Effect of Weekend Road Traffic on the Use of Space by Raptors

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Abstract: *The traffic load near large cities may show dramatic cyclical changes induced by weekend tourism, and this could induce cyclical changes in the activity patterns of wildlife. We studied a 19-km-long section of a road that crossed a high-use raptor area near a large city in Spain. We observed 18 raptor species along this segment of the road, including some threatened species, such as the Spanish Imperial Eagle (*Aquila adalberti*). The number of cars increased dramatically on Saturdays and Sundays, so we assessed the effect of varying traffic loads on raptor behavior by recording all birds of prey as close or distant to the road during working days and weekend days. On weekends, the occurrence of Spanish Imperial Eagles and vultures decreased near the road. The occurrence of other species did not change between working days and weekend days. The activity decrease on weekends by Imperial Eagles and other large raptors suggests that there are weekly cycles in raptor activity. Weekly cycles in wildlife caused by human activity are a source of concern in conservation biology.*

Key Words: noise, raptors, roads, Spanish Imperial Eagle, weekly cycles

Efecto del Tráfico de Fin de Semana sobre el Uso de Espacio por Rapaces

Resumen: *El tráfico en carreteras cercanas a las grandes urbes muestra incrementos cíclicos debidos al turismo de fin de semana, lo que podría inducir ciclos semanales en los patrones de actividad de las aves de presa. Cerca de una gran ciudad estudiamos una sección de 19 Km en una carretera que cruza una de las mejores áreas para las rapaces de toda España. Observamos 18 especies de rapaces en el área de estudio, incluyendo varias en peligro de extinción, como el águila imperial ibérica (*Aquila adalberti*), una de las rapaces en mayor peligro de extinción del mundo. Registramos los movimientos de todas las rapaces observadas en una malla de cuadrículas UTM clasificadas como cercanas o lejanas a la carretera para estudiar si las observaciones de rapaces eran diferentes en días de semana y en fines de semana, dado que hubo un incremento muy marcado en la intensidad de tráfico los fines de semana. Comprobamos que el águila imperial y los buitres utilizaban con menor frecuencia las inmediaciones de la carretera durante los fines de semana, restringiendo su actividad a las áreas remotas y poco transitadas. Los cambios cíclicos en actividad humana durante los fines de semana podrían por tanto inducir también cambios cíclicos en los patrones de actividad*

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Paper submitted November 13, 2002; revised manuscript accepted September 12, 2003.

de especies amenazadas como el águila imperial. Los ciclos semanales de actividad en la fauna tienen mucho interés para la biología de la conservación, ya que son consecuencia de la actividad humana.

Palabras Clave: Águila Imperial Ibérica, carreteras, ciclos semanales, ruido, rapaces

Introduction

The environmental effects of roads on wildlife have often been reported (e.g., Van der Zande et al. 1980; Forman & Alexander 1998; Trombulak & Frissell 2000). Roads may have no effect on wildlife or may benefit some species, particularly those typical of habitat edges and open areas or associated with human activities (Clark & Karr 1979; Ferris 1979; Laursen 1981). Negative effects of roads on wildlife may be caused by increased pollution, road casualties, habitat loss or alteration, and noise (Illner 1992; Forman & Alexander 1998; Spellerberg 2002).

Above certain threshold levels, car traffic appears to diminish habitat quality for breeding birds over distances of 100–1500 m away from main roads (Reijnen et al. 1995). Roads with heavy and light traffic loads have been compared (Foppen & Reijnen 1994; Reijnen & Foppen 1994; Reijnen et al. 1996; Reijnen et al. 1997), but it is unknown whether varying traffic levels on the same road segment affect the behavior of birds and to what extent such disturbance may affect large birds of prey.

A possible cyclic effect of traffic load on raptor behavior may be estimated by contrasting behavioral observations of raptor activity whenever there is a significant change in traffic load between working days and weekends. The increase in human-induced pollutants caused by a higher volume of traffic and industrial activities during working days may induce an increase in the frequency of storms on weekend days (Cerveny & Balling 1998). Such weekly cycles associated with human activities (Gordon 1994; Cerveny & Balling 1998) may also affect the use of space by wildlife species. We investigated whether the differences between weekend and weekday traffic volume affect raptors' use of space.

Roads facilitate increased use of an area by pedestrians (e.g., Aradis & Carpaneto 2001). In otherwise remote areas, raptor activity may change in response to the presence of people rather than traffic. We avoided this confounding factor by studying an area where most vehicles pass through and people do not get out of their cars.

Methods

Study Area

The study area was in the southwest section of the Madrid Province of central Spain (Fig. 1). The climate is Mediterranean, with hot, dry summers and cool, wet winters. The study area is hilly with small ridges and several vantage points, particularly good for accurate location of raptors. The habitat is primarily Mediterranean forest and shrub land (evergreen oaks [*Quercus ilex* L.], lavender [*Lavandula stoechas* L.], broom [*Retama sphaerocarpa* L. Boiss], and cistus [*Cistus ladanifer* L.]), with scattered fallows, cultures, and pastures for livestock.

The Spanish Imperial Eagle (*Aquila adalberti*) is one of the most endangered birds of prey in the world (Meyburg 1989; Tucker & Heath 1994; González 1996) and is the most endangered species observed in our study area. Twenty-four pairs of this species were located in Madrid Province in 2001 (González & Oria 2001), and at least five breeding pairs used our study area for hunting or breeding (Palacín 1996). Several large private properties dedicated to big-game hunting, usually guarded and not accessible to the public, occur in the study area and are used by raptors for breeding. There are also public timber lands (old pine plantations), which are important for breeding raptors. The rest of the area is communal grounds for small game hunting, lands where only people living in the nearby villages may hunt. Rabbit (*Oryctolagus cuniculus*) is the most abundant game species. The western portion of the study area (Fig. 1) includes a European special protected area (SPA) for birds, designed by the Spanish Wildlife Administration (Viada 1998).

We studied a road that has heavier traffic on weekend days than on working days. The road, M-501, is commonly used on working days by people driving between some small villages and Madrid, a city of more than 3 million people. Traffic increases on the road dramatically on weekends, when many people living in the city use the road to access recreational areas situated about 30–50 km from the city and beyond the study area.

The M-501 is two-way, single-lane, and approximately 8 m wide, with verges of variable width (1–5 m) that were not maintained except for mowing during summer. The habitat near the road is similar to the larger landscape bisected by the road. We studied a 19-km-long section along the road, beginning 22 km from the city center of Madrid (Fig. 1). Although the study area was close to the city, up to 18 raptor species have been observed hunting or foraging in the area crossed by the road section (Bautista et al. 2000). The number of Imperial Eagle pairs and nest locations were known because they are monitored yearly by the national wildlife services.

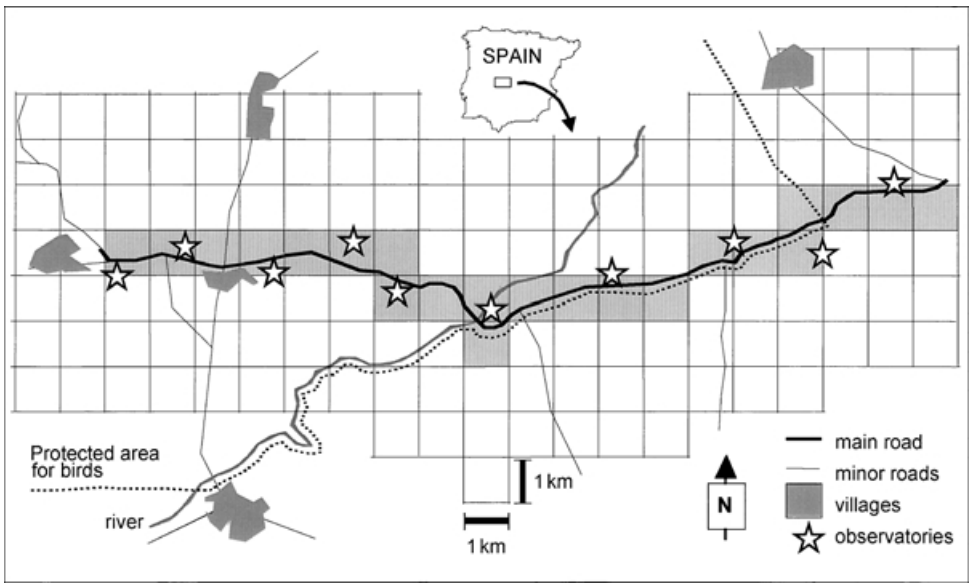

Figure 1. Map of the Iberian Peninsula showing the location of the study area and the universal transverse mercator grid squares where raptor observations were recorded as near the road (shaded squares) or distant from the road (empty squares) in 10 observation sites (stars). The road crosses the edge of a protected area for birds (dashed line).

Sampling

To gather data on space use by raptors around the road, we made standardized observations of raptors from 10 observation sites, regularly distributed along the 19-km section of the road and located up to 300 m from the road verges (Fig. 1; Madders 2000). Previous studies in this area indicate that it is possible to detect large raptors flying at a distance of as much as 4 km (Bautista et al. 2001; Viñuela & Bautista 2001). Thus, we covered a maximum observation area of 150 km^2.

Data were gathered for 84 days between November 1999 and June 2000. We visited the study area 2–3 days in most weeks, one or two working days (Monday to Friday) and a weekend day (Saturday or Sunday). In some weeks we sampled working days or weekend days only. Each observation site was sampled at least 8 days during the study. Each surveillance period started 2–3 hours after dawn and lasted until 2–3 hours after noon. Results from previous studies in this area show that this is the optimal observation period, covering the daily period of maximum raptor flying activity and optimal observation conditions (Viñuela & Bautista 2001). Daily surveillance periods lasted 3–4 hours in midwinter to 5–6 hours in summer.

At each observation site, we scanned for birds in all directions, alternating 15-minute surveys with binoculars and 15-minute surveys with telescopes. We rested 5 minutes between surveys. When we located a raptor other than a Spanish Imperial Eagle, we tracked its course for up to 3 minutes, at which time we looked for a new raptor. We were able to track the course of up to five raptors during a 15-minute survey. Only Spanish Imperial Eagles were tracked longer than 3 minutes and until they landed or were lost behind a landmark. Most surveys lasted 15 minutes because we observed one to five raptors. Some surveys lasted longer than 15 minutes because a Spanish Imperial Eagle was observed and it was in the air longer than that period.

For each raptor, we recorded the initial and final time of the observation and whether it flew over the universal transverse mercator (UTM) grid squares crossed by the road (shaded area in Fig. 1). The flight lines of each observed raptor were plotted on 1:25,000 maps.

For 58 days we counted the number of vehicles crossing in both directions within a five-minute period. We calculated a mean traffic load for each day based on these 5-minute samples. Each day we took 5.7 ± 1.0 samples.

Data Analysis

For statistical analyses we reduced the sample to the 65 days with optimum field conditions (absence of rain and strong wind). Eighteen out of these 65 days were weekend days. We classified observations conservatively into two categories: close, when birds flew over UTM grid squares that spanned the road, and distant, when birds did not fly over gird squares that spanned the road. We used only observations with reliable distance estimations. Distance estimation was reliable when birds crossed between two or more landmarks (e.g., hills, towers).

We analyzed the distribution of the number of observations with a nonparametric test (Fisher exact probability test; Siegel & Castellan 1988) in which factors were type of day (weekend vs. working day) and distance to the road (close or far). We used a Student t test to check for differences in traffic load between working days and weekend days.

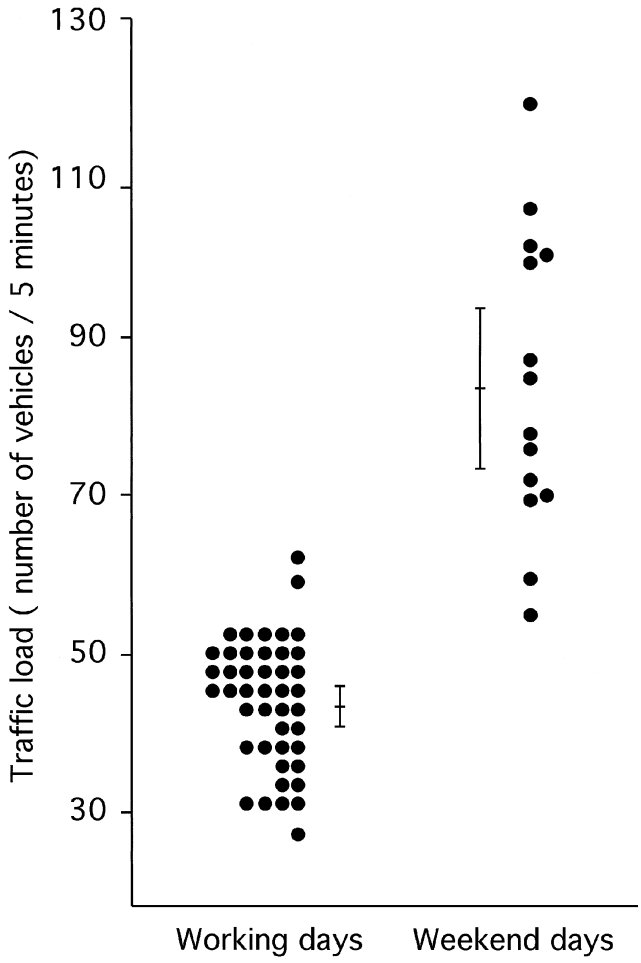

Figure 2. Traffic load on working days and weekend days on a 19-km section of road that crossed a high-use raptor area near a large city in Spain. The mean number of vehicles counted in periods of 5 minutes is shown as a dot for each day. The means (± 95% confidence interval) for working days and weekend days are shown as horizontal and vertical lines.

Results

Traffic load was nearly two times greater on weekend days than on working days ($t_{56} = 11.5, p < 0.01$; Fig. 2). Given a conservative assumption of road inactivity with little or no traffic during 14 hours per day, we calculated that at least 10,000 and 5,000 motor vehicles traversed the road on weekend days and working days, respectively. Traffic load was not correlated with the distance of the observation site from the city (on weekends, $r = 0.14$, $p = 0.59$; on working days, $r = -0.09$, $p = 0.53$); therefore, traffic load did not change along the road segment.

Eighteen raptor species were recorded during 431 hours of observation. Nine species were observed on working days and weekends in both distance categories (close and distant; Fig. 3). Most of these nine species were detected closer to the road than distant from the road. However, there was a significant effect of distance to the road and day type on the number of European Black Vultures (*Aegypius monachus*), Griffon Vultures (*Gyps fulvus*) (for each species, $p < 0.01$, Fisher's exact test), and Spanish Imperial Eagles observed ($p = 0.037$, Fisher's exact test). These species were observed more frequently near the road during working days than on weekend days. There was no significant effect of distance to the road or day type on the number of the other six species of raptors.

After 431 hours of observation, four resident pairs and up to six immature Spanish Imperial Eagles were detected in 43 observations in the study area. Most observations (28) were of birds flying in pairs. On two occasions four eagles were observed at the same time during territorial fights. The other 13 observations were of solitary eagles. Overall, Spanish Imperial Eagles were seen more often on the west side of the study area, where all nesting sites were located (Fig. 4). They were observed up to 5 km from the road, but also hunting or perching near the road (100 m). They restricted their activity to a smaller area on weekend days, keeping to their breeding sites and away from the road.

Discussion

Three of nine raptor species—Spanish Imperial Eagles, European Black Vultures, and Griffon Vultures—were seen less often near the road when the traffic load was greater on weekend days. We did not identify the exact cause of this change in space use, but traffic noise emanating from vehicles may disturb wildlife (Hill 1990; Reijnen et al. 1995; Reijnen et al. 1997; Hofer & East 1998; Brotons & Herrando 2001), and traffic load is a good estimator of noise levels (Reijnen et al. 1997). There is little evidence, however, that noise disturbs large birds of prey (but see Andersen et al. 1989; Trimper et al. 1998). Results of studies on the impact of roads on wildlife suggest that traffic noise is an important disturbance factor, although visual disturbance and prey concealment on the road borders are other plausible factors.

Besides a greater traffic load on weekends, the negative effect of the road on the movement patterns of Spanish Imperial Eagles and vultures may have been shaped to some extent by an increase in human presence in the countryside. We controlled for this effect by selecting a study area occupied by private closed lands where tourism was not allowed, although in the western part of the study area people were occasionally seen walking and running. Quite surprisingly, the Spanish Imperial Eagles were observed in higher numbers in the western part of the study area. Therefore, we suggest that human disturbance on weekend days may not be the main cause of the behavioral change seen in eagles and vultures.

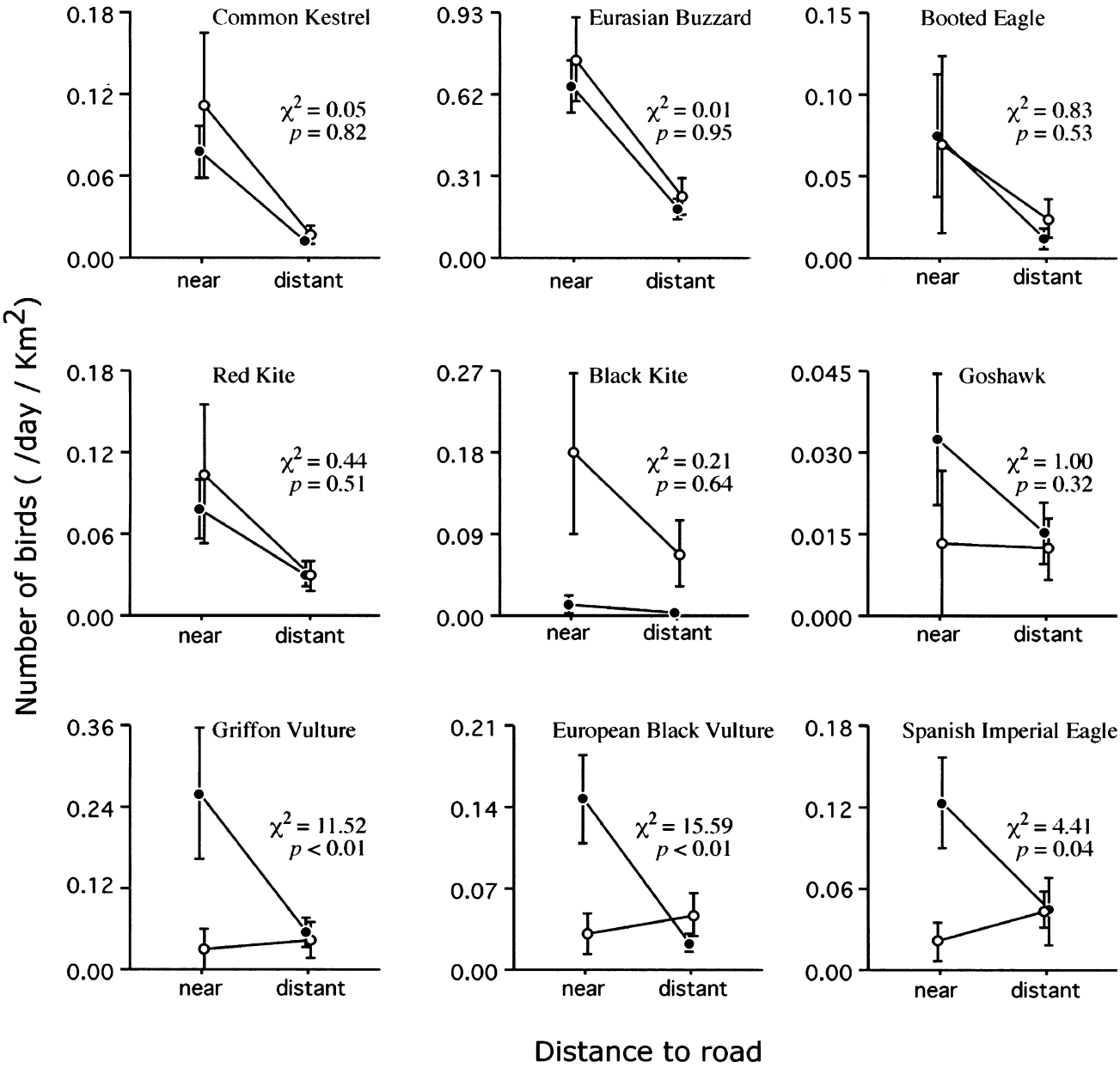

Figure 3. Mean (±SE) number of raptors per day and per square kilometer near and distant from a road on working days (Monday to Friday, black dots) and weekend days (Saturday to Sunday, white dots).

Another human activity in the study area was hunting. People hunted rabbits, the main prey of Spanish Imperial Eagles. However, data from working days and weekend days included a balanced sample of days with and without hunting activity in both types of days; thus, this factor was reasonably controlled for. Nonetheless, we cannot completely rule out human hunting and pedestrian activities as significant contributors to the differences in raptor observations between working days and weekend days.

The increase in traffic load on weekends did not change the number of observations for six other raptor species: Common Kestrel (*Falco tinnunculus*), Eurasian Buzzard (*Buteo buteo*), Booted Eagle (*Hieraaetus pennatus*), Red Kite (*Milvus milvus*), Black Kite (*Milvus migrans*), and Goshawk (*Accipiter gentiles*). A similar result was reported in France: traffic volume on motorways did not affect buzzards and kestrels (Meunier et al. 2000), perhaps because traffic was a routine disturbance over time (Preston & Beane 1996). In general, these six species were detected closer to the road regardless of the day of the week. Kestrels, buzzards, kites, and Booted Eagles are more tolerant of human activities than other raptors (e.g., Spanish Imperial Eagles), and they can be commonly seen on hunting flights near or even over villages. Thus, it is not surprising that weekend traffic did not change their activity near the road.

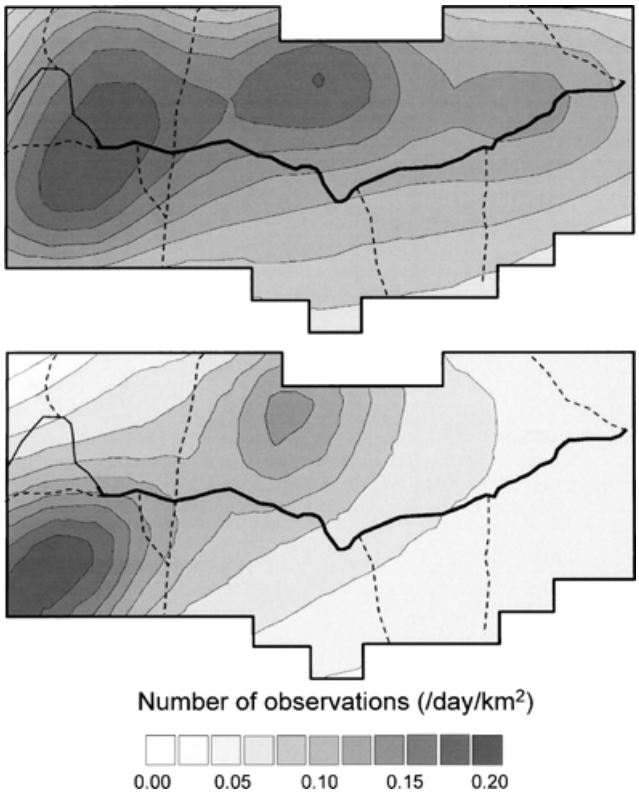

Figure 4. Mean number of Spanish Imperial Eagles in the study area on working days (top) and weekend days (bottom). Main road is the central bold line. Secondary roads are dashed lines. Mean number of daily observations in each universal transverse mercator grid square was calculated with the number of eagles that crossed each square kilometer in each day. The means were smoothed to draw this figure.

Why did we observe all birds more often closer than distant to the road on working days? First, and perhaps primarily, observations increased simply because birds are more easily detected when they are closer to observers (Buckland et al. 1993). This sampling effect did not alter the value of our study because we investigated the interaction between day type and distance to the road in the number of observations and not in the overall number of observations.

Second, prey may have been more abundant near the road, either in the form of road kill or live prey. It is well documented that traffic load affects rates of road kill (Forman & Alexander 1998; Sherwood et al. 2002). Black Kites commonly eat road kill (Cramp & Simmons 1980) and were seen more often near the road on weekends, but this trend was not statistically significant. The greater traffic load on weekend days may produce an increased animal mortality with respect to the rest of the week, providing kites with more food on weekends. Furthermore, kites are attracted by human activities that may signal a possible source of food. Lastly, kites may have benefited from the reduction of activity near the road of other antagonistic raptor species on weekend days.

In addition to sources of road kill, roadsides can be important hunting grounds for diurnal raptors in agricultural landscapes (Meunier et al. 2000). Some prey may be particularly abundant in the microhabitat of road ditches; thus, raptors may select road ditches as hunting areas. This has been observed for kestrels, and buzzards may also select road borders for hunting voles and shrews (Meunier et al. 1999).

Rabbits are the primary prey of Spanish Imperial Eagles in the study area (Bautista et al. 2001). Some of the highest rabbit densities in Spain occur in our study area (Blanco & Villafuerte 1993; Villafuerte et al. 1998). Although rabbit populations in Spain have declined dramatically over the last decade as a result of a new disease (Villafuerte & Viñuela 1999; Viñuela & Villafuerte 2004), they were particularly common along the edges of the road in our study area, probably because of reduced hunting pressure by humans, good microhabitat, and availability of optimal soil in which to build warrens (Bautista et al. 2001). Thus, we suggest the decrease of overall rabbit densities outside the road borders in the study area (Bautista et al. 2001) as a second explanation for why eagles looked for rabbits near the road edges. Besides noise, high traffic loads also produce short-term seismic activity (Sherwood et al. 2002), which may have reduced the activity of rabbits near the road borders on weekend days.

Traffic load could be a significant factor reducing the activity range of Spanish Imperial Eagles. Although our results are only a circumstantial demonstration of a detrimental effect of traffic on the activity of Spanish Imperial Eagles and other large raptors (Martínez et al. 2003), our results suggest that there were weekly cycles in raptor activity. Weekly cycles in wildlife that are the consequence of human activity must be a source of concern in conservation biology.

Acknowledgments

We greatly appreciate the thoughtfulness and editorial advice of T. Donovan, E. Main, and J. C. Bednarz. Two anonymous referees also improved the manuscript with their support and positive comments. L. M. Carrascal explained spatial statistics to us and helped us use the software. M. Romero provided M.B.M. with her personal vehicle for fieldwork. This study was partially funded by a contract of the Museo Nacional de Ciencias Naturales—Consejo Superior de Invesigaciones Científicas with the Comunidad de Madrid.

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