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IMPACT OF HUMAN ACTIVITY ON DAILY MOVEMENT PATTERNS OF WOLVES, *CANIS LUPUS*, IN THE BIAŁOWIEŻA FOREST, POLAND

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Abstract: It is important for the management of recolonizing wolves (*Canis lupus*) in Europe to understand the wolves' reactions to human activity. The aim of this study was to find out whether human activity affects the daily movement patterns of wolves. During 3 winters (1996-1999), we radiotracked 6 female wolves and monitored the pattern of human activity in the Białowieża National Park and the commercial part of the Białowieża Forest, eastern Poland. The 24-hour movement patterns of wolves living in the commercial part of the Białowieża Forest with high human activity were negatively correlated with the activity pattern of humans. The movement patterns of wolves from the national park—where human activity was low—were not correlated with the human activity. However, there was no difference in movements between wolves from the national park and those from the commercial forest during the time of maximum human presence from 0800 hours to 1500 hours. We concluded that human activity affected the wolves' movement pattern, but that the influence was not strong enough to reduce the animals' daytime movements.

Key words: activity, disturbance, human, movements, Poland, wolf

As a result of their protection in many European countries, wolves (*Canis lupus*) are expanding their range into Central Europe. It is critical for management of this species to determine where these animals will be able to settle (Schröder and Promberger 1993). Human activity is an important factor because it can influence the activity patterns and distribution of wolves (Thurber et al. 1994, Vilà et al. 1995, Ciucci et al. 1997). Vilà et al. (1995) and Ciucci et al. (1997) found that wolves in agricultural landscapes reduced their movements during the daytime to avoid humans. In forested areas, the movements of wolves and the activity of humans should also be negatively correlated. Wolves confronted by high human activity should move less during the day than animals that live in parts of the forest where there is low human activity. We studied the impact of human activity on the wolves of the Białowieża Forest (eastern Poland) where the forest is divided into areas of high and low human activity. This paper will present the effects of human activity on the daily movement patterns of wolves in the Białowieża Forest.

STUDY AREA

The Białowieża Forest is on the border between Poland and Belarus (52°30'–53°N, 23°30'–24°15'E). The Polish part of the Białowieża Forest (580 km²) comprises the Białowieża National Park (100 km²) and a commercial forest (480 km²). Human density is about 10 inhabitants per km² in the Białowieża Forest and 70 inhabitants per km² on the regional scale (Białystok administration district). The home range of 1 wolf pack covers the national park; 3 other packs live in the commercial forest. In winter, few people visit the Białowieża National Park, so the impact of humans on wolves at that time can be considered negligible. The core area of the national park pack is in the strictly protected part of the Białowieża National Park (Okarma et al. 1998) where there is no motorized traffic. The road density in the commercial forest is about 2 km/km². During winter, human activity in the commercial forest consists mainly of forestry operations. In the Polish part of the Białowieża Forest, wolves have been protected since 1989, however, they are hunted in the Belarussian part (Jędrzejewska et al. 1996). For a detailed description of the study area see Jędrzejewska and Jędrzejewski (1998).

METHODS

During 3 winters from 1996 to 1999, we radiotracked 5 female and 2 male wolves living in the commercial forest and 3 females of the wolf pack living in the national park. Here, we only used the winter movements of 6 adult female wolves to avoid differences that could be a result of age, sex, or season. We followed wolves by continuous telemetry over 1-week periods and noted the wolf's location every 15 minutes by ground triangulation. We calculated distances

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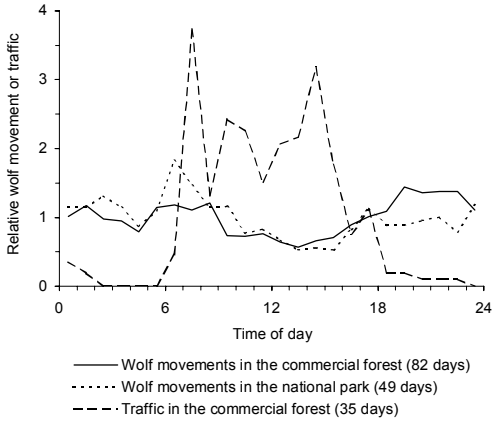

Fig. 1. Relative wolf movement patterns (mean hourly travel distances expressed as the proportion of the daily mean, 1 = daily mean) and relative traffic pattern (mean hourly numbers of vehicles expressed as the proportion of the daily mean, 1 = daily mean) in the Białowieża Forest during the winters of 1996 to 1999.

traveled as the straight-line distance between 2 consecutive locations. Therefore, we obtained mean movements for 96 intervals of 15 minutes per day as a measure of the wolves' movement patterns. Musiani et al. (1998) showed that radiolocations taken at 15-minute intervals accurately represent the actual distance traveled by wolves in the Białowieża Forest.

We used 12,630 intervals of 15 minutes for our analysis, which corresponded to about 131 full days of radiotracking. To compensate for individual differences in daily travel distances, we used relative movements to compare the daily movement patterns of each wolf. We calculated the relative movements of each wolf by dividing the mean movement of each 15-minute interval (from 0000 hr to 0015 hr, from 0015 hr to 0030 hr, etc.) by the mean distance the given wolf had traveled during all 15-minute intervals. This procedure gave mean relative movements for 96 intervals/day. The value 1 represented the expected mean movement over a full 24 hours, so a <1 for movements indicated that the wolf was moving less than the daily mean. We compared the movement patterns of wolves with Student's *t*-test for matched pairs.

During winter 1998–1999, we used a magnetic traffic counter card (NC-30, Nu-Metrics, Uniontown, Pennsylvania, USA) to record the number of passing vehicles on dirt roads in the commercial forest in 1-hour intervals for periods of 1 week. The results of the traffic count are based on 35 days of continuous counting of vehicles on 5 dirt roads in the forest. To compare the patterns of traffic with those of wolf movement, we calculated relative traffic by dividing the mean number of vehicles for each hour by the daily mean.

RESULTS

The movement patterns of wolves from the commercial forest and the national park were similar (Fig. 1). A negative correlation existed between the relative hourly movement of wolves from the commercial forest and the relative hourly traffic in the commercial forest ($r = –0.514$, $P = 0.01$). To ensure that the correlation was based on a dependence and was not random, we also compared the movements of wolves from the national park with the traffic in the commercial forest, which should not be correlated since results were obtained from separate areas. Indeed, no correlation occurred between the movement pattern of wolves from the national park and the traffic pattern in the commercial forest ($r = –0.309$, $P = 0.142$).

When comparing individual movement patterns of the 6 wolves with the traffic pattern in the commercial forest (Table 1), we found negative correlations for 2 wolves (Bura, Siwa) in the commercial forest. The

Table 1. Mean relative movements of 6 female wolves in the daytime (0800-1500 hr) compared to the daytime movement of the wolf, Bura, and correlation of wolf movements with the traffic in the commercial forest during the winters of 1996 to 1999, Białowieża Forest (NP: national park, CF: commercial forest).

	Relative movements of wolves		Movements of wolves compared to those of Bura		Correlation of wolf movements with traffic	
Wolf	$\bar{x}$	SD	*t**	*P*	*r*	*P*
Ruda (NP)	0.88	0.45	4.10	<0.001	-0.042	0.847
Chytra (NP)	0.88	0.53	3.76	0.001	-0.079	0.714
Chyża (NP)	0.74	0.42	2.56	0.016	-0.252	0.235
Sroga (CF)	0.88	0.24	5.95	<0.001	-0.041	0.848
Siwa (CF)	0.75	0.39	3.58	0.001	-0.447	0.029
Bura (CF)	0.49	0.24	–	–	-0.697	<0.001

* Degrees of freedom = 27

individual movement patterns of wolves (Ruda, Chytra, Chyża) from the national park were not correlated with traffic. Interestingly, the third wolf (Sroga) from the commercial forest was the least correlated with traffic.

No difference occurred (t = 1.15, 27 df, P = 0.262) between the mean relative movements for 15-minute intervals of wolves from the national park and those from the commercial forest during the time of maximum human presence from 0800 hours to 1500 hours (Fig. 1). When we compared the daytime movements of wolves, 1 wolf (Bura) from the commercial forest moved less during the day than all other wolves (all $P \leq 0.016$, Table 1). No significant differences occurred in relative movement during the daytime among the other wolves.

DISCUSSION

In the Białowieża Forest, wolves reacted differently to human activity. The 2 wolves whose movements correlated the most and the least with traffic were both from the commercial forest. The road density in the home range core area of the wolf least influenced by humans was not lower than the road density in areas used by other wolves. The impact of human activity did not appear strong enough to reduce the daytime movements of wolves in the commercial forest compared to movements of wolves in the national park. The daytime drop in movements seems to be affected by other factors than human activity. Spanish and Italian wolves studied in agricultural mountainous regions with human densities of 20–30 inhabitants per km² hardly move in the daytime (Vilà et al. 1995, Ciucci et al. 1997). In Minnesota and Alaska in the United States, in areas where human densities are probably lower, wolves moved for 28% (Mech 1992) and 50% (Peterson et al. 1984) of the daylight hours, respectively. Although they lived closed to people, wolves in the Białowieża Forest did not reduce their movements during the day, probably because the area is well forested. In Italy and Spain, less than 40% of the area in wolves' home ranges was forested (Vilà et al. 1995, Ciucci et al. 1997). Wolves in the Białowieża Forest left the forest only at night (J. Theuerkauf et al., unpublished data). We conclude that, in the Białowieża Forest, wolves did not reduce their movements in the daytime because of human activity. However, the daylight prevented them from leaving the forest cover.

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