Road Density as a Factor in Habitat Selection by Wolves and Other Carnivores in the Great Lakes Region

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Abstract

*Although wolves (*Canis lupus*) and many other carnivores are habitat generalists, certain landscape features can be used to predict suitable habitat. Thiel examined the concept of road density as an important factor in the persistence of wolf populations in Wisconsin prior to the 1960s and found a relationship with the disappearance of breeding wolf populations when average road density exceeded 0.58 km/km^2. Mladenoff and colleagues examined road density in the early 1990s as a factor in predicting favorable habitat of wolves colonizing Wisconsin between 1980 and 1992, and found that areas with road densities less than 0.45 km/km^2 had greater than a 50% probability of being colonized by wolf packs. Mladenoff and colleagues updated this work in the late 1990s by examining 23 packs colonizing Wisconsin between 1993 and 1997; 78% continued to occupy areas with road densities below 0.45 km/km^2. In a recent examination of radio-collared wolves in Wisconsin, a total of 60% of human-induced mortality occurred at road densities above 0.63 km/km^2. Although road density may become less of a factor as human tolerance changes, and wolf populations increase, it continues to be an important factor in habitat selection by wolves and probably other carnivores.*

Introduction

Gray wolves (*Canis lupus*) are generalists in their use of habitat, and historically have been found in most regions across temperate, boreal, and arctic regions of North America (Mech 1995). Despite this generalist nature of habitat use, landscape features, especially those relating to human impacts, can be used to predict suitable wolf habitat (Corsi et al. 1999; Massolo and Meriggi 1998; Mladenoff et al. 1995). Road density has frequently been used as a landscape feature to predict suitable wolf habitat (Corsi et al. 1999; Frair 1999; Fuller et al. 1992; Jensen et al. 1986; Mech et al. 1988; Mladenoff et al. 1995; Thiel 1985).

Early development of concept of road density

As a graduate student under Aldo Leopold, Thompson (1952) studied wolf food habits in northern Wisconsin in the late 1940s, about 10 years before wolves disappeared from the state. Thompson (1952) warned that development and opening of roads across the logged forests of northern Wisconsin could cause wolves to become extirpated from the state. As predicted, wolves were extirpated from Wisconsin by 1960 (Thiel 1985; Wydeven et al. 1995).

Thiel (1985) examined the disappearance of breeding populations of wolves in Wisconsin from 1926 to 1960. Using State Highway Commission Reports, he determined that breeding wolves disappeared from 10 Wisconsin counties after road densities in these counties exceeded 0.48 to 0.68 km/km^2 (X=0.58 km/km^2). The value of 0.6 km/km^2 has since been used frequently as the threshold level at which wolf populations can be maintained. This level was found to correspond well with areas of occupied wolf range in Minnesota (Fuller et al. 1992; Mech et al. 1988), Michigan, and Ontario (Buss and Almeida 1998; Jensen et al. 1986).

GIS analysis of road density

Through elimination of bounties and protection by the 1973 Endangered Species Act, wolves were provided protection that allowed re-colonization of Wisconsin in the 1970s (Wydeven et al. 1995). Mladenoff et al. (1995) used a geographic information system (GIS) to assess landscape features that contributed to re-colonization of 14 Wisconsin wolf packs from 1980 to 1992. Known pack territories of radio-collared wolves were compared to 14 random non-pack areas scattered across northern Wisconsin. Areas occupied by wolf packs (80% isopleth of harmonic mean) had average road densities of 0.23 km/km^2 (Table 1). Road density was based on paved roads, and improved dirt and gravel roads that appeared as solid lines on U.S. Geological Survey (USGS) 1:100,000 quadrangle maps (Mladenoff et al. 1995). Other important features of wolf pack areas included lack of urban and agricultural areas, extensive forest (X=93%), high percentage wetland (X=29%), mostly public lands and industrial forest land (X=80%), and low human population density. Human density compared closely to road density.

Mladenoff et al. (1995) used road density as the main factor used in a logistical regression model that predicted areas of suitable wolf habitat (Table 2). Areas with < 0.45 km/km^2 were considered highly suitable wolf habitat and were estimated to have > 0.50 probability of being colonized by wolf packs. Minnesota had the most extensive area of highly suitable habitat, and packs expanded outside perceived suitable habitat in some areas (Berg and Benson 1998). Fuller et al. (1992) indicated that in 1989, 88% of wolf pack areas had road densities < 0.70 km/km^2. As predicted, most areas of highly suitable habitat were occupied by wolves in Michigan (James Hammill, personal communication).

Based on the logistical regression model, areas with > 0.60 km road/km^2 have less than a 10% chance of being occupied by wolf packs. Thus, the GIS analysis agrees with the threshold found by Thiel (1985).

Table 1. Average landscape variables for 14 wolf packs, random non-pack areas (n=14) and overall Wisconsin study area (modified from Mladenoff et al. 1995).

Variable	Pack Territories	Non-Pack Areas	Study Area
Land Cover			
Urban Areas	0%	0.2%	1.0%
Agriculture	2%	28%	21%
Total Forest	93%	63%	73%
Upland Forest	68%	51%	59%
Lowland Forest	25%	12%	14%
Marsh or Bog	4%	2%	2%
Water	1%	6%	4%
Land Ownership			
Public Lands	70%	24%	27%
Private Industrial	10%	1%	5%
Other Private Land	21%	75%	66%
Density			
Road Density	0.23 km/km^2	0.74 km/km^2	0.71 km/km^2
Human Density	1.52 km/km^2	5.16 km/km^2	7.43 km/km^2
Deer Density	8.58 km/km^2	8.38 km/km^2	8.22 km/km^2

Roads as a factor in wolf habitat in other studies

A habitat model developed in the Great Lakes region was used as a basis for assessing potential wolf habitat in the northeast U.S. (Harrison and Chapin 1998; Mladenoff and Sickley 1998). Mladenoff and Sickley (1998) estimated 53,500 km^2 of potential habitat in Maine and New Hampshire and 16,020 km^2 in New York. Harrison and Chapin (1998) estimated 48,787 km^2 of potential habitat in Maine and New Hampshire, and 14,618 km^2 in New York. Mladenoff and Sickley (1998) relied mainly on road density values, while Harrison and Chapin used a combination of road density and human population density.

Road density has also been found to be important in predicting wolf habitat in Italy (Corsi et al. 1999; Massolo and Meriggi 1998). The estimated area of highly suitable habitat in Italy (14,200 km^2) (Corsi et al. 1999) was similar to the area estimated in Wisconsin (14,864 km^2) (Mladenoff et al. 1995).

Kohn et al. (2000) conducted a variety of studies examining the relationship of wolves to roads in north-

Table 2. Area of wolf habitat probability classes from a logistical regression model and corresponding road density for portions of three Great Lakes states (from Mladenoff et al. 1995).

Probability Class (P)	Road Density km/km2	Minnesota Area (km2)	Michigan Area (km2)	Wisconsin Area (km2)
>0.50	<0.45	50,200 (72%)	29,348 (70%)	14,864 (25%)
0.10 - 0.49	0.45 - 0.60	10,612 (15%)	7,160 (17%)	7,160 (21%)
<0.10	>0.60	9,328 (13%)	5,476 (13%)	32,100 (54%)

west Wisconsin. Shelley and Anderson (1995) found road densities in northwest Wisconsin wolf territories to average 0.33 km/km^2 for eight pack areas. Although wolves selected areas of low road density, travel areas selected by packs were generally close to trails and forest roads (Gehring 1995). Unger (1999) found that wolves selected den sites in roadless or low road density areas; dens were generally located more than 1 km from improved roads. Frair (1999) found that wolves most frequently used areas away from roads, and average road density in wolf territories was 0.25 km/km^2; road density was found to be the best predictor of suitable wolf habitat.

Recent examinations of road densities in Wisconsin

Mladenoff et al. (1999) examined 23 additional wolf territories that colonized Wisconsin from 1993 to 1997. Five packs (22%) exceeded the 0.45 km/km^2 threshold of road density and one (4%) exceeded the 0.60 km/km^2 threshold. Thirteen packs were radio collared and provided more precise data on area of pack use; two (15%) exceeded the 0.45 km/km^2 threshold and one (7%) exceeded the 0.60 km/km^2 threshold. In general, the road density model continued to be a good predictor of suitable wolf habitat. The one territory that exceeded the 0.60 km/km^2 threshold was in a state wildlife area that had a higher road density (0.71 km/km^2), but greater access control may have nullified the effects of higher road density.

The wolf population in Wisconsin increased from 15 wolves in 1985 to 248 wolves in 2000, totaling 66 packs (Wydeven and Wiedenhoeft 2000). We examined whether packs occurred within areas of suitable habitat as illustrated by Mladenoff et al. (1995, 1999). Of 66 packs in Wisconsin, 53 (80%) were contained in areas mapped as highly suitable wolf habitat ($P > 0.50$), seven (11%) were contained within marginal wolf habitat ($0.50 > P > 0.10$), and six (9%) occurred in areas mapped as poor wolf habitat ($P < 0.10$). Thus, packs continued to occur mainly in areas of low road density. Even those packs occurring in areas that seemed unsuitable (road density > 0.60 km/km^2), were within 10 km of areas of highly suitable habitat.

We recently examined the relationship between wolf mortality and road density. Fifty radio-collared wolves died in Wisconsin between 1979 and 1999. The road densities for 47 wolf mortalities were collected (Figure 1). The average road density for natural mortalities was 0.65 km/km^2 and for human-induced mortalities was 0.78 km/km^2.

Highest natural mortality was at the road density range of 0.63 to 0.84 km/km^2, areas considered poor habitat. We initially had expected natural mortality to be highest in areas of most suitable habitat where wolves most frequently occurred, but higher rates at higher road density make sense. Wolves dying from natural mortality, died mainly from disease or intraspecific strife. Diseased animals lose their fear of humans, and often wander off by themselves into poor habitat. An adult female with severe mange crawled into a garage in 1993. Mortality from intraspecific strife usually occurs near the edge of a territory and often pack boundaries are near roadways. Thus even wolves dying from natural mortality are more likely to be killed closer to roads.

Human-induced mortality peaked at relatively high road densities (Figure 2). Most shootings and vehicle collisions occurred at road densities of 0.84 to 1.14 km/km^2. A total of 60% of human-induced mortality occurred at a road density greater than 0.63 km/km^2.

In general, wolves appear more likely to be killed at higher road densities. Although most wolves spend little time at these higher densities, they are at a much greater risk of being killed in these areas.

Discussion

As human attitudes toward wolves improve and wolf populations continue to increase, road densities may become less of a factor in wolf habitat selection (Mech 1995). In the Great Lakes region, road density provides a useful proxy for human disturbance and risk of mortality. In mountainous terrain where ungulate distribution is very patchy, road density may be a less useful index (Diane Boyd, personal communication), but in the generally homogeneous land-

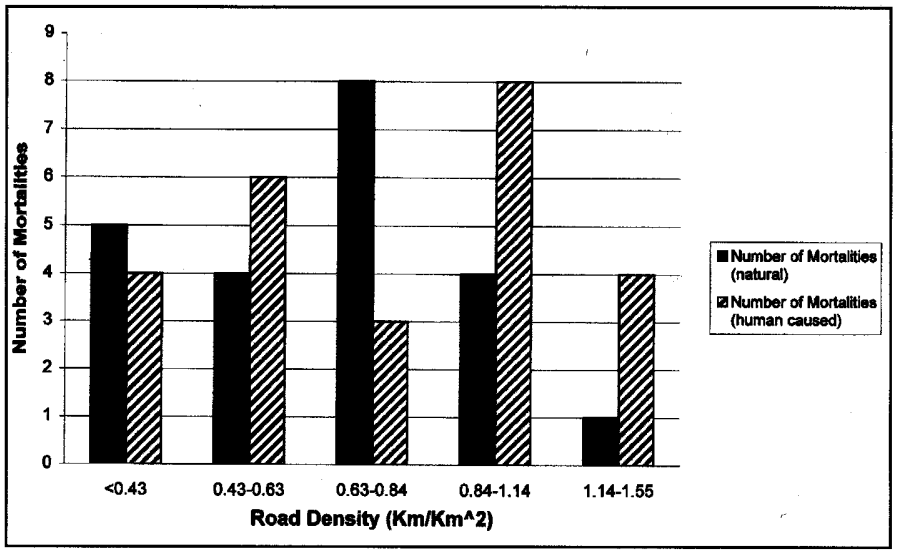

Figure 1. Cause of mortality of radio-collared wolves in Wisconsin 1979 to 1999 in relation to road density.

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Exceptions to the usefulness of road density will continue to occur. Mech (1989) cites an example of areas with road densities of 0.73 km/km^2 supporting wolf packs in Minnesota but having large wilderness reservoirs nearby. Merrill (2000) indicates that a military base in Minnesota with a road density of 1.42 km/km^2 has supported a wolf pack for over six years. Strict control on access, and human activity limited to day light hours, can nullify the effect of road density. In Wisconsin, packs occur in the Crex Meadow Wildlife Area and Necedah National Wildlife Refuge that are classified as low probability of pack occupation, but stricter access control by the management agency reduces the effects of high road densities. Wolves do not have an aversion to roads, and readily travel on roadways if traffic levels are low (Gehring 1995). Wolves learn to avoid roads with high traffic volumes, but readily use gated roads (Thurber et al. 1994). Although wolves seem to cross secondary roads, they vary in willingness to cross busy highways (Frair 1999). Some dispersers do extensive crossings of highways (Kohn et al. 2000; Mech et al 1995; Merrill and Mech 2000).

Road density as a habitat factor has applicability to other carnivores. Roads affect movements and harvest of black bear populations (*Ursus americanus*) (Brody and Pelton 1989). Bobcat (*Lynx rufus*) avoid certain types of roads and seem more attracted to areas with low traffic volume (Lovallo and Anderson 1996). American marten (*Martes americana*) may be impacted by trapping when access is high and avoid crossing large open areas, which could be impacted by road density (Chapin et al. 1998). Other carnivores that require large home ranges may also be affected by road density.

Management and research recommendation

Road density appears to be an important habitat factor for wolves and other carnivores; therefore public lands managed for these species should maintain suitable habitats with low densities of roads. Forested areas managed for wolves should maintain overall road densities of 0.6 km/km^2. Core wolf habitat should be managed at road densities of 0.45 km/km^2. If productive packs exist in areas at much higher road density, a reduction to lower densities would not be necessary, but attempts should be made to avoid increasing road density or changing traffic levels.

On public forest lands, new logging roads should be closed or obliterated after logging operations are completed. Where possible, temporary, winter-only roads should be used, because these roads cause least damage and revert back to vegetated areas. Areas within 100 meters of den sites should be kept undeveloped, and logging roads and trails should stay more than 100 meters from those sites.

The impact of road density is not well known for other carnivores; therefore research on habitat use should include assessments of road density as a habitat value. The impacts of various types of

roads on carnivores should be studied and impacts from all-terrain vehicles (ATVs), snowmobiles, and other off-road vehicles should also be investigated. Roads are important habitat variables for carnivores that need to be more carefully researched.

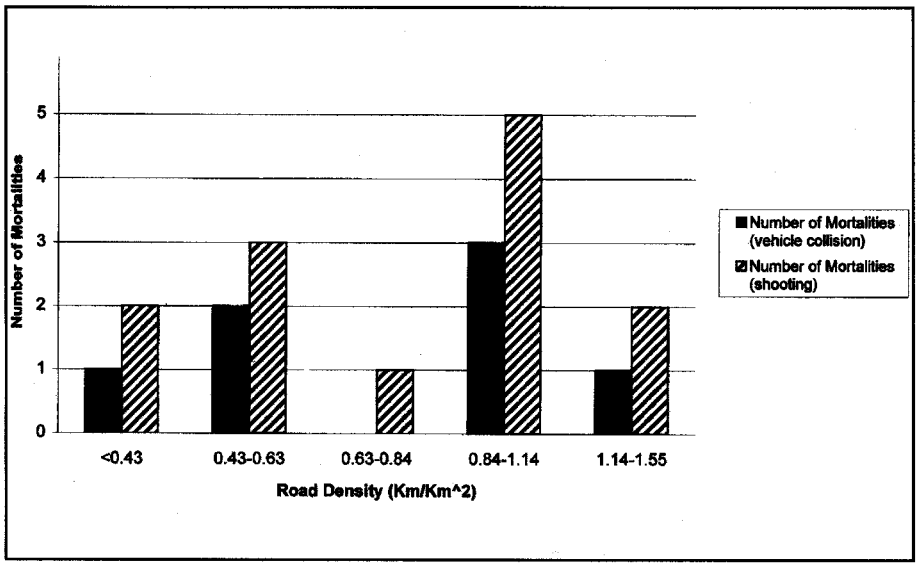

Figure 2. Human causes of mortality of radio-collared wolves in Wisconsin 1979 to 1999 in relation to road density.

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