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Seasonality and habitat types affect roadkill of neotropical birds

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ABSTRACT

Roadkills are amongst the most significant biodiversity impacts, although little is known about the factors which influence the roadkill of neotropical birds. Hence, the objective was to evaluate differences in roadkill richness and rates for neotropical birds according to the seasons of the year and habitat types associated with roads. The data was collected along two federal highways, in southern Brazil. We identified 57 roadkilled species, for a mean roadkill rate of 0.06 ind./km/day (Min. = 0.009; Max. = 0.47). Our results demonstrate that richness and roadkill rates change according to seasonality and habitat types. Roadkills were concentrated in rice fields and wetlands, intensifying both in richness and rates during the summer and autumn. Nearby areas have similar roadkill rates, independent of habitat types. This probably occurs due to the movement of several species seeking food and shelter. Juvenile dispersion, harvest and grain transportation periods, as well as flight and foraging behaviors over road lanes seem to be related to the increasing roadkill occurrences and richness regarding more abundant species. However, given the elevated number of occasionally roadkilled species (more than 70% with $N < 5$), we believe that highway surface and traffic act as physical barriers which inhibit the movement of many species which either present occasional roadkills or none at all.

1. Introduction

Wildlife roadkills represent one of the main highway-related impacts on biodiversity. Some authors recognize that roadkills affect a greater number of individuals when compared to other factors such as hunting (Forman and Alexander, 1998) and predation (Bujoczek et al., 2011).

The first studies on bird roadkills were in temperate climates (Channing, 1958; Dunforth and Errington, 1964; Finnis, 1960; Sargent and Forbes, 1973). Concerning neotropical environments, the pioneers in this field are Brazil (Bencke and Bencke, 1999; Novelli et al., 1988) and India (Chhangani, 2004; Dhindsa et al., 1988), which mainly provides lists of roadkill species, without elaborating or testing hypotheses for bird roadkill patterns.

Factors such as landscape and seasonality determine the distribution of resources in the environment, influencing the composition, abundance, and mobility of species, and consequently the seasonal and spatial patterns of roadkills (Erritzoe et al., 2003; Keller and Yahner, 2007; Miller and Cale, 2000; Trombulak and Frissell, 2000). In temperate regions, roadkills generally occur in clusters along the road and are concentrated in specific seasons (Clevenger et al., 2003; Erritzoe et al., 2003; Smith and Dodd, 2003). In subtropical regions, clustered bird roadkills were observed in forest areas with higher bird roadkill rates during the spring (Coelho et al., 2008; Taylor and Goldingay, 2004).

Due to the existing knowledge gap concerning bird roadkill patterns in neotropical regions, our objective was to evaluate differences in bird roadkill richness and rates according to the seasons of the year and habitat types associated with roads. The following hypotheses were tested for this purpose: (1) the seasonality results in different bird roadkill richness and rates throughout the year; (2) the habitat type is related to bird roadkill richness and rates along the road.

2. Material and methods

The monitoring was performed along 117 km in two Brazilian federal highways: 33 km within BR 392 and 84 km within BR 471. These roads connect the cities of Pelotas (31°48′19″S and 52°19′39″W) and Santa Vitória do Palmar (32°40′35″S and 52°35′42″W) (Fig. 1). The latter includes 17 km within a protected federal area (Taim Ecological Station – ESEC Taim) which receives an average of 1100 vehicles per day. The climate is subtropical, with a mean annual temperature of 17 °C and annual precipitation

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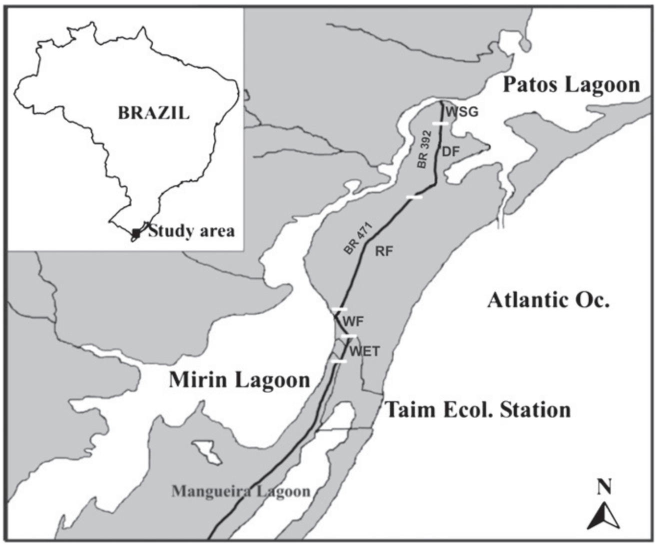

Fig. 1. Study area between the cities of Pelotas and Santa Vitória do Palmar in southern Brazil, showing the location of habitat types. White lines mark the beginning and end of each habitat type. WSG: wetlands of the São Gonçalo Channel floodplain; WET: wetlands of ESEC Taim; DF: shoreline dry field; WF: shoreline wet field; RF: rice field.

between 1200 and 1500 mm (Klein, 1998). Permanent and seasonal wetlands, open fields, coastal dunes, rice fields and scrub thickets with pioneer vegetation occur along the studied roads (Gomes et al., 1987; Waechter and Jarenkow, 1998).

We made 51 monitoring trips between January 2002 and February 2003, and 44 monitoring trips between September 2004 and December 2005. The road was traveled from Pelotas to ESEC Taim by car, at an average speed of 50 km h^{-1}, and at least two observers were present, avoiding weekends and rainy days. The sampling processes always started at 7 am and were concluded between 12 am and 3 pm. The road only has one lane on each direction, which allowed the sampling of roadkilled birds along its entire width, including shoulders. We recorded the geographical location and collection date for each animal.

2.1. Bird roadkill and seasonality

For seasonality, we only used data from 2002 and 2005 because all the months were monitored in those years. We grouped the months according to the seasons: summer (January, February, and March), autumn (April, May, and June), winter (July, August, and September), and spring (October, November, and December).

In order to evaluate richness, all specimens with unidentified species or genus were excluded and the seasonal variation in the number of species was tested through rarefaction, using Ecosim software (Gotelli and Entsminger, 2007). The roadkill rate was calculated using all data, including unidentified individuals, and represents the number of roadkilled individuals per kilometer per day. In order to evaluate roadkill rate variations (response variable) between the seasons of the year, the monitoring processes were used as replicas and tested through Kruskal–Wallis (Dunn a posteriori).

2.2. Bird roadkill and habitat type

We divided the highways into segments according to the habitat type in the surrounding landscape, which was identified on a satellite image at a scale of 1:50,000. We classified the landscape in five habitat types: wetlands of the São Gonçalo Channel floodplain (WSG), which is 12.26 km long and includes wetlands with extensive aquatic macrophytes stands (Bencke et al., 2006); wetlands of ESEC Taim (WET), 16.57 km, composed by extensive areas of permanently flooded wetlands and a wide variety of lacustrine and marsh habitats (Gomes et al., 1987); shoreline dry field (DF), 29.7 km, has a matrix of fields with brief flood pulses during the year, wetland areas, and the influence of permanently dry fields and disturbed grazing and urbanized areas (Batista et al., 2007); shoreline wet field (WF), 6.17 km, has a matrix of fields that are flooded for longer periods, and is directly influenced by the ESEC Taim; and rice field (RF), 47.55 km long.

The richness was compared through rarefaction between each habitat type, and roadkill rates through Kruskal–Wallis (Dunn a posteriori), using the same procedure which has been described for seasonal analysis.

Table 1
Observed richness (S_{Obs}), estimated richness (±SD) (S_{Est}) and total number of roadkilled birds (N), including unidentified individuals, during the seasons of years 2002 and 2005 on studied Brazilian federal highways.

	S_{Obs}	S_{Est}	N
Summer	39	39 ± 0	265
Autumn	34	36 ± 2	220
Winter	13	16 ± 4	73
Spring	16	17 ± 4	113
Total	55	–	671

3. Results

We found 708 roadkilled individuals, for a mean roadkill rate of 0.06 ind./km/day (Min. = 0.009; Max. = 0.47). Among the roadkilled individuals, 455 (64%) could be identified at a genus or species level. We identified 57 species, including one locally endangered, the Rusty-collared Seedeater *Sporophila collaris* ($N = 2$). Over 70% of species were considered occasional, possessing less than 1% of abundance ($N < 5$) for the total numbers of identified individuals.

Six species represented 66.7% of roadkill occurrences. Chestnut-capped Blackbird *Chrysomus ruficapillus* presented the most roadkill occurrences (27.3%), followed by Guira Cuckoo *Guira guira* (11.2%), Rufous Hornero *Furnarius rufus* (9.7%), Spotted Nothura *Nothura maculosa* (6.6%), Great Kiskadee *Pitangus sulphuratus* (6.2%) and House Sparrow *Passer domesticus* (5.7%).

3.1. Bird roadkill and seasonality

The observed and estimated seasonal richness demonstrated that the number of roadkilled species during the summer and autumn is more than twice the number of roadkills during the winter and spring (Table 1). The summer also presented a roadkill rate over twice as high as the winter and spring rates ($p < 0.01$) (Fig. 2). Although the autumn rate is as elevated as the summer rate (Fig. 2), these seasons also presented different values ($p = 0.009$). The remaining seasons presented similar roadkill rates ($p > 0.08$).

The group of roadkilled birds during the autumn was dominated by *C. ruficapillus*, which represented 55% of the roadkilled animals, followed by *G. guira*, representing 7% of roadkills in this season. The remaining seasons were dominated by *G. guira*, *F. rufus*, *C. ruficapillus* and *P. sulphuratus*.

3.2. Bird roadkill and habitat type

The WSG and RF areas presented the greatest roadkill richness (estimated and observed) and roadkill rates, besides a greater

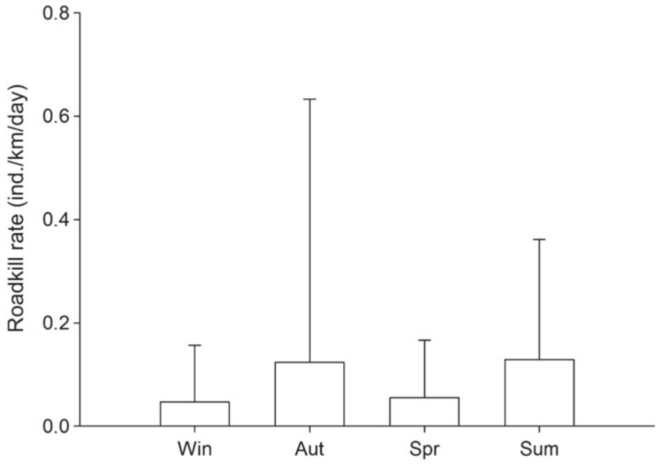

Fig. 2. Roadkill rate of birds in the winter (Win), autumn (Aut), spring (Spr) and summer (Sum) of years 2002 and 2005 on studied Brazilian federal highways.

number of exclusive species (Table 2; Fig. 3). The estimated richness values demonstrated that RF has the greatest number of species, WF has the lowest richness and the remaining areas present intermediate and similar values (Table 2).

Concerning roadkill rate variations, nearby areas have similar roadkill rates independent of habitat types, generating two large segments. The first segment corresponds to stretches passing through the RF, WSG and DF, and the second corresponds to WF and WET (Figs. 1 and 3). This distinction is possible because roadkill rates in these habitat types are different between the two segments ($p < 0.05$); however, roadkill rates in each habitat type within each segment are similar to each other ($p > 0.05$).

In the stretch which includes DF, two species dominated the group of roadkilled birds: *F. rufus* (21.3%) and *G. guira* (20%). The latter was also dominant throughout the WF stretch (22.2%). *C. ruficapillus* was dominant along RF (37.5%), WSG (22.4%) and WET (20%).

4. Discussion

Laurance et al. (2009) raise the possibility of wildlife from tropical regions being more vulnerable to road impacts, when compared to temperate regions, due to their greater diversity and different ecological demands. Regarding roadkills, it is difficult to measure if they are capable of causing significant population declines, due to the lack of knowledge on populations and communities surrounding the road. However it is known that roadkills randomly eliminate healthy individuals of the population, which can result in worse decline situations for these populations, which are already fragmented by roads (Bujoczek et al., 2011). In fact, roadkill data must be cautiously interpreted, considering the differences between the applied methods (e.g. monitoring speed and interval) (Bager and Rosa, 2011), carcass removal rates and carcass detection rates (by observers) (Antworth et al., 2005).

Table 2
Observed richness (S_{Obs}), estimated richness (±SD) (S_{Est}), number of exclusive species (S_{Excl}) and total number of roadkills (*N*), including unidentified individuals, for the community of birds killed on Brazilian highways in the different habitat types. DF: shoreline dry field; WF: shoreline wet field; RF: rice field; WSG: wetlands of the São Gonçalo Channel floodplain; WET: wetlands of ESEC Taim.

	S_{Obs}	S_{Est}	S_{Excl}	N
DF	18	21 ± 5	2	149
WF	13	10 ± 3	1	30
RF	39	39 ± 0	11	336
WSG	24	19 ± 5	8	117
WET	16	16 ± 4	3	76
Total	57	–	–	708

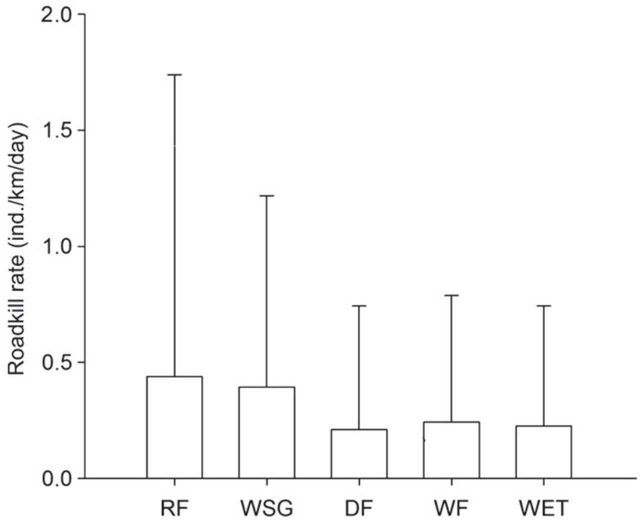

Fig. 3. Roadkill rate of birds in habitat types surrounding the highway – rice field (RF), wetlands of the São Gonçalo Channel floodplain (WSG), shoreline dry field (DF), shoreline wet field (WF) and wetlands of the Taim Ecological Station (WET) – on studied Brazilian federal highways.

Roadkills affect at least a quarter of the species that occur in our study area (Dias and Burger, 2005; Dias and Maurício, 1998; Mähler et al., 1996). As found by other authors (Novelli et al., 1988; Clevenger et al., 2003; Erritzoe et al., 2003), bird roadkills seem to affect a small, concentrated number of species which are intensely roadkilled, including some synanthrope species (e.g. *Passer domesticus*) which are intensely roadkilled in both temperate and neotropical zones (Coelho et al., 2008; Erritzoe et al., 2003). We do not discard the possibility of insufficient rare species identifications, with a bias toward more common and easily identifiable species. However, most of the unidentified individuals were found damaged due to time spent on the road surface. Thus, we believe that this has generated a homogeneous error throughout our study area, although not compromising the analysis of richness variation in roadkilled species.

4.1. Bird roadkill and seasonality

Our results demonstrate seasonal roadkill patterns, concentrated during the summer and autumn. An increased number of species was verified during the summer in areas within seasonal wetlands, due to the sampling of migratory species (Gotelli, 2009; Isacch and Martínez, 2001). However, we only found two migratory species (Dark-billed Cuckoo *Coccyzus melacoryphus* e Fork-tailed Flycatcher *Tyrannus savana*), which were occasionally roadkilled. Therefore, we believe that two main factors affect the increase of roadkill richness and rates during the summer: vacation, harvest and cargo transportation periods, which increase vehicle traffic and grain spillage on the road (Clevenger et al., 2003; Coelho et al., 2008); and the increased abundance of individuals due to juvenile dispersion, which occurs during the summer months (Isacch and Martínez, 2001), when a greater number of birds pass through the road.

Within the studied region, it is possible to observe that the summer and the autumn have increased vehicle traffic, mostly due to rice harvesting and transportation. Concurrently, several bird species can be observed transiting between the different habitat types during this period, seeking food and shelter (Dias and Burger, 2005). These are all factors which could increase roadkill richness and rates during these two seasons. However, each season presented different roadkill rates. This occurs due to roadkill peaks in the autumn, reaching 0.47 ind./km/day in a single sample, while the highest summer rate does not exceed 0.22 ind./km/day. The largest flocks of *C. ruficapillus* and other species are observed during the autumn, foraging on rice fields and roads (Dias and Burger, 2005).

4.2. Bird roadkill and habitat type

We found differences in roadkill impact magnitudes between different habitat types, according to the observations of Clevenger et al. (2003). In our study area, Dias and Burger (2005) observed a constant movement of individuals between habitats WSG and RF, given that both are important sources of food and shelter for regional bird species. The DF is located between these two areas, demonstrating that the proximity (Fig. 1) and movement of individuals between these habitats are probably responsible for roadkill rate similarities. We believe the same occurs between WET and WF. Therefore, concerning roadkill rate variations, we believe that the proximity between the areas is more important than the habitat type, and this is related to resource availability within the landscape.

While analyzing roadkill rates for some species and associating them to foraging and flight behavioral factors (Clevenger et al., 2003) or to each species' tolerance and capacity for movement over the roads (Laurance et al., 2004), some patterns have been observed. In RF, we have mainly found *C. ruficapillus* individuals, probably due to their high abundance in local rice fields (Dias and Burger, 2005), which are associated to their foraging behavior. However, the high *G. guira* roadkill rates in rice field areas is caused by their abundance in open areas (Dias and Burger, 2005), which is associated to their constant movement between opposite road sides and their low and slow gliding flight behavior, as previously observed in our samplings and noted by Novelli et al. (1988). Likewise, Southern Screamer *Chauna torquata* roadkill occurrences, which were exclusive to WET, are a result of the species' preference toward wetlands with lower hydric deficit intensities (Fontana et al., 1994). The abundance of this species in ESEC Taim (Fontana et al., 1994) and the presence of an aquatic environment which is directly associated to the road are likely related to the species' roadkill rates. Most Southern Caracara *Caracara plancus* individuals were also roadkilled in this area, where they often eat carcasses of roadkilled animals, which increases their own chance of collision with vehicles (Taylor and Goldingay, 2004).

Some theoretical models suggest that species which are abundant around roads are more likely to be roadkilled (Jaeger et al., 2005); our work demonstrates this for a few species. However, we believe that this is not, by itself, a determining factor toward bird roadkills, since several abundant species from open fields and rice fields (Dias and Burger, 2005) either presented low roadkill rates or were not identified within the samples.

On the other hand, we believe that the populations suffer other highway-related impacts such as habitat loss (Findlay and Bourdages, 2000; Findlay and Houlahan, 1997; Laurance et al., 2002), barrier effect (Develey and Stouffer, 2001) or sensitivity to road noises (Parris and Schneider, 2009). These hypotheses must be tested, since the studies by Findlay and Bourdages (2000) and Findlay and Houlahan (1997) are the only available information on how birds from natural open areas, such as wetlands, behave within habitats which are segmented by roads. The existing studies concerning the effects of paved and unpaved roads on birds are focused on forest areas and mainly concern canopy birds (Develey and Stouffer, 2001; Laurance et al., 2002, 2004; Parris and Schneider, 2009).

5. Conclusions

Our results demonstrate that bird richness and roadkill rates change according to seasonality and habitat type. We believe that the road is responsible for other impacts affecting bird communities, such as the barrier effect or edge effect, as some species of the surrounding areas exclusively occur more than 150 m from the road surface (Bager and Rosa, unpublished results). When working on cases in which roadkill occurrences affect rare or endangered species, the monitoring processes must be conducted in parallel to population and behavioral monitoring actions along the road's surrounding areas. These procedures enable the development of roadkill selectivity analyses and effective impact mitigation measures focused on specific species, following existing examples concerning several mammal species (Huijser et al., 2009; Philcox et al., 1999; Romin and Bissonette, 1996).

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