and the assumption of phase equality at the changepoint was violated. The smoothing spline visually indicated avoidance of the highway itself, but increased use at approximately 1 km.

Overall, both models failed to account for much of the variation in relative use (3–18% for 2-phase model, 11–34% for spline model). Residual analysis indicated no systematic errors in either model; this was true of the models for all data sets.

On the eastern boundary of the refuge, bordering national forest, there was no detectable difference in wolf use ($n = 50$, $Z = 0.28$, $P = 0.82$) inside or outside the refuge (Fig. 3). On the western boundary, adjacent to private, developed land, there was greater use within the refuge, with 48 of 50 distance categories exhibiting greater use than the corresponding distance category outside the refuge ($Z = 6.51$, $P < 0.001$).

Of 23 radiocollared wolves that died on the study area while their collars were transmitting, 87% were killed by humans (including 1 by illegal harvest) and the rest died of natural causes (Peterson et al. 1984). Distribution of reported wolf harvest (1974–1980) was concentrated in areas of easy human access near roads or frozen lakes (Peterson et al. 1984:30, Fig. 15). During 1976–1980 only 9 and 5 wolves, of 94 harvested on the study area, were killed within the studied portions of the refuge's western and eastern boundaries, respectively.

DISCUSSION

Wolf location patterns indicated avoidance of the oilfield access roads, which received a

Table 1. Impact, changepoint (X_0), and proportion of explained variance for wolf use of roads in Kenai National Wildlife Refuge, Alaska, 1976–1980.

					(1 − SSE/SSTOT)•100	
Road type	Impact (%)	SE	X_0 (km)	SE	2-phase	Spline
Oilfield	−43	10	2.14	0.90	17.8	22.8
Pipeline	+93	39	2.84	1.42	3.2	31.6
Secondary	+77	39	1.20	0.74	9.8	10.6
Highway	NA		NA		NA[a]	34.4

[a] 2-phase model could not be fit to this data set.

substantial amount of worker traffic and were open for public use all year. Low wolf use may be related to avoidance of human presence rather than direct harvest attrition because reported wolf mortality was low in this area (Peterson et al. 1984). Lack of prey was probably not a factor, as a former large burn contained abundant moose forage and moose were common in this area (Bangs et al. 1985). The pipeline road, to which wolves were attracted, may have provided an easy travel corridor with little human use. Three packs had territories bordering the pipeline (Peterson et al. 1984), and all 3 packs apparently used the closed road. The secondary roads also were used more by wolves, probably because most were unplowed during winter. Access by humans was thus limited and these roads also provided easy travel corridors for wolves.

Data used in this study originated primarily in winter, when human activity in wolf habitats was at a seasonal minimum. Wolf responses might be different at other times of year, such as the firearm hunting season, when human activity is greatly modified.

Wolf use of lands adjacent to the well-traveled state highway indicated no clear avoidance during this study. During 1973–1978 the territory of a study pack was bisected by the highway (Peterson et al. 1984), and a den used by this pack was located 1 km from the highway. Therefore the overall ambivalent response (and the peak in use at approx 1 km) may have been caused by the close proximity of the den. An alternate explanation may be the presence of many moose, because the lowland area along the highway and immediately to the south was a traditional wintering area for moose (Bailey et al. 1978).

The study pack whose territory straddled the highway showed no decline in numbers from harvest (starting in 1974) until 1978–1979 when 10 of 12 pack members were killed. After 1979, the remaining members roamed only the northern portion of their previous territory, while loners and members of an adjacent pack used remaining portions to the south of the highway (Peterson et al. 1984). After 1980, when wolves were radiotracked sporadically, separate packs seemed to form on each side of the highway (T. N. Bailey, KNWR, pers. commun., 1982).

Brody and Pelton (1989) suggested that black bears (*Ursus americanus*) in North Carolina moved their territories from a heavily-used highway when hunter success was low enough that avoidance behavior could be learned. Before the initiation of wolf hunting and trapping seasons on the Kenai Peninsula study area, mortality from traffic and illegal harvest was apparently insufficient for wolves near the highway to learn avoidance. It was only after these wolves declined from intensive hunting and trapping during 1978–1979 that territorial adjustments may have reflected avoidance of this heavily-used highway. This case provided evidence of road avoidance by wolves in response to human-caused attrition. Although the shift in territorial boundary may have been caused by pressure from new pack formation to the south, it seems unlikely that chance alone would result in pack territory boundaries coinciding with the road.

Along the western KNWR boundary, we attribute the avoidance of nonrefuge lands to the presence of human settlement outside the refuge. No vegetation differences were discernible at this boundary. In winter, moose were probably more abundant outside the refuge, based on studies of radiocollared moose (Bailey et al. 1978, Bangs et al. 1989) and the frequency of roadkills (K. Hundertmark, Alas. Dep. Fish and Game, Soldotna, pers. commun., 1991), so wolves were not remaining on the refuge because of prey shortage in settled areas. Finally, wolf mortality was not high on either eastern or western boundaries (Peterson et al. 1984), thus attrition from harvest was not a reasonable explanation.

Avoidance behavior was evident in local areas where harvest was not documented. Uniform avoidance by wolves of areas with human activity did not seem to arise from concurrent exposure to human-caused mortality. Wolves may transmit avoidance behavior to subsequent generations either through direct learning or genetically-based behavioral traits (E. Klinghammer, Purdue Univ., West Lafayette, Ind., pers. commun., 1991). Wolves in Isle Royale National Park, Michigan, even though totally protected for 45 years, have continued to avoid humans (R. O. Peterson, unpubl. data). Avoidance behavior was probably strong in the founding pack of wolves at Isle Royale, which came from Ontario, Canada. In the present study, our data indicate that wolf absence from human-settled areas and heavily used roads in and around the KNWR seemed to be caused by wolf behavioral avoidance.

MANAGEMENT RECOMMENDATIONS

Our results indicate that human presence, even without direct wolf attrition, was sufficient to cause wolf avoidance of settled areas and 1 year-round public road. Thus, continual exposure of wolves to harvest is not required to separate wolves from human activities. Gated or seasonally closed roads away from settled areas represent management recommendations that will provide wolf travel corridors with low human impact. Roads, whether they attracted or repelled wolves, seemed to be a landscape feature that may influence spatial organization of packs.

SUMMARY

The response of gray wolves to different road types and human presence at the boundaries of Kenai National Wildlife Refuge, Alaska, was examined in a study of radio-collared wolves in 1976–1979. Wolf activity within discrete distances up to 5 km from roads and boundaries was computed. Wolves avoided oilfield access roads open to public use ($P = 0.001$), yet they were attracted to a gated pipeline access road ($P = 0.013$) and secondary gravel roads ($P = 0.048$) with limited human use. Wolf response to a major public highway was equivocal, perhaps because wolves used a den only 1 km away. There was no detectable difference in wolf use of land on either side of the eastern refuge boundary adjacent to national forest lands ($P = 0.82$), but on the western, settled boundary wolves used refuge lands more than adjacent private land ($P < 0.001$). Our data suggest that wolf absence from settled areas and some roads was caused by behavioral avoidance rather than direct attrition resulting from killing of animals.

Acknowledgments.—We thank many coworkers who provided information and field assistance, particularly T. N. Bailey and J. D. Woolington, and also the U.S. Fish and Wildlife Service for funding the fieldwork that formed the basis of this study. Comments of R. D. Boertje, C. H. Flather, J. S. Whitman, and an anonymous reviewer are greatly appreciated.

LITERATURE CITED

BAILEY, T. N., A. W. FRANZMANN, P. D. ARNESON, AND J. L. DAVIS. 1978. Kenai Peninsula moose population study. Alas. Dep. Fish and Game P-R Final Rep. W-17-R, Juneau. 84pp.

BANGS, E. E., T. N. BAILEY, AND M. F. PORTNER. 1989. Survival rates of adult female moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 53:557–563.

———, S. A. DUFF, AND T. N. BAILEY. 1985. Habitat differences and moose use of two large burns on the Kenai Peninsula, Alaska. Alces 21:17–35.

BRODY, A. J., AND M. R. PELTON. 1989. Effects of roads on black bear movements in western North Carolina. Wildl. Soc. Bull. 17:5–10.

CONOVER, W. J. 1971. Practical nonparametric statistics. John Wiley and Sons, Inc., New York, N.Y. 462pp.

CRAVEN, P., AND G. WAHBA. 1979. Smoothing noisy data with spline functions. Numerische Mathematik 31:377–403.

EUBANK, R. L. 1988. Spline smoothing and nonparametric regression. Marcel Dekker Inc., New York, N.Y. 438pp.

JENSEN, W. R., T. K. FULLER, AND W. L. ROBINSON. 1986. Wolf, *Canis lupus*, distribution on the Ontario-Michigan border near Sault Ste. Marie. Can. Field-Nat. 100:363–366.

MECH, L. D. 1989. Wolf population survival in an area of high road density. Am. Midl. Nat. 121: 387–389.

———, S. H. Fritts, G. L. Radde, and W. J. Paul. 1988. Wolf distribution and road density in Minnesota. Wildl. Soc. Bull. 16:85–87.

Peterson, R. O., J. D. Woolington, and T. N. Bailey. 1984. Wolves of the Kenai Peninsula, Alaska. Wildl. Monogr. 88. 52pp.

SAS Institute Inc. 1985. SAS user's guide: statistics. Fifth ed. SAS Inst. Inc., Cary, N.C. 956pp.

Seber, G. A. F. 1982. The estimation of animal abundance. Macmillan Inc., New York, N.Y. 653pp.

———. 1989. Nonlinear regression. John Wiley and Sons, Inc., New York, N.Y. 768pp.

Thiel, R. P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. Am. Midl. Nat. 113:404–407.

Received 31 November 1991.
Accepted 12 May 1993.
Associate Editor: Flather.

***Wildl. Soc. Bull.* 22:68–73, 1994**

IMPACTS OF MINING FACILITIES ON FALL MIGRATION OF MULE DEER

EVELYN H. MERRILL,[1] ***Idaho Department of Fish and Game, Soda Springs, ID 83276***

THOMAS P. HEMKER,[2] ***Idaho Department of Fish and Game, Soda Springs, ID 83276***

KENT P. WOODRUFF,[3] ***Young Adult Conservation Corps, U.S. Fish and Wildlife Service, Soda Springs, ID 83276***

LONN KUCK,[4] ***Idaho Department of Fish and Game, Soda Springs, ID 83276***

Key words: migration, mining impacts, mule deer, *Odocoileus hemionus*

In southeastern Idaho, mule deer (*Odocoileus hemionus*) traditionally exhibit long-range migrations of 15–40 km from high-elevation summer ranges to low-snowfall winter ranges (L. Kuck et al., unpubl. rep.). North of Soda Springs, Idaho, mule deer migration routes lie across some of the world's largest known phosphate reserves. In the early 1970's, increased demand for phosphate for fertilizer stimulated phosphate mining in this area. Mining caused concern for the impacts on mule deer migration.

To assess the impact of phosphate mines and associated facilities on deer migration, we followed movements of radiocollared mule deer and counted tracks of deer in 1978–1982 as they migrated by Conda Partnership's Maybe Canyon Phosphate Mine, 24 km northeast of Soda Springs, and by Monsanto's phosphate processing plant on the northern edge of Soda Springs. Maybe Canyon Mine and the processing plant were established >10 years before the study and no premining data existed on deer movement through the area. Therefore, we could evaluate movements of deer migrating near the mine only in relation to deer that migrated to the north or south of these facilities.

We hypothesized that if mining facilities did not hinder deer movements, radiocollared deer that migrated through Maybe Canyon would not take substantially longer to cross Dry Ridge than other deer crossing to the north or south

[1] Present address: Department of Zoology and Physiology, University of Wyoming, Box 3166, Laramie, WY 82071.

[2] Present address: Idaho Department of Fish and Game, 600 S. Walnut, Boise, ID 83707.

[3] Present address: U.S. Forest Service, P.O. Box 466, Tanasket, WA 98855.

[4] Present address: Idaho Department of Fish and Game, 600 S. Walnut, Boise, ID 83707.