UNIVERSIDADE FEDERAL DE LAVRAS

THÁLITA DE RESENDE CARDOSO

DOES THE ANALYSIS UNIT AFFECT THE CONSISTENCY OF THE FACTORS INFLUENCING SMALL VERTEBRATE ROAD-KILLS?

LAVRAS-MG

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Dissertação apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ecologia Aplicada, área de concentração em Ecologia e Conservação de Recursos Naturais em Paisagens Fragmentadas e Agrossistemas, para a obtenção do título de Mestre.

Orientador
Dr. Alex Bager

Co-orientadora
Dra Clara Grilo

LAVRAS – MG

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LAVRAS – MG

2013

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"Aprenda como se você fosse viver para sempre"

Mahatma Gandhi

RESUMO

Estudos de atropelamento são importantes para compreender a magnitude do impacto sobre a persistência das populações no entorno das rodovias. A decisão do tamanho e do uso de *buffers* ou segmentos como unidade de análise para a coleta de dados de fatores da paisagem que influenciam os atropelamentos é arbitrária. Ela pode influenciar os resultados e a definição das medidas de mitigação. Neste estudo tivemos como objetivo testar este problema utilizando unidades com diferentes formas (buffers e segmentos) e tamanhos (movimento diário, padrão e dispersão). Os dados de atropelamentos foram coletados em 2005, em uma extensão de 137 km de duas estradas federais brasileiras. Foram analisados os registros de dois répteis, cobra d'água (*Helicops infrataeniatus*) e tartaruga tigre-d'agua (*Trachemys dorbigni*) e três mamíferos, gambá de orelha branca (*Didelphis albiventris*), nutria (*Myocastor coypus*) e skunk (*Conepatus chinga*). O percentual de variância explicada de forma independente para cada classe de uso do solo foi determinada utilizando o particionamento hierárquico (HP) de modelos de regressão múltipla. Os nossos resultados mostraram que a forma de *buffer* é a melhor forma para ser utilizado nas análises, e que o papel do tamanho das unidades é complexo e pode ser específico da espécie. No entanto, o tamanho padrão (1000 m) parece ser uma solução razoável, uma vez que funcionou bem para as espécies com pequena e grande área de vida.

PALAVRAS-CHAVE: Análises multi-escalas, segmentos de estrada, análise de buffers, atropelamento de fauna, particionamento hierárquico.

LISTA DE ILUSTRAÇÕES

SUMÁRIO

Does the analysis unit affect the consistency of the factors influencing small vertebrate road-kills?

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ABSTRACT

Road-kill studies are important to understand the magnitude of the impact on the persistence of the surrounding populations. The size and the decision between the use of buffers or segments as analysis unit to data collection of landscape factors influencing roadkill are arbitrary. It may influence the results and the definition and placement of mitigation measures. In this study we aimed to test this issue by using units with different shapes (buffers and segments) and sizes (daily movement, standard and dispersal) in five small vertebrate species. The road-kill data were collected weekly in 2005 in an extension of 137 km encompassing two Brazilian Federal paved roads. We analyzed records of two reptilians, water snake (Helicops infrataeniatus) and D'Orbigny's slider (Trachemys dorbigni), and three mammals, white-eared opossum (Didelphi salbiventris), nutria (Myocastor coypus) and skunk (Conepatus chinga). We used those species because they have different life-history traits and are frequently killed on the assessed roads. The percentage of variance explained independently for each land-use class was determined using hierarchical partitioning (HP) of multiple regression models. Our results showed that buffer shape is the best shape to be used on the analyses, and that the role of size of units is complex and may be species-specific. However standard size (1000 m) seems to be a reasonable solution as it worked well for species with both low and high home-range values. Our study highlights the importance of prior analysis with several scales and shapes to identify the appropriate unit for road-kill modeling.

KEYWORDS: Multi-scale analysis, road segments, buffer analysis, wildlife-vehicle collisions, Hierarchical Partitioning, road-kill.

1 INTRODUCTION

Wildlife-vehicle collisions (WVC) are considered the most noticeable impact caused by roads. It is frequently pointed out as the main cause of vertebrate mortality by direct human influence (Forman and Alexander 1998; Fahrig and Rytwinski 2009). In the last few decades, researchers have used available locations of WVC to model distribution patterns along roads in order to implement measures to minimize the road mortality rate (Gunson et al. 2010). These analyses have indicated that WVC along roads are not randomly distributed but are spatially clustered and therefore, some factors may increase the road-kill likelihood (e.g. Joyce and Mahoney 2001).

Ecological patterns result from processes occurring at multiple spatial and temporal scales (Collinge 2001). It is required to integrate knowledge across scales to characterize the whole context of road-wildlife interactions: from site/individual to landscape/population (e.g. DeCesare 2012). Yet, the majority of mortality studies are mainly focused in one unit of analysis. Analysis units are defined set of "objects" analysis relating to the same data set. The different units are used for the extraction of data on the variables of the landscape around the road studied. Thus, there is a lack of understanding on the role of different analysis units in determining the land use factors that explain the likelihood of WVC. This fact prevents accurate comparisons, assessments and extrapolations of the patterns to other regions, and therefore creates problems in measures to minimize WVC (Danks and Porter 2010).

In general, analysis units comprise two different features: shape and size. Two shapes are commonly used in the road-kill analysis: a buffer area around the road-kill spot (e.g. Langen et al. 2009; Colino-Rabanal et al. 2011) or the road surveyed is segmented in sections with pre-defined length where the road-kill records areas signed to each segment (e.g. Gomes et al. 2009; Grilo et al. 2011). Although the majority of studies used 1000m as the length of the units (e.g. Langen et al. 2009; Carvalho and Mira 2011), some unit sizes are arbitrarily chosen, ranging from 50m to 5000m for buffer radius (Barrientos and Bolonio 2009; Colino-Rabanal et al. 2011) and from 100m to 1000m for road segments length (Malo et al. 2004; Jancke and Giere 2011). However, no research has evaluated the effect of different unit shapes and sizes in road-kill results. Only a few studies compared

the unit size when using buffers to identify the features promoting road-kills (e.g. Farmer et al. 2006; Ng et al. 2008; Langen et al. 2009; Danks and Porter 2010; Colino-Rabanal et al. 2011) with contrasting results: Ng et al. (2008) with the deer Odocoileus spp. and Colino-Rabanal et al. (2011) with Iberian wolf Canis lupus signatus found better predictions with larger buffer sizes. On the other hand, Danks and Porter (2010) with the moose Alces alces and Langen et al. (2009) with reptiles and amphibians found better predictions with smaller buffer sizes. Thus, the evaluation of the result consistency over different approaches is required to better understand the effect of shape and size on the road-kill analysis.

The main aim of this study is to examine the effect of analysis unit shape and size in determining the mortality risk for small vertebrates with different life-history traits. More specifically, we want to address the following goals: (1) Do variables related to the mortality risk vary according to the used analysis unit shape and size? We believe that variables with different resolutions and spatial variability influences or have different amounts depending on the size of the analysis unit (2) Does the weight of those variables are similar in units with different shape and size? With these insights we intend to contribute for a better understanding on the role of analysis unit shape and size in determining the mortality-risk factors and therefore, to a successful application of mitigation measures.

2. METHODS

2.1 STUDY AREA

The study site is located in coastal plain in, Southern Brazil (Fig. 1). This region is characterized by coastal plains with low and rectilinear relief dominated mainly by wetlands associated with fresh- and salt-water lakes. This landscape comprises extensive perennial and seasonal wet areas, seaside dunes and rice fields (Tagliani 2003). Climate is characterized by raining throughout all months of the year, with temperatures averaging between 22ºC and 24ºC in the hottest month and around 13ºC in the coldest month (Nimer 1989).

A total of 137 km of Brazilian Federal paved roads was surveyed (33km from BR392 and 104km from BR471). The road segment start at Pelotas town (52º19' 38''O, 31º48'18''S) and ends on Santa Marta's Farm (52º41'27''O, S 32º49'32''S), in Santa Vitória do Palmar town.

2.2 TARGET SPECIES

We selected five species representing different life-history traits. We analyzed records of two reptile species - water snake (Helicops infrataeniatus) and D'Orbigny's slider turtle (Trachemys dorbigni); and three mammal species - white-eared opossum (Didelphis albiventris), nutria (Myocastor coypus) and skunk (Conepatus chinga). During the road survey, we recorded 186 water snakes, 67 D'Orbigny's sliders, 121 white-eared opossums, 68 nutrias and 54 skunks.

Water snake is an aquatic species, spread through southern Brazil (Rio Grande do Sul and Santa Catarina), Uruguay and Argentina (Aguiar and Di-Bernardo 2004). It is a species particularly vulnerable to road mortality (Kunz and Ghizoni-Jr 2009; Mainardi and Hartmann 2009;Aguiar and Di-Bernardo 2004; 2005;Bager and Rosa 2011).

D'Orbigny's slider is a fresh water turtle species, which inhabit swamps, lakes, and slow-moving rivers in Brazil, Uruguay and Argentina (Bager et al. 2012).Since it moves slowly this species is a common victim of road traffic (Hengemühle and Cademartori 2008).Bager and Fontoura (2013) presented a road-kill rate of 0.23 individuals/100km/day in our study area.

White-eared opossum is a generalist, solitary and omnivorous species (Cabrera and Yepes 1960). Although this species occupy a broad ecological niche, it is mostly found in open deciduous forests (Cerqueira 1985) from Colombia to central Argentina (Emmons and Feer 1990). With the deforestation raise, individuals have been approaching urban areas and acquiring synanthropic habits (Sanches et al. 2012). The high road-kill incidence must be related to the tolerant and opportunistic habit of the species (Rosa and Mauhs 2004; Hengemühle and Cademartori 2008;Cherem et al. 2007).

Nutria is an aquatic rodent from South America. Their occurrence in river sides and humid zones in those countries resulted from escapes and possible releases from nutria farms. Bager and Fontoura (2013) estimate a road-kill rate of 8.25 individuals/100km/day in BR471.

Skunk is a carnivore species widespread in northern Argentina, Uruguay, southern Brazil, Paraguay, southern Bolivia, southern Peru and northern Chile (Eisenberg and Redford 1999; Cheida et al. 2006). They inhabit mostly low vegetation areas, avoiding dense forests (Lyra-Jorge et al. 2008). Bager and Fontoura (2013) estimate a road-kill rate of 0.03 individuals/100km/day in BR471.

2.3 DATA COLLECTION

2.3.1 ROAD-KILL DATA

Road-kill data were obtained from "Estrada Viva" project database (Bafs 2014). Locations were recorded weekly from January to December 2005, by car, at approximately 50 km/h, with at least two observers, avoiding weekends, holidays and rainy days. Road surveys were performed between 7am and 3pm and road-kill locations were recorded with a handheld GPS (maximum error 5 m).

2.3.2 LAND-USE DATA

We have used a land-use map based on an earlier database and maps from Tagliani (2003). Tagliani's map was created from Landsat 7 satellite images (2000) using SPRING software (Camara 1996). The size of the imaged scene is 185km x 185km, with spatial resolution of 30x30m.The analyzed representative land-use classes in the study site were: predominant rice field, sandbank vegetation, seaside fields, wetlands and non-native vegetation. Predominant rice field are areas mainly covered by irrigates rice culture; sandbank vegetation are areas of low open arboreal vegetation, influenced by the ocean and located high on dunes and slopes, on dry soil; seaside fields are flood fields of low grass; wetlands are floodplains with fertile clay soils; and non-native vegetation are forestation of

eucalyptus and pine (Eucalyptus sp. and Pinus sp.). Land-use data collection was performed using ArcGis 9.3 (ESRI 2005**)**.

2.4 DEFINITION OF UNITS OF ANALYSIS

For this analysis we used two shapes: a buffer area around the road-kill location and road segments with a pre-defined length (Fig. 2). In the first one defines a buffer size created around the roadkill spot (Fig. 2a), and in the second the monitored road is segmented in sections with pre-defined sizes and posterior buffer citation around the central point of these sections (Fig. 2b,c).

We used average daily movement distance and average dispersal ability of each species as well as the standard size (1000m) to define buffer diameters and road segment lengths (Table 1). Daily movement distance was estimated using information of the average home-range size for each species (Bowman et al 2002). Accordingly to this study daily movement can be estimated the square root of the home-range size. Standard size was the measure used in most studies, which was 1000m. Dispersal is seven times the daily movement distance (Bowman et al 2002). For water snake, no information was available in terms of home-range size. Thus, we used the data of a research on a species of the same family - Liophis (Liophis poecilogyrus) (Hartz et al. 2001) that was surveyed close to our study site. For all units we extracted the area (m²) of each land-use class for each species.

Twice numbers of the read-kill are the total buffer number (presence and absence of roadkill) used in the analyses. The number of road segments analyzed for the daily movement, standard and dispersal sizes were respectively: 164, 67 and 98 for water snake; 108, 72 and 64 for D'Orbigny's slider; 174, 110 and 114 for white-eared opossum; 68, 64 and 30 for nutria and 64, 72 and 10 for skunk. Half of these numbers represents the number of segments with road-kill presence for each species.

2.5 DATA ANALYSIS

We analyze the consistency of landscape variables to influence the presence / absence of each species of roadkill. This consistency was compared between the different

sizes and shapes of the analysis units.The percentage of model adjustment explained independently for each land-use class in all possible multiple regression models was determined using Hierarchical Partitioning (HP) (Mac Nally 2000; 2002). HP procedures due to the tendency of linear models to be seriously affected by multicollinearity among several explanatory variables (Grahan 2003). Therefore, HP identifies the contribution (weight) of each isolated (I's) and joint (J's) land-use class to analyze the effect of unit size and shape on road-kills likelihood. Independent effect represents the effect of the isolated variables, by reducing the influence of multicollinearity effects (Heikkinen et al. 2004; Olea et al. 2010). We used log-likelihood as a goodness-of-fit measure in HP (Mac Nally 2002). To assess the statistical significance of variables, 1000 randomizations of the data matrix were generated to compute I's distributions for each predictor. Results were expressed with significance of $\alpha=0.05$ (Z-score>1.96) (Mac Nally 2002). Previously, select a training set similar number of buffers or segments with road-kills and random buffers or segments without road-kills.

All statistical analyses were performed using the R statistical software (R Development Core Team 2006, Vienna, Austria). Hierarchical partitioning was performed using the "hier.part package" Version 1.0 (Walsh and Mac Nally 2004).

3. RESULTS

We found out that the different shapes were not consistent (significative % of explained variance of similar variables) in the different species except for water snake and D'Orbigny's slider. We noticed that for every other species buffer shape had more consistent results through the different sizes.

To each species, the shape sizes (daily movement, standard and dispersal) when up in crescent order are different. Meaning, to Water Snake and D'Orbigny's slider: daily movement, dispersal and standard; white-eared opossum and nutria: daily movement, standard and dispersal and to skunk: standard, daily movement and dispersal. Regardless the extraction degree of the landscape variables to each size and the species perception, we observed that standard size presented most consistency in most species. In general the variable inconsistence increases from water snake to D'Orbigny's slider, white-eared

opossum, nutria and finally to skunk. This occurs as we observe more sizes and shapes with no variable and with significative % of explained variance and different variables with a larger effect in each size. Water snake and D'Orbigny's slider showed consistence in all unit shapes and sizes. For white-eared opossum we found differences only in dispersal size/segment, which presented the sandbank vegetation variable. For nutria there was no difference on independent effects among the three sizes with buffer shape. However, there were differences between buffer and segment due to the lack of any significant variable in the segment shape. For skunk there was consistency of the predominant rice field variable on dispersal size/buffer and daily movement and standard size/segment. On standard size/buffer a variable different from the other analysis units, non-native vegetation, had the highest weight. Moreover, no variable with significant weight was found for skunk at the daily movement size/buffer and dispersal size/segment.

Summarizing, the variables with the highest effect on road-kill occurrence were seaside fields for water snake, white-eared opossum and nutria and predominant rice fields for D'Orbigny's slider and skunk. We have found more consistency in buffer shape throughout the sizes. The best examples for this fact were water snake, D'Orbigny's slider and white-eared-opossum results (Figure 2).

4. DISCUSSION

Inferences from an observation may be biased, if the size and shape of units does not detect the species' spatial requirements (Cadotte and Fukami 2005). There is little knowledge and no, respectively, on the effect of size and shape on the road-kill analysis (Farmer et al. 2006; Ng et al. 2008; Langen et al. 2009; Danks and Porter 2010; Colino-Rabanal et al. 2011). Such information is valuable for accomplishing mitigation objectives as the definition and placement of the most appropriate measure to prevent WVCs. In this study we aimed to clarify this issue by using different shapes and size of analysis units based on the spatial requirements of five small vertebrate species with different life-history traits.

Overall, the definition of the analysis unit is a critical issue to understand the ecological processes (McMahon and Diez 2007). Our results show that the variables related

to road-kill vary less in buffer shape and fine scales (smaller unit sizes). We believe that the best shape for researches with small vertebrates is buffer, once it shows higher consistencies in results with different sizes the unit analysis and the life-history traits the species. The inconsistences happened in broader scales (larger sizes). Despite standard not always being the smaller size, it seems to be a reasonable solution as it worked well for species with both low and high home-range values. However our findings show that the definition of the analysis is complex and may be species-specific.

Analyzing in the following sequence: water snake, D'Orbigny's slider, white-eared opossum, nutria e skunk, we observed that as the home-range size increases, the differences among the% of explanation of the variables between the shapes and sizes also increase.

We argue that the resolution of the map may explain dissimilarities among species with small home ranges. Most species-habitat relationship studies do not present any scientific support to explain why some image resolution was chosen to generate the land-use map (e.g. Hubbard et al. 2000; Haijun et al. 2011). In fact, we can raise the hypothesis that some important fine-scale features may have not been detected since we used a land-use map generated from an image with 30m resolution (Tagliani 2003). Thus, for species with low dispersal ability, it is suggested finer scales of the land-use variables to detect differences (Langen et al. 2009). Actually, when analyzing the relationship between herpetological fauna and land use, Langen et al. (2009) using a high-resolution map of 1m, obtained better results with smaller scales (100m) than for 500 and 1000m. It's important to highlight that high resolution images in Brazil are hardly available and expensive.

One explanation for the dissimilarities on species with large home ranges could be the potential generalist character of the species. Home range is the area used by an individual to forage, reproduce and perform all of its daily activities. This area varies mainly according to animal size and feeding habits (Campioni et al. 2013). Species with larger home ranges and dispersal ability are generally less habitat specialists, being able to explore distinct places according to resource availability (Pigliucci 2001; Ye et al 2013). Thus, differences in the effect of the variables can be explained by a larger diversity of explored habitats by the species, such as nutria e skunk.

Our results are based on data of small vertebrate species with territories ranging from 0.0003 to 1.65km². Nevertheless, studies with larger body-sized species are in line

with our findings (Ng et al. 2008; Colino-Rabanal et al. 2011). For example, among three unit sizes, Colino-Rabanal et al. (2011) found better results at the largest size (5000) (among buffers of 1000, 2500 and 5000 meter radius) for Iberian wolf. Ng et al. (2008) using road-kill data of North American deer, compared results among the sizes of 100, 200, 400 and 800m radius, found better results with the largest radius. Other studies show that the definition of analysis unit size is complex. For instance, Danks and Porter (2010), using data of moose, found that units with 2500m radius better predict the landscape composition, while units with 5000m radius better predict the landscape configuration. In the other hand, Farmer et al. (2006), using data from black-tailed deer Odocoileus hemionus sitkensis, found that habitat factors described in units of 500 and 1000m radius better explain adult females and juvenile road-kills, while habitat variables in smaller sized units better explained adult male road-kills.

There is also another factor related to study site that may explain our results. Seaside fields and predominant rice fields are the more frequent variables in the results. Our study sites in a region of pioneer vegetal formations with seasonal floods and strong irrigated rice culture. The rice culture in the area represents 79% of the country's production (Cordeiro and Hasenack 2009). There are a few differences in the land use of the region, having a strong relation with agriculture. Evidences of this agricultural use are irrigation/drainage channels and "taipas" resultants from the irrigated rice culture in wetlands and seaside fields, as well as in terraces on dry fields (Cordeiro and Hasenack 2009). The studied species often showed use of these environments since they are well adapted to seasonal water conditions (Rosa and Mauhs 2004; Kunz and Ghizoni-Jr 2009; Bager et al. 2012; Bager and Fontoura 2013).

Management Implications

The implementation of mitigation measures based on researches with arbitrary use of analysis unit sizes and shapes is fragile. Our research highlights the importance of the unit size and shape to analyze road-kill data, considering species with different life-history traits. Show that the diluted form is the best to be used in the analysis and that the role of size of units is complex and may be species-specific. However, standard size seems to be a

reasonable solution as it worked well for species with both low and high home-range values. Our study highlights the importance of prior analysis with several sizes and shapes to identify the appropriate unit for road-kill modeling and testing the use of maps with better resolutions for small species.

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TABLES AND FIGURES
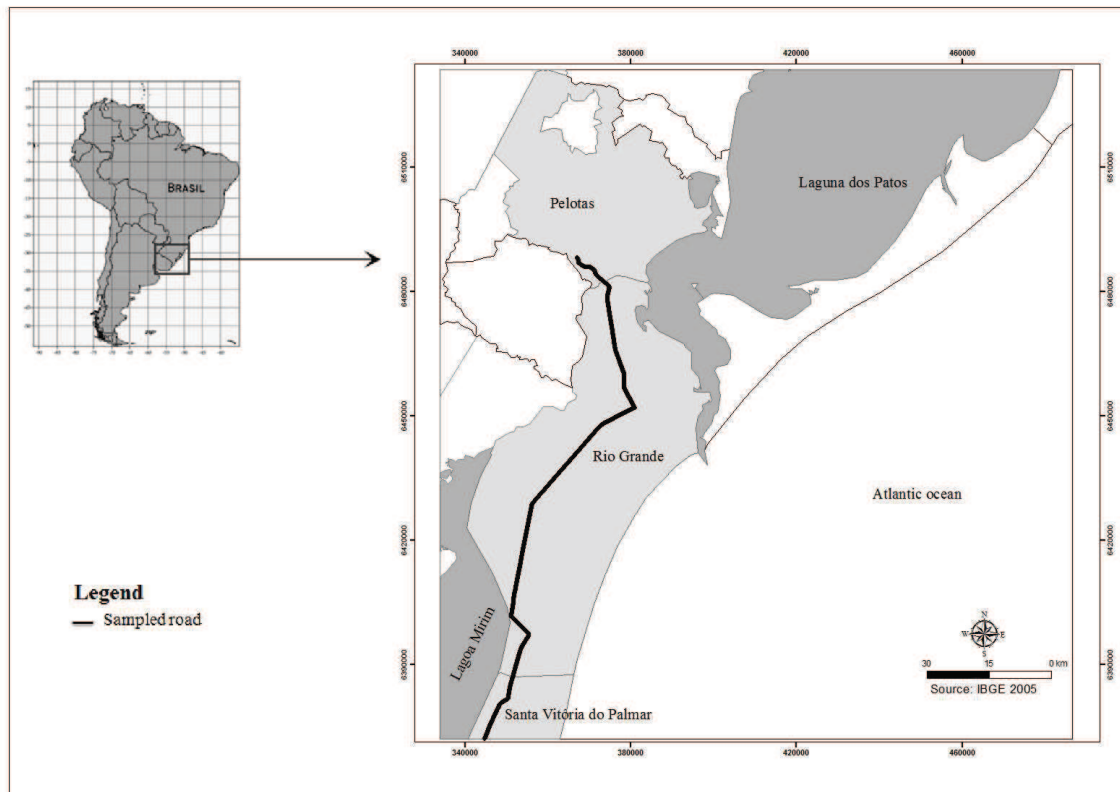
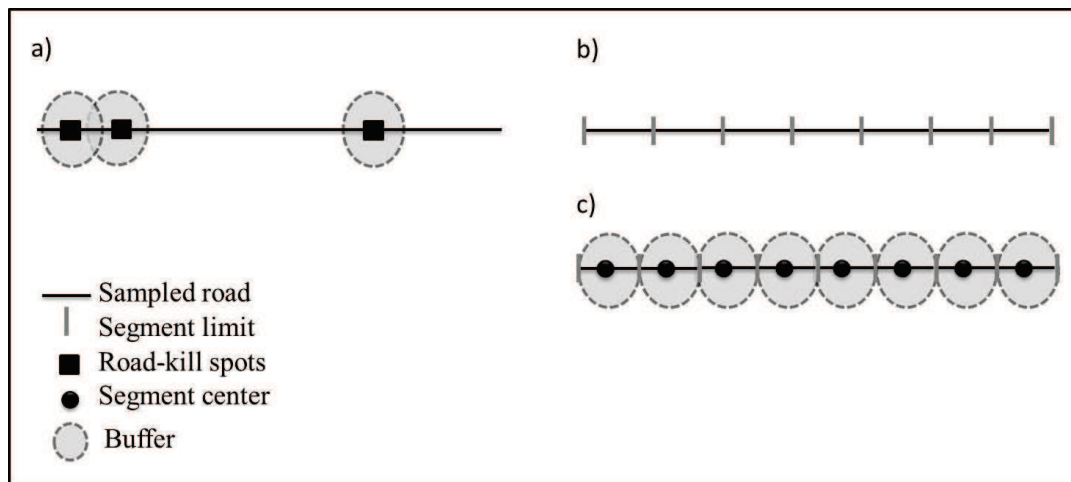
Fig 1 Sampled road stretch

Fig 2 Definition of units analyses. Two shapes: a buffer area around the road-kill location and road segments with a pre-defined length. In the first one we define a buffer size created around the roadkill spot (Fig. 2a), and in the second the monitored road is segmented in sections with pre-defined sizes and posterior buffer citation around the central point of these sections (Fig. 2b,c)

Table 1 Average home range size (m²) for each species obtained through the literature and the estimated daily movements, standard, and dispersal ability scales accordingly to Bowman et al (2002)

Common name	Home range	Reference	Daily movement	Dispersal	Standard
Water Snake	3649	Hartz et al., 2001	60	420	1000
D'Orbigny's slider	17424	Bager et al. (2012)	132	924	1000
White-eared opossum	23300	Sanches et al. (2012)	153	1071	1000
Nutria	327000	Nolfo-Clements (2009)	572	4004	1000
Skunk	1650000	Kasper et al. (2011)	1285	8995	1000

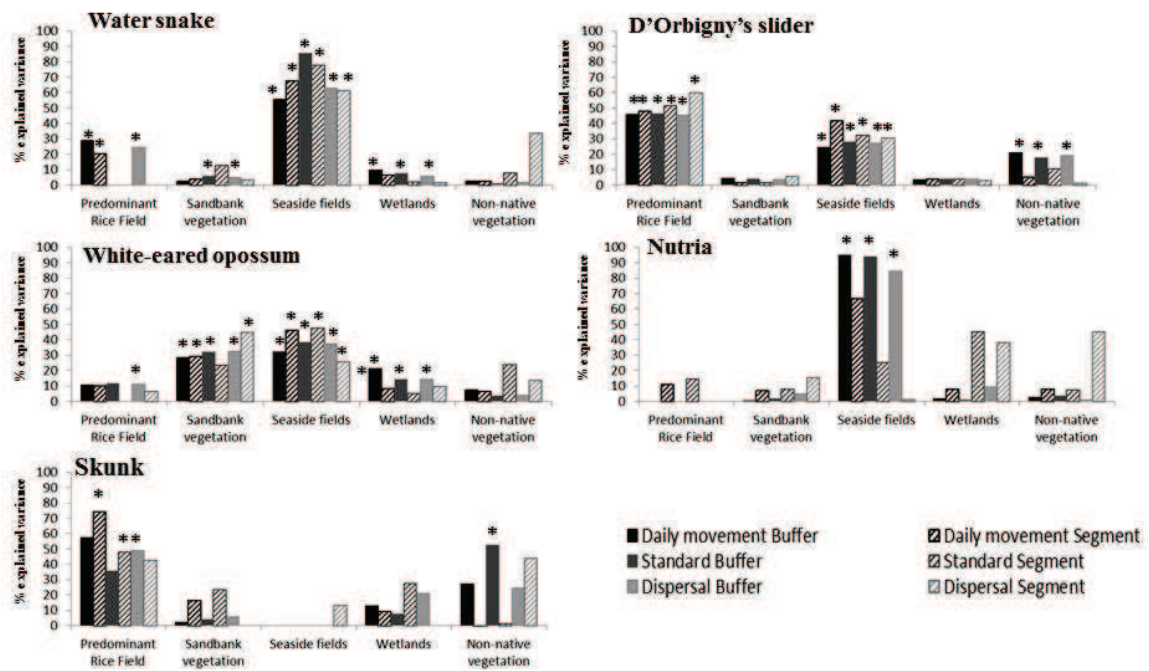**Fig 2** Percentage of variance in the occurrence of road-kills for each species explained independently (I) by the five land use variables