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EFFECT OF SUBURBAN DEVELOPMENT ON DENSITY OF COYOTES IN NORTHWEST WYOMING

ABSTRACT

*We compared relative densities of coyotes (*Canis latrans*) in a suburban/agricultural area to an adjacent undeveloped area in northwest Wyoming by skiing transects in areas after snowfall and recording number of tracks that crossed each transect. Relative density was the numbers of tracks on each transect divided by the number of hours since the last snowfall. This modification accounted for the increase in track numbers with increased time since last snowfall. The regression equation of study area, surface snow penetration, and night temperature versus relative track density accounted for 74 percent of variation in relative track density. At equal snow penetration and night temperature, the relative density of coyotes was greater in the suburban/agricultural area than the undeveloped area. The presence of remaining open spaces in the suburban/agricultural area combined with high productivity due to both natural and anthropogenic food sources may account for this high relative track density. Coyote densities may increase with development until open space is no longer available to establish and maintain territories.*

Key words: *Canis latrans*, coyote, density, development, suburban, track surveys

INTRODUCTION

The densities of coyotes (*Canis latrans*) in a variety of land-use types have been determined throughout North America (Camenzind 1978, Pyrah 1984, Roy and Dorrance 1985, Windberg 1995, McClure *et al.* 1996, Windberg *et al.* 1997). Average densities ranged from 0.23 coyotes/km^2 in northwestern Wyoming (Camenzind 1978) to 3.7 coyotes/km^2 at the interface of a suburban area and a national monument in the southwestern United States (McClure *et al.* 1996).

Ultimately, local prey abundance regulates coyote density (Knowlton and Gese 1995). High levels of prey abundance in undeveloped areas may lead to higher densities of coyotes (Winberg 1995). However, Windberg (1995) and Winberg *et al.* (1997) observed that higher coyote densities and limited prey availability might eventually limit the population size. Thus, within the carrying capacity of an area, coyote density will increase with an increase in prey abundance until behavioral constraints such as territoriality restrict further growth. Other studies have concluded that prey abundance and lack of exploitation (McClure *et al.* 1996), winter ungulate availability (Weaver 1977), exploitation in late winter (Roy and Dorrance 1985), and mortality (Mills and Knowlton 1991) control population density in a given area. Exploitation is defined as intentional human-caused mortality.

Despite extirpation efforts over the last 150 years, coyotes have significantly expanded their range and numbers

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(Gier 1975, Bekoff 1977, Nowak 1979, Crete and Lemieux 1996). This is due to the extirpation of dominant predators such as the wolf (*Canis lupus*) and resulting lack of competition (Nowak 1978), clearing of land for agricultural uses, and adaptability of coyotes to different habitats and food sources (Bounds 1994). Coyotes have adapted well to new environments created by increasing human populations and resulting urban, suburban, and agricultural development (MacCracken 1982, Shargo 1988, Soule *et al.* 1988, Atkinson and Shackleton 1991, Quinn 1992).

Developed areas tend to support higher population densities of coyotes (Shargo 1988, McClure *et al.* 1996). Human-occupied areas provide increased resource availability in the form of human food wastes and domestic animals (Shargo 1988, McClure *et al.* 1996). The reported reduction in home range size with maintenance of social group size may account for these increases. However, coyotes can be exposed to higher levels of exploitation in areas of development, thus potentially decreasing population densities (Knowlton and Gese 1995).

Our study area in northwestern Wyoming provided an opportunity to measure potential differences in coyote density between an undeveloped area and a suburban/agricultural area. We hypothesized that coyote density would be greater in developed areas due to greater food abundance, maintained group size, and reduced home range size (compressed territories).

STUDY AREA

We conducted our research on two adjacent areas in Jackson Hole, Wyoming (43° 40′N, 110° 43′W, Fig. 1). The suburban/agricultural study area (SAA) consisted of primarily private land devoted to agricultural, commercial, and residential uses (0.03 – 0.99 structures/ha). Progressive building development and subsequent reduction of open space have characterized the SAA for the last two decades. Occasional coyote depredation was reported in the SAA. The undeveloped study area (UNDA) was at the southern end of Grand Teton National Park (0 – 0.08 structures/ha). Grazing by domestic livestock and big game hunting were permitted during limited times in this otherwise protected area.

Much of the valley surface is covered with glacial outwash interrupted by four buttes. Elevation ranges from 2000–2333 m. Open portions of both study areas are dominated by big sagebrush (*Artemesia tridentata*). Both study areas contain stands of lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), Englemann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and quaking aspen (*Populus tremuloides*). Narrowleaf cottonwood (*Populus angustofolium*) and Colorado blue spruce (*Picea pungens*) dominate riparian areas throughout the valley. The SAA vegetation is interspersed within an agricultural/suburban matrix. Mean annual temperatures (1961-1990) ranged from -9°C to 16°C in the SAA and 11°C to 15°C in the UNDA. Precipitation was mostly in the form of snow from October to April, with a mean annual precipitation (1961 –1990) of 42 cm in the SAA and 53 cm in the UNDA (High Plains Climate Center, Lincoln, NE).

METHODS

We used USGS (United States Geological Survey) 1:24,000 topographic maps to randomly locate 10 transects in the SAA and 12 transects in the UNDA. Randomization was done by selecting random UTM coordinates within the study area boundaries to determine the starting point of each transect. However, true randomization was violated because transects could only be located

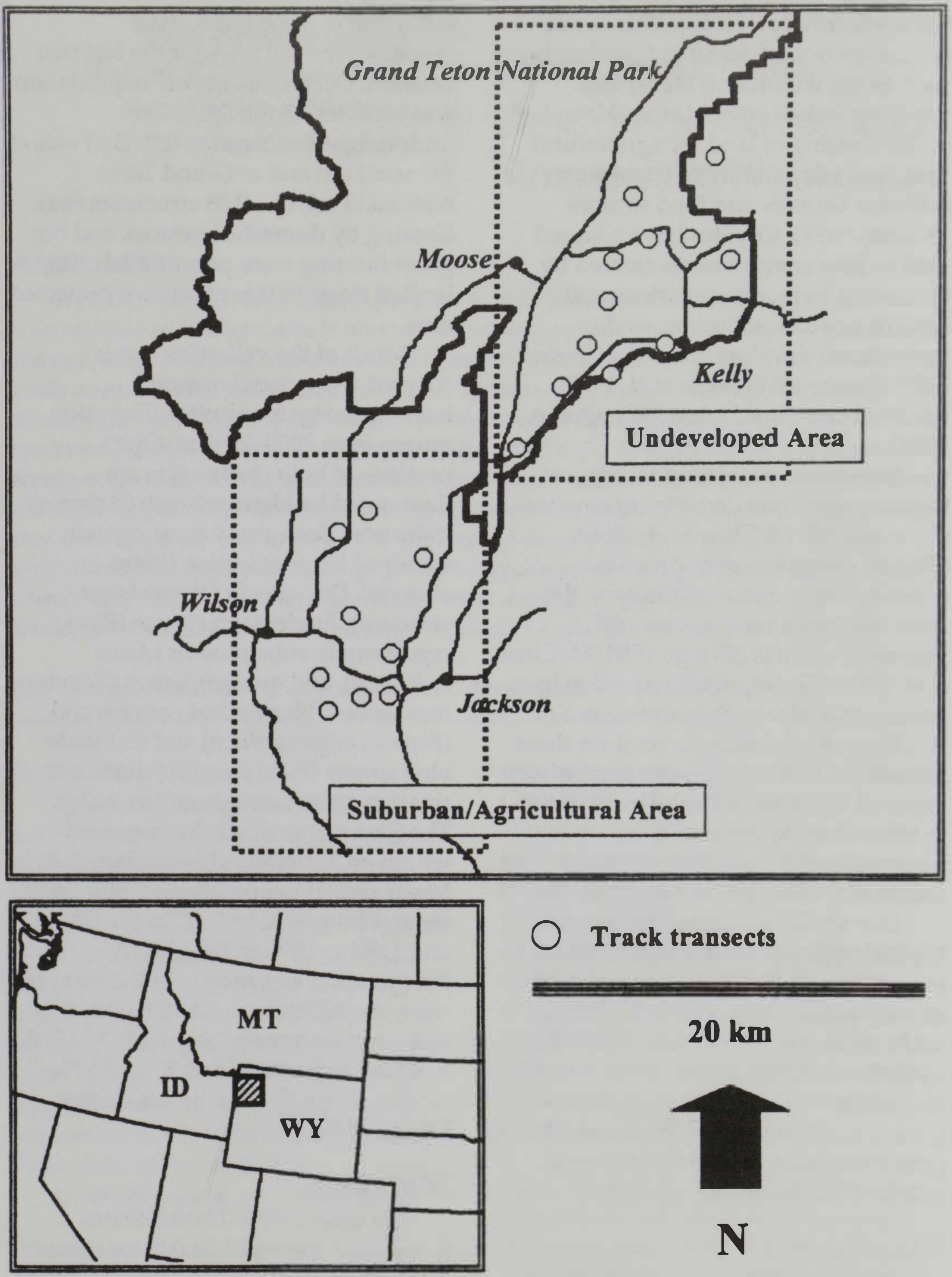

Figure 1. *Location of study areas in Jackson Hole, Wyoming.*

where permission was given for access to private lands in the SAA. Each transect extended 2 km and was aligned on a north-south axis. We skied as many transects as possible after each new snowfall until new tracks were no longer discernable due to snow deterioration. Where obstructions such as trees, rocks, or ponds occurred along the transect, we moved east or west until we could continue north unimpeded. We recorded the number of times that coyote tracks completely crossed a transect, but to avoid double counting tracks we counted only those tracks separated by enough distance on the transect to be discerned from other track crossings. We also recorded time since last snowfall (hours), cloud cover (clear or cloudy), minimum temperature the night before we completed the transect (°C), and percent of each habitat type present for each transect. We classified habitat as riparian, conifer, aspen, or open. Open habitat consisted of sagebrush or grassland covered completely with snow. For each habitat type, we recorded three snow penetration readings as a measure of surface snow density. To measure depth of penetration, a 591-ml plastic bottle (6.5-cm diameter) filled with 300 ml of water was dropped from a 33-cm height. This measurement approximated the snow penetration of a coyote foot in various habitat types (Robison 1999). We then calculated mean penetration for each transect. We determined transect completion order randomly before the start of the study. This ensured that each transect was completed once in each area before a transect was repeated. To avoid independence violations, we used the means of the data from transects that were completed multiple times.

To incorporate the direct relationship between number of tracks and hours since snowfall, we calculated a relative track density value. Relative track density equaled the number of tracks divided by the hours since last snowfall. We compared relative track density between the two areas after accounting for effects of other variables using multiple regression techniques (Minitab Statistical Package, Release 12.21). Mean penetration, night temperature, night cloud cover, area (SAA or UNDA), and percent of habitat categories in each transect were the variables regressed against relative coyote density (coyote tracks/hour).

RESULTS

We completed a total of 27 transects from January to April 1999; 12 transects in the SAA and 15 transects in the UNDA. Because we calculated mean values for repeated transects, total sample size was 22 transects. For the full model (Table 1), only snow penetration ($t = -4.84$, $P = 0.000$) and night temperature ($t = 2.59$, $P = 0.022$) were significant predictors of tracks/hr. Although area was not a significant predictor ($t = 0.127$, $P = 0.128$), we included it in the reduced regression model because our hypothesis

Table 1. *Comparison of coyote track densities between a suburban/agricultural area and an adjacent undeveloped area in Jackson Hole, Wyoming, 1999. Full regression model with all predictor variables. Response is relative density (tracks/hour).*

	Regression Model				*Analysis of Variance*		
Predictor	Coef.	*SD*	*t*	*P*	r^2	F	*P*
Intercept	-0.0500	7.3350	-0.01	0.995	0.79	17.21	0.000[a]
Area	0.1568	0.0960	1.63	0.127			
Penetration	-0.0523	0.0108	-4.84	0.000[a]			
Night Temp	0.0235	0.0091	2.59	0.022[a]			
Cloud Cover	-0.2099	0.1629	-1.29	0.220			
% Open	0.0158	0.0725	0.22	0.831			
% Conifer	0.0146	0.0724	0.20	0.844			
% Aspen	0.0132	0.0729	0.18	0.860			
% Riparian	0.0162	0.0726	0.22	0.827			

[a] $P \leq 0.05$

concerned comparison between areas.

The reduced model predicted tracks/hr with area, penetration, and night temperature (Table 2). All regression residuals were normal (Ryan-Joiner correlation test, $P \geq 0.05$, $r = 0.9606$, $n = 22$, H_0: normality). No heterogeneity of variance was observed in the reduced regression model (modified Levene's test, $P = 0.505$, H_0: homogeneity). A plot of residuals against order confirmed the independence of predictor variables. The reduced regression predicted 74 percent of the variation in tracks/hr using area, penetration, and night temperature. All predictor coefficients were significantly different from zero ($P \leq 0.05$) and the F lack-of-fit test confirmed a linear relationship ($F = 17.21$, $P = 0.000$). No interaction terms were significant in either the full or reduced regression model. For fixed values of night temperature and penetration, the model predicted that the SAA would have 0.179 more tracks/hr than the UNDA.

DISCUSSION

After accounting for snow penetration and temperature, the data supported our prediction of increased coyote densities in developed areas. Although snow penetration and night temperature would not affect the actual density of coyotes, these factors affected the number of tracks recorded crossing a transect. The negative coefficient from the penetration variable indicated that as snow penetration increased, detected coyote tracks decreased (if area and temperature were held constant). Similarly, the positive coefficient for the temperature variable suggested that increased temperatures resulted in increased number of coyote tracks (if the other predictors were constant). Thus, relative track comparisons were feasible only after accounting for the decreased travel of coyotes in deep snow or cold temperatures.

In the few studies that investigated coyote density in suburban areas, densities of coyotes appeared to be higher when compared to rural or undeveloped areas. Higher food availability from both natural and anthropogenic sources was cited as the primary cause of this increased density (Shargo 1988, Quinn 1991, McClure *et al.* 1996). Coyote populations in these studies resided in suburban or urban areas, but all had access to adjacent undeveloped areas. In Washington, density of coyotes appeared to be greater in the northern suburbs compared to the central urban area. The northern suburbs, with some high-density housing developments, were adjacent to undeveloped land. However, the data were based on coyote observations by survey participants,

Table 2. *Comparison of coyote track densities between a suburban/agricultural area and an adjacent undeveloped area in Jackson Hole, Wyoming, 1999. Reduced regression model with area, snow penetration (cm), and night temperature (°C). Response is relative density (tracks/hour).*

	Regression Model				*Analysis of Variance*		
Predictor	Coef.	SD		*P*	r^2	F	*P*
Intercept	1.0640	0.1634	6.51	0.000[a]	0.74	17.21	0.000[a]
Area	0.1787	0.0747	2.39	0.028[a]			
Penetration	-0.0437	0.0081	-5.41	0.000[a]			
Night Temp	0.0249	0.0082	3.02	0.007[a]			

[a] $P \leq 0.05$

which may be biased (Quinn 1991). An analysis of coyote scat collected in the SAA revealed a higher percent occurrence of voles (*Microtus* spp.) than the coyote scat collected in the UNDA. Although human-related foods were rarely found in the scat from coyotes in the SAA, scat was collected only in the agricultural areas adjacent to suburban developments (Wigglesworth 2000). Previous studies found higher prey abundance in suburban areas (Shargo 1988, McClure *et al.* 1995). Data collected by Wigglesworth (2000) suggested that there are more voles in the SAA than the UNDA. Plentiful food sources near suburban areas combined with habitat constricted by development may cause increased densities of coyotes in these areas.

Densities of coyotes can be measured with the knowledge of the percent of resident coyotes (belonging to social groups), mean group size, and mean territory size (Knowlton and Gese 1995). Wigglesworth (2000) reported no statistical differences in coyote group size between the SAA and UNDA despite smaller reported home ranges in the SAA (McClennen 2000). Given a consistent percentage of resident coyotes in both study areas, the prey base must be sufficient to support higher densities of coyotes in the suburban/agricultural areas.

Our data supported the hypothesis that densities of coyotes were greatest in areas of development with adjacent refuge areas. These suburban/agricultural areas may provide open areas for pup-rearing as well as additional food sources such as domestic pets, pet food, garbage, and livestock (Shargo 1988, McClure *et al.* 1996, Wigglesworth 2000). Although the food sources may be plentiful in developed agricultural areas, less open area can eventually reduce the habitat where coyotes can defend territory and raise pups.

Due to the lack of permission for access to some private land in the SAA, transects there were not representative of the entire area. We did not include areas of dense subdivisions and small residential plots (approximately 30%) in the surveys. Decreased coyote densities may have been observed in these areas. Thus, increased relative densities of coyotes in the SAA may be only reflective of the remaining habitable land in this matrix of development and not the overall SAA. Densities might not be different between the entire areas.

As agricultural land is converted to development in a suburban/agricultural landscape, we predict that coyote densities will ultimately decrease despite high levels of anthropogenic food sources cited in other studies (Shargo 1988, McClure *et al.* 1996). We believe decreased densities will result from increased potential for mortality from trapping, shooting, or vehicle collisions coupled with lower reproductive success as coyote social structure collapses. Although mortality of some coyotes has been shown to increase pup production in a territorial group (Hodges 1990, Windberg 1995), eventual lack of space for pup-rearing and reduced chances for mated pairs to come together may decrease reproductive success.

Coyotes are highly adaptable animals that survive well in developed areas. Their behavioral plasticity allows them to thrive in areas of suburban development given sufficient refuge to breed and protect young. Although coyotes will exist in urban areas, their densities will be controlled by behavioral and demographic factors that will limit any increases in density caused by increased food sources.

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