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Human impact on wolf activity in the Bieszczady Mountains, SE Poland

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Human activity is sometimes seen as the reason for nocturnal activity of wolves (*Canis lupus*). We tested this assumption in the Bieszczady Mountains (southeastern Poland), a region with a human density of 44 inhabitants km^{-2}, and where wolves were hunted until recently. The radio tracked wolves of three packs moved throughout the day with one major peak around dawn. Wolves avoided the area around main public roads more at night (up to a distance of 1.5 km) than in the day (up to 0.5 km). Wolves avoided a 0.5-km area around secondary public roads and paved forest roads both at night and in the day but did not avoid the surroundings of settlements. As compared with other studies, wolves in this study were the least nocturnal although human density was the highest. We conclude that human activity is unlikely to be the reason for nocturnal activity in wolves.

Introduction

Activity patterns of wolves (*Canis lupus*) differ considerably among study areas: wolves were mainly nocturnal in Italy (Ciucci *et al*. 1997), Spain (Vilà *et al*. 1995), Croatia (Kusak *et al*. 2005) and Minnesota (Chavez & Gese 2006), active in the day and at night in Canada (Kolenosky & Johnston 1967) and Alaska (Fancy & Ballard 1995), and had bimodal activity patterns in northeastern Poland (Theuerkauf *et al*. 2003a). Vilà *et al*. (1995), Ciucci *et al*. (1997) and Kusak *et al*. (2005) related the mainly nocturnal activity patterns of wolves in southern

Europe to human activity in the day, whereas wolves in northeastern Poland avoided humans spatio-temporally (Theuerkauf *et al.* 2003b). Human density in the different study areas may have been the reason for these contradictory findings as there were about 20–30 inhabitants km^{-2} in southern Europe (Vilà *et al.* 1995, Ciucci *et al.* 1997, Kusak *et al.* 2005) against only 7 inhabitants km^{-2} in northeastern Poland (Theuerkauf *et al.* 2003b). Although in northeastern Poland wolves did not become nocturnal because of human activity, a possible influence of human activity on daily patterns of wolf activity can not be ruled out. Furthermore, as Johnson (1999, 2002) argued, it is necessary to repeat entire studies in different areas at different times before being able to generalise conclusions. It is important to know the potential influence of humans on wolf activity as a change to nocturnal activity might influence the hunting success of wolves. Wolves kill their prey most often at dawn and dusk (Theuerkauf *et al.* 2003a), so a shift to nocturnal behaviour might reduce their predation success. It is therefore essential for the conservation of wolves in regions were they co-exist with humans to know whether human activity can cause nocturnal behaviour of wolves. The aim of this study was to test whether wolves avoided humans temporally or spatially in the Bieszczady Mountains (southeastern Poland), where wolves were hunted until 1998 and where the human density was higher than in any other wolf activity study. The relatively high human density and human hunting pressure on wolves made the Bieszczady Mountains an ideal location to test the influence of humans on wolf activity patterns.

Study area and methods

The Bieszczady Mountains are located in the easternmost part of the Polish Carpathians. Our study area covered about 1000 km^2 with altitudes ranging between 300 and 900 m a.s.l. (49°19´–49°50´N, 22°15´–22°45´E). Mean annual temperature was 5.5°C and annual precipitation was 800–1200 mm. Mean human density in the region was 44 inhabitants km^{-2} (area of 2000 km) and 36 inhabitants km^{-2} in the minimum convex polygon of all wolf locations (data of 2004 from the local administrations). The density of paved roads was 0.64 km km^{-2} and 62% of the area was forested. Forest mainly consisted of beech (*Fagus sylvatica*), fir (*Abies alba*), spruce (*Picea abies*) and grey alder (*Alnus incana*). The degree of forest fragmentation (calculated following Jaeger 2000) was 74%.

During 24-hour radio tracking sessions in 2002–2006 (usually one session per month for each wolf), we radio tracked wolves of three packs: a breeding female (n = 44 days in 2002–2005) until we found her under a hunting tower shot by a poacher, a breeding male (n = 29 days since 2003), and a female of unknown breeding status (n = 5 days in 2005–2006) until we found her dead of unknown reasons. We located the tracked wolves every 15 min using ground triangulation from a mean distance of 1.25 km on average (SD = 0.97), which is a distance at which trackers have no influence on wolf behaviour (Theuerkauf & Jędrzejewski 2002). We drew bearings on maps of 1:50 000 with a metric co-ordinate system, and wrote locations to the nearest 25 m. We calculated the distance travelled by wolves as the straight-line distance between two consecutive locations. Based on a few occasions when we could check radio locations and with the knowledge of our method's error (Theuerkauf & Jędrzejewski 2002), we estimated that our locations were accurate to about 250 m. We used the daily pattern of distance travelled per hour to represent the daily activity patterns of wolves because we assumed that a potential human disturbance would most influence the extent of movements. Locations during 24-hour radio tracking are usually not independent of each other. However, we decided not to reduce our radio tracking data in order to obtain temporally independent locations, as this would have resulted in a lower accuracy of results (*see* Rooney *et al.* 1998, de Solla *et al.* 1999). Instead, we eliminated autocorrelation among consecutive radio locations by calculating one value of the distance travelled for each wolf or day (Theuerkauf *et al.* 2003a). Accordingly, we used the variation among wolves or days and not among radio locations for statistical testing.

We used a magnetic counter card (NC-30, Nu-Metrics, Uniontown, Pennsylvania) placed

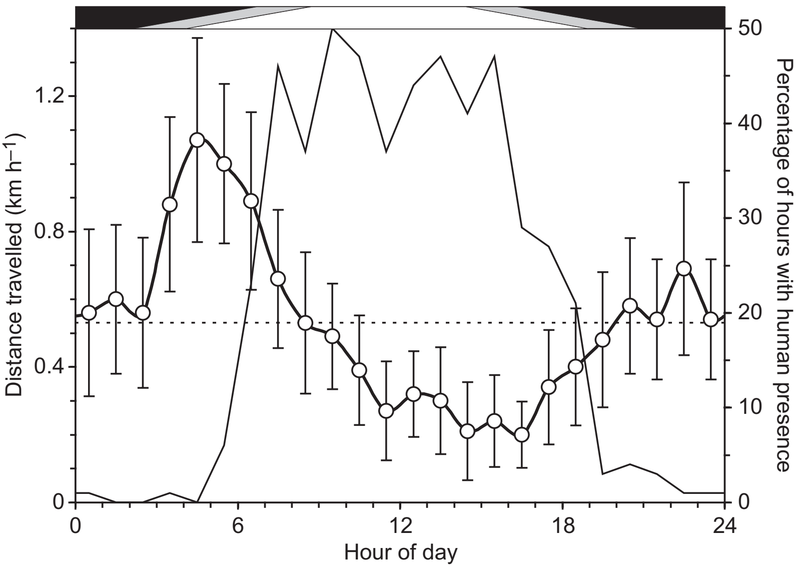

Fig. 1. Daily patterns of mean distance travelled per hour (bold continuous line with open circles and 95% confidence intervals, dotted horizontal line for daily mean) by three wolves (*n* = 78 days) and mean percentage of hours with human presence (continuous line) on forest roads (*n* = 10 points monitored for periods of one week) in the Bieszczady Mountains in 2002–2006. The bar indicates length and variation of night (black), dawn (sunrise ± 1 hour) and dusk (sunset ± 1 hour) (grey), and day (white).

in forest roads at ten different counting points to document the daily pattern of human activity. The counter card recorded numbers of passing vehicles per hour for continuous periods of one week. We defined each counting hour as an hour with or without human presence, according to whether or not a vehicle had passed the observation point during a given hour.

We created 1000 random points with a geographic information system inside the home range of each wolf (100% minimum convex polygons). We calculated selection by comparing radio locations of a wolf with the locations of random points inside the home range of the given wolf. We used Ivlev's electivity index (Jacobs 1974) to indicate selection:

$$\text{Selection index} = (p_w - p_r)(p_w + p_r - 2p_w p_r)^{-1}$$

where p_w is the proportion of wolf locations in a given category, and p_r is the proportion of random points in a given category. Selection indices can vary from +1 (total selection) to –1 (total avoidance). We categorised wolf or random point locations in 500-m-wide classes according to the distance to roads and settlements. We calculated selection indices first for each wolf, and then mean selection indices and 95% confidence intervals (CI) for the variation among wolves. We considered that wolves selected (avoided) a given category if the lower (upper) limit of the 95% CI was greater (smaller) than zero. We classified roads as primary public roads (paved roads with more than 1000 vehicles day^{-1}), secondary public roads (paved roads with 100–1000 vehicles day^{-1}), and forest roads (paved roads less than 100 vehicles day^{-1}). We used Ivlev's electivity index also to calculate nocturnality of wolves by comparing the distance wolves travelled (or percentage of time wolves were active) at night (defined as the period from sunset to sunrise) with the distance wolves travelled (or percentage of time wolves were active) in the day (+1 for totally nocturnal and –1 for totally diurnal). We estimated nocturnality indices also for other studies based on data given in these publications. As not all studies provided data on movements, we used the percentage of time wolves were active to compare different study areas.

Results

Wolves moved at any time of the day with a major peak of the distance travelled per hour around dawn, a trough in the afternoon and a small peak in the early night (Fig. 1). Nocturnality indices for the distance travelled ranged between 0.53 and –0.44, the mean was 0.15 ± 0.59 (95% CI, *n* = 3 wolves). Nocturnality indices for the time wolves were active varied from 0.05 to 0.22, the mean was 0.10 ± 0.11. Most

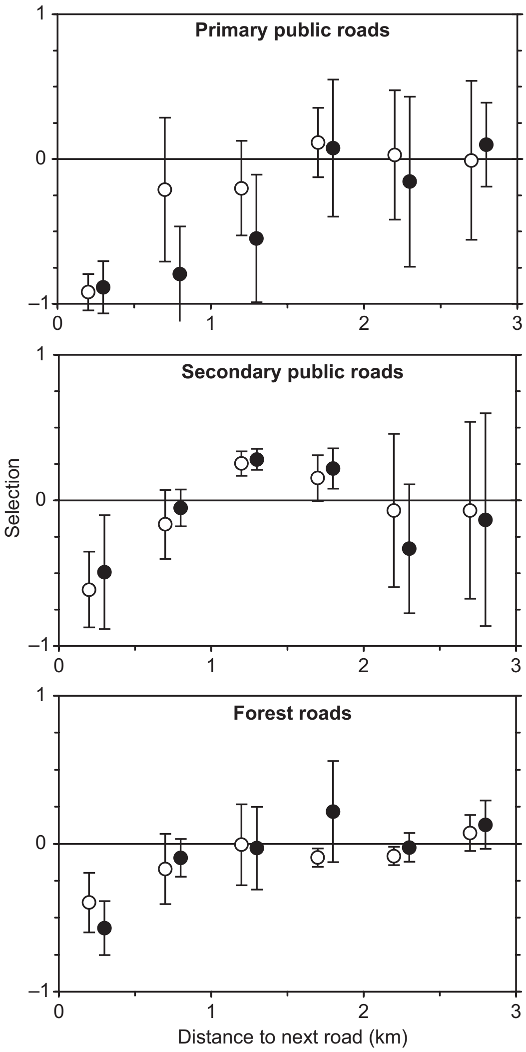

Fig. 2. Daytime (white circles) and nighttime (black circles) selection* (with 95% confidence intervals, *n* = 3 wolves) in relation to the distance to roads in the Bieszczady Mountains in 2002–2006. * Calculated using Ivlev's electivity index (Jacobs 1974) comparing radio locations of a wolf with the locations of random points inside the home range of the given wolf (+1 for total selection and –1 for total avoidance).

humans were present in the forest from 06:00 to 19:00 but distances travelled by wolves were only lower than the daily mean from 11:00 to 18:00.

Wolves avoided the area up to 1.5 km from primary public roads at night and up to 0.5 km in the day (Fig. 2). Both at night and in the day wolves avoided a 0.5-km area around secondary public roads and forest roads. Whether day or night, wolves did not avoid the surroundings of settlements (all 95% CI included the selection index of "0").

Nocturnality of wolves in the five studies that provided data on wolf activity and human density did not depend on human density (Table 1). If nocturnality increased with human density, the correlation should be positive, but the correlation in the five studies was not significant and even negative ($r_S = -0.300$, $P = 0.624$).

Discussion

Twenty-four-hour radio tracking is labour-intensive, so most studies of wolf activity patterns are based on a few individuals: 1 wolf in Italy (Ciucci *et al.* 1997), 2 wolves in Ontario (Kolenosky & Johnston 1967), 2 wolves of 2 packs in Croatia (Kusak *et al.* 2005), 3 wolves of 3 packs in southeastern Poland (this study), 4 wolves of 4 packs in Spain (Vilà *et al.* 1995), 7 wolves of 3 packs in Minnesota (Chavez & Gese 2006), 11 wolves of 4 packs in northeastern Poland (Theuerkauf *et al.* 2003a), and 23 wolves of 11 packs in Alaska (Fancy & Ballard 1995). Although the sample size of this study lays in the average, we do not expect that a larger number of wolves would have changed the general results. In northeastern Poland, individual activity patterns did not vary greatly even among wolves of different packs (Theuerkauf *et al.* 2003a). We therefore consider that the activity patterns of the three studied wolves are representative for the study area.

Animals adapt their activity patterns according to their environment, which enables them to exploit the available resources with efficiency (Daan & Aschoff 1982). From an evolutionary perspective, it would be a disadvantage for wolves to adjust their temporal activity patterns to those of humans if the risk of being killed is low. By reducing their daytime activity, wolves may fail to effectively exploit the available food resources. Activity patterns of wolves should therefore be geared towards optimising their foraging strategy while minimizing the risk of being killed by humans. In case of persecution by man, this may include a shift to a more nocturnal behaviour: coyotes moved less in the day during a period of persecution by man compared to animals that had not been persecuted for more than eight years (Kitchen *et al*. 2000). However, Ciucci *et al*. (1997) and Vilà *et al*. (1995) did not report such a heavy persecution in Italy and Spain. Wolves of the Bieszczady Mountains on the other hand were heavily persecuted until the late 1960s, regularly hunted until 1998, and are occasionally still being poached (as at least one of the radio tracked wolves as well as four other wolves, R. Gula unpubl.). Furthermore, these animals live in an area where the density of paved roads is 0.64 km km^{-2}, which Thiel (1985), Jensen *et al*. (1986), Mech *et al*. (1988), Mech (1989), and Potvin *et al*. (2005) considered as the threshold for wolf occurrence. The wolves we tracked, however, were still more diurnal than the wolves radio tracked elsewhere in Europe (Table 1), although human density in the Bieszczady Mountains was higher than in all other study areas. In northeastern Poland, wolves were also less nocturnal than in southern Europe, although humans caused many wolf deaths (Jędrzejewska *et al*. 1996). We therefore think that it is unlikely that human activity is the reason for nocturnal wolf activity patterns. Other factors such as prey activity and temperature are more likely to influence wolf activity patterns (Theuerkauf *et al*. 2003a).

Similar as in Alaska (Thurber *et al*. 1994), northeastern Poland (Theuerkauf *et al*. 2003b) and Finland (Kaartinen *et al*. 2005), wolves avoided the surrounding of roads in our study. However, this avoidance was less pronounced than in northeastern Poland, where human density was much lower. These observations might appear on the first view contradictory as a higher human activity usually causes higher avoidance in wolves: in northeastern Poland, wolves avoided large villages more than small ones and heavily used roads more than less used ones (Theuerkauf *et al*. 2003b). However, on a larger scale this relationship seems to be reciprocal. We assume that wolves living in close contact to humans avoid people less than wolves in regions of low human density, because they are more habituated to the contact to people.

Human disturbance is important if it affects survival and causes a population to decline (Gill *et al*. 2001). Applying this definition, a disturbance to wolves would be mainly restricted to direct persecution such as killing or taking pups from the dens, and if human activity caused breeding females to permanently abandon their young. In fact, wolves usually avoid the neighbourhood of human settlements and roads for their den and rendezvous sites (Theuerkauf *et al*. 2003c, Capitani *et al*. 2006) but once they use a den site, they can tolerate human activity in the near (Thiel *et al*. 1998, Theuerkauf *et al*. 2003c). The ability to habituate to humans may enable wolves to live in regions with any human density as long as they have enough to eat and are not extirpated. In Minnesota, wolves persisted in a military training area with a road density of 1.4 km km^{-2} (Merrill 2000). The occurrence of wolves in India with human density of up to 600 inhabitants km^{-2}, where they were even observed to kill children (Jhala & Sharma 1997, Rajpuro-

Table 1. Nocturnality indices of wolves in relation to human density (inhabitants km^{-2}) in five European study areas.

Region	Active at night (%)	Active in the day (%)	Nocturnality index[1)]	Human density	Authors
Italy	75	17	0.87	26	Ciucci *et al*. 1997[2)]
Spain	37	13	0.59	20–30	Vilà *et al*. 1995[2)]
Croatia	53	35	0.35	30[3)]	Kusak *et al*. 2005
NE Poland	49	41	0.16	7	Theuerkauf *et al*. 2003a[2)]
SE Poland	34	30	0.10	44	this study

[1)] calculated using Ivlev's electivity index (Jacobs 1974) considering the percentages of time wolves were active at night and in the day (+1 for totally nocturnal and –1 for totally diurnal).
[2)] night [day] activity estimated as: (10 night [day] activity + 1 dawn activity + 1 dusk activity)12^{-1}.
[3)] J. Kusak pers. comm.

hit 1999), also supports this assumption. We conclude that human activity is unlikely to be the reason for nocturnal activity in wolves and that human activity should not generally be considered as a disturbance as wolves can habituate to the presence of humans.

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