



UNIVERSIDADE DE ÉVORA
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DEPARTAMENTO DE BIOLOGIA

“Identificação de fatores determinantes que influenciam o atropelamento de serpentes no sul de Portugal”

Eliana Denise Simões Loureiro

Orientação: Paulo Alexandre Cunha e Sá de Sousa

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Paulo Alexandre Cunha e Sá de Sousa

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Thesis

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Eliana Denise Simões Loureiro

Supervisor

Paulo Alexandre Cunha e Sá de Sousa

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***If you're not prepared to be wrong, you'll never
come up with anything original.***

Sir Ken Robinson.

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RESUMO

“Identificação de fatores determinantes que influenciam o atropelamento de serpentes no sul de Portugal”

O impacto das rodovias é bastante marcado ao nível da fauna vertebrada terrestre, sendo comum encontrar serpentes atropeladas. Com base num registo diário de 2 anos analisaram-se padrões espaciais no atropelamento de serpentes em quatro troços de estradas ao longo de 50.6 km. Os dados de atropelamento foram analisados ao nível da comunidade de serpentes e das espécies principais. O maior atropelamento da comunidade de serpentes e de *Rhinechis scalaris* ficou assim associado a maior cobertura de *Montado*, enquanto a cobertura arbustiva foi então associada a uma menor probabilidade de atropelamentos. A rugosidade do terreno e os terrenos agrícolas revelaram-se também importantes no padrão de atropelamento até valores intermédios. *Hemorrhois hippocrepis* estava fortemente ligada às áreas influenciadas pelas atividades humanas, enquanto que *Natrix maura* atropeladas foram associadas à proximidade de charcos. Além disso, evidenciou-se um maior risco de atropelamento em estradas nacionais do que em estradas municipais. Assim, demonstrou-se a importância de considerar elementos paisagísticos para melhor compreender o atropelamento de serpentes.

Palavras -chave: Colubridae, serpentes, padrão espacial de atropelamento, Inferência multimodelo, Alentejo

ABSTRACT

“Identifying key factors that impact snake roadkill in southern Portugal”

The impact of roads is a serious issue among terrestrial vertebrate fauna, in fact snakes are frequently found dead on roads. To analyse snake roadkill spatial patterns, roadkill data was collected over a 2 year period from 4 road stretches that are 50.6 km long. The data was analysed at the snake community and species level. Snake community and *Rhinechis scalaris* roadkill were associated to *Montado* cover, while shrub cover lowered the chance of roadkill. Terrain roughness and agricultural land were also an important roadkill feature occurring up to intermediate levels. Increased *Hemorrhois hippocrepis* roadkill was highly associated to human influenced areas, while *Natrix maura* roadkill was strongly linked to the proximity of water sources. The risk of snake roadkill was higher in national roads than in municipal roads. In brief, taking into account landscape factors seems to be an important step to improve our understanding on snake roadkill.

Keywords: Colubridae, serpents, roadkill spatial pattern, multimodel inference, Alentejo

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FORWARD

This dissertation text is mostly set as a scientific paper in order to facilitate its final publication as soon as possible after the public defence of this thesis. Despite leaving some paragraphs in the text as explanatory views, I found it important for a better judgment in terms of the dissertation. However, the final text and figures aiming the future article may be a bit more succinct for editorial reasons. Nevertheless, I am the main author of the following text for all purposes.

INTRODUCTION

Impacts of Roads on Fauna

Roads are an important physical structure that provide connections between populated areas and are often considered an essential infrastructure to improve the development and productivity of a region (Coffin 2007). However, with the increased development of road networks in the last century, environmental impacts on fauna have been a growing issue in recent years (Bekker 2003; Coffin 2007).

The impacts of roads on fauna start with the construction phase and continue to disrupt the natural environment with its daily use. Besides road location determining the magnitude to which wildlife will be exposed, it also influences surroundings up to 100 - 800 m beyond the road's edges (Andrews, Gibbons & Jochimsen 2006; 2008). As a result, direct impacts usually consist of wildlife vehicle collisions, while indirect impacts range from habitat loss, habitat fragmentation and degradation to behavioural change of wildlife (Brito & Álvares 2004; Spellerberg 1998; Underhill & Arnold 2000).

Furthermore, animals may avoid roads, in which case a barrier effect is created (Andrews, Gibbons & Jochimsen 2006; van Langevelde, Dooremelan & Jaarsma 2009). If a road creates an impermeable barrier to animal movement then demography, population structure and genetic diversity may be modified (Brito & Álvares 2004). Even if roads do not pose a barrier, populations may still be at risk if a significant proportion is killed by roads and not compensated by higher birth rates (Gomes *et al.* 2009).

Factors Influencing Snake Roadkill

The extent to which roads impact snake populations is still poorly understood. One of the main reasons for this omission is due to the cryptic nature of these species, along with the failure to have a standard fauna sampling method that can adequately detect them (Dorcas & Willson 2009; McDonald 2012). Despite the sampling issues, it is clear that roadkill is affecting several snake species (Colino-Rabanal & Lizana 2012). In North America, roadkill studies have already demonstrated considerable damage to snake populations (Jochimsen 2006; Rosen & Lowe 1994). Also, a long term study about population viability on a snake species concluded that road mortality of more than 3 adult females per year was enough to increase the extinction probability to >90% (Row, Blouin - Demers & Weatherhead 2007). Lastly, results from another study suggested that populations of large snake species are reduced by 50% or more up to a distance of 450 m from roads with moderate use (Rudolph *et al.* 1999).

Understanding the impacts of roadkill in snake populations is essential for their conservation, as snakes play an important ecological role both as predators and prey in different ecosystems (Pragatheesh & Rajvanshi 2013). Snakes have several ecological traits that increase their probability of suffering a vehicle collision mentioned in the literature (Colino-Rabanal & Lizana 2012). Since snakes have a long life span and mature slowly, they usually present a low reproductive rate and show a natural low adult mortality. These traits add up to a number of characteristics that make snake mortality in roads an increased risk for populations (Hartmann, Hartmann & Martins 2011) and altogether make population dynamics extremely vulnerable to adult mortality (MacKinnon, Moore & Brooks 2005). The snake's ability to cross a road can also be influenced by speed and defensive behaviours which are features that greatly vary from species to species. Also, matters can be aggravated when human and animal activities overlap as some snakes show a crepuscular behaviour during parts of the year that may match with rush -hour traffics (Andrews, Gibbons & Jochimsen 2006). Furthermore, although some snakes flee from danger as an initial response, others immobilize themselves hindering their chance to cross the road safely (Andrews, Gibbons & Jochimsen 2006). Nevertheless, research has shown that snakes tend to cross roads perpendicularly taking the shortest possible route (Andrews & Gibbons 2005; Shine *et al.*

2004), thus probably bettering their chances to cross successfully. In addition, snakes may use roads for their thermoregulation needs, favouring paved roads for its suitable heating surface (e.g. tigmotactism) and therefore increasing their vulnerability to roadkill (Andrews, Gibbons & Jochimsen 2006; Brito & Álvares 2004). This behaviour is particularly noticeable in the ladder snake that often takes advantage of the warm surface roads provide at night (Pleguezuelos 2009b). Also an important element for snake roadkill to occur is snakes' movement patterns. These patterns are mainly driven by snakes' breeding or migration periods or can simply refer to attending their basic needs (e.g. prey searching) and highlight the dispersive nature and temporal trends of snake species (Bonnet, Naulleau & Shine 1999; Brito & Álvares 2004; Jochimsen 2006). For example, the male Montpellier snake is more likely to be found dead on roads in the mating season due to their greater mobility in this season (Pleguezuelos 2009a). In autumn, juveniles after birth also have a higher probability of being run over when they start dispersing (Pleguezuelos 2009a).

Reports about snake mortality in roads go far back as the fifties (e.g. Campbell 1953; Hellman & Telford 1956). However, investigation on why roadkill occurs has only started in recent years (Colino-Rabanal & Lizana 2012). Even with an increasing number of published articles arising, only a few are related to snake mortality in roads. Indeed, most published papers on the subject are from North American studies (Andrews & Gibbons 2005; Clark *et al.* 2010; Enge & Wood 2002; Gibson & Merkle 2004; Jochimsen 2006; Roe, Gibson & Kingsbury 2006; Row, Blouin -Demers & Weatherhead 2007; Rudolph *et al.* 1999; Shine *et al.* 2004), with only a few papers being published elsewhere (Bonnet, Naulleau & Shine 1999; Ciesiołkiewicz, Orłowski & Elżanowski 2006; Hartmann, Hartmann & Martins 2011; Pragatheesh & Rajvanshi 2013). In Portugal, one paper has been published by Brito & Álvares 2004 identifying viper roadkill patterns (age, sex and seasonal activity).

These studies have generally investigated temporal patterns and snake behaviours in roads, while only a few investigated the influence of spatial patterns (Enge & Wood 2002; MacKinnon, Moore & Brooks 2005; Pragatheesh & Rajvanshi 2013). Spatial patterns regarding habitat characteristics influencing wildlife movement may have an important

role in identifying major roadkill spots (Clevenger, Chruszcz & Gunson 2003; Forman & Alexander 1998).

Investigating the spatial patterns of snakes should give an important contribution towards understanding the role of spatial features in snake road mortality. After all, snakes in Portugal are no exception to the impact of roads as roadkill is one of the major threats for this group (Loureiro *et al.* 2010). In Portugal, more than 30% of recently registered specimens of *R. scalaris* were found dead on roads (Pleguezuelos 2009b).

Objectives

Since one knows that snakes are being killed in roads and that they play an important role in the ecosystem, it is essential to understand roads impacts in snake populations. Thus, the main objective of this study is to understand the influence of spatial factors in snake roadkill and therefore to determine the patterns and importance of environmental factors. The specific objectives are: to describe the ecology and biology of snakes in the study area linked to roadkill; identify the spatial factors that could be influencing roadkill in snakes; describe the spatial patterns of factors influencing roadkill.

Looking ahead, the results of this study should help recognize landscape's key factors linked to snake roadkill and may be used in future studies, improving road management practices or mitigation planning.

MATERIAL & METHODS

Study Area

This study was conducted in the southern part of Portugal, in the Alentejo Central region (NUT III), comprising the municipalities of Évora and Montemor -o -Novo. The study area includes consecutive stretches of four roads along 50.6 km that, altogether, draw an irregular square: two national roads (N114 and N4) and two municipal roads (M370 and M529) – see Figure 1. Also, the highway (A6) is located nearby the N114 road.

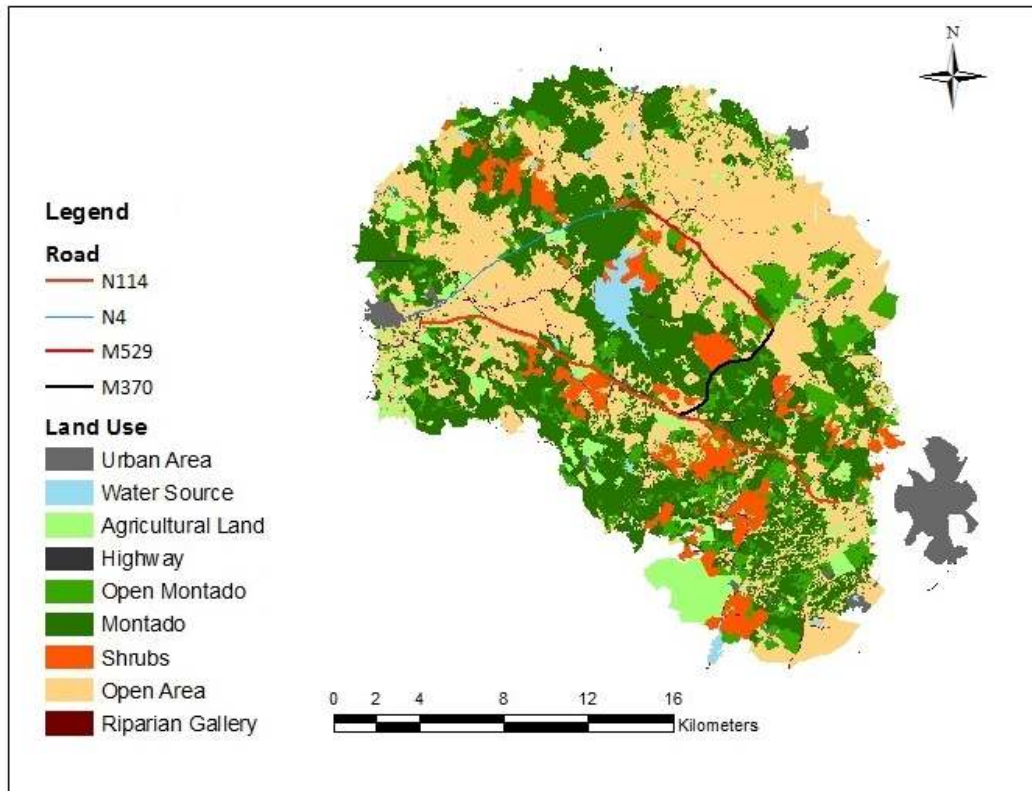


FIGURE 2 – LANDSCAPE SURROUNDING SURVEYED ROADS (ADAPTED FROM “MOVE” PROJECT).

Alentejo Central’s main landscape has been the so -called “Montado”. It consists mainly of an agrosilvopastoral ecosystem, mostly composed by cork (*Quercus suber*) or holm oak trees (*Q. rotundifolia*), shaping as a savanna like land cover pattern that is known for its cork production, as well as for its multiple supplementary productions that supports a diversity of ecosystems and biodiversity (Correia, Ribeiro & Sá -Sousa 2011; Godinho, Santos & Sá -Sousa 2011).

Being a type of Mediterranean region, the Alentejo Central’s climate has broad thermal ranges and quite different seasons with the hot dry season averaging 20 to 23 °C and low rainfall (June to October) and the cool wet season averaging 10 to 15°C with rainfall superior to 80mm (Galantinho & Mira 2008).

Snakes in Portugal

According to Carrascal & Salvador (2009) and the updated IUCN (2013), there are ten species of snakes distributed in Portugal: two vipers (Viperidae), two Natricidae, one Psammophiidae and five Colubridae. Among them, a total of seven species occur in southern Portugal (Table 1; Figure 2). These are mostly distributed through Western Europe and North Africa, generally occupying Mediterranean environments.

Table 1 summarizes some snake features (taken elsewhere from Carrascal & Salvador 2009 and Loureiro *et al.* 2010) that may influence road crossing. Different characteristics may have rather different impacts in the snake's vulnerability to roadkill. For example, in the Iberian Peninsula some snake species have an active foraging behaviour during the day period that may make them more vulnerable to roadkill (Malkmus 2004; Pleguezuelos 2009; Salvador & Pleguezuelos 2002).

Roadkill Surveys

The road circuit (Figure 1) was surveyed daily from 16 of March 2010 to 15 March 2012, often in the morning. These roads differ in their features, mainly in their traffic flow. In brief, the national roads have a medium/high traffic (<10000 vehicles/day), while more local roads have a low traffic (<4000 vehicles/day, EP 2005). Snake roadkill was surveyed by car at a low speed (15 - 20km/h) in both road directions.

A global positioning system (GPS) was used to set the geographic coordinates of each snake carcass found on the pavement. Species name, age and sex were also recorded on the spot whenever possible. Finally, carcasses were removed from the road, avoiding double counting. Figure 3 shows the number of recorded snakes killed in roads during the course of the survey.



Coronella girondica



Hemorrhois hippocrepis



Macropodonton brevis



Rhinechis scalaris



Natrix maura



Natrix natrix



Malpolon monspessulanus

FIGURE 2 – PHOTOGRAPHS OF THE SNAKE SPECIES FOUND IN SOUTHERN PORTUGAL.

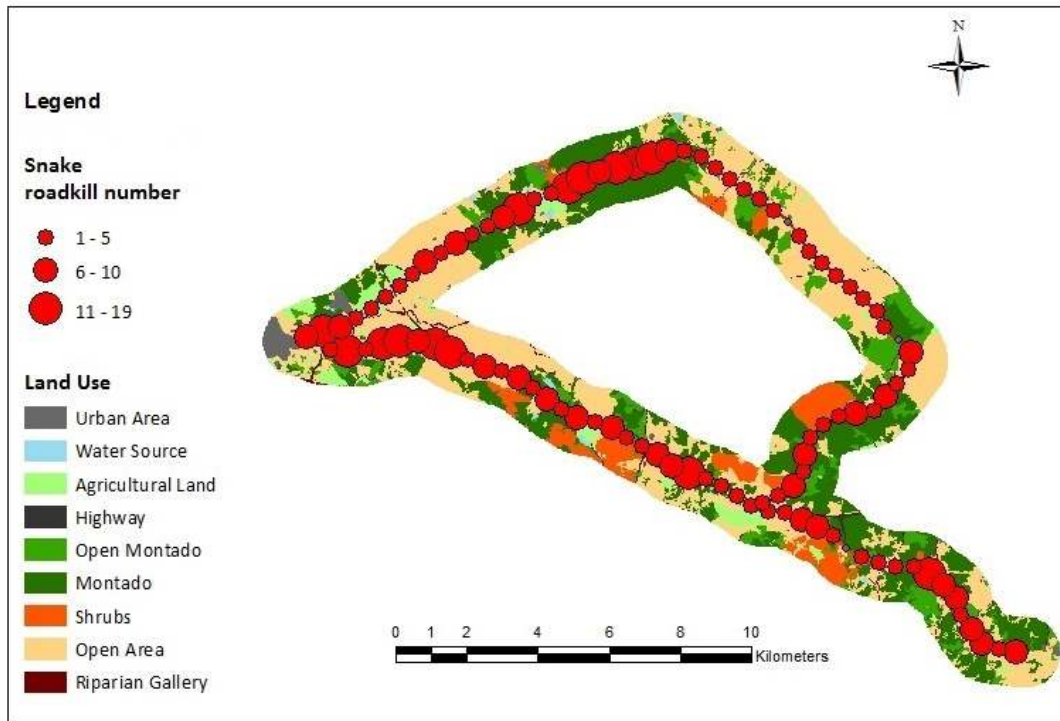


FIGURE 3 - STUDY AREA WITH A 1000m BUFFER DISTANCE AROUND THE SURVEYED ROADS (ADAPTED FROM “MOVE” PROJECT) AND SNAKE ROADKILL NUMBER.

Statistical Analysis

To investigate the importance of spatial factors and find patterns and magnitudes of parameters influencing roadkill, Generalized Linear Models (GLM) were built using a Poisson error distribution with a log link function. Models developed were used for model selection and multimodel inference (MMI) within an information theoretic approach.

TABLE 1 – SEVERAL SNAKE FEATURES THAT MAY INFLUENCE ROADKILL IN SOUTHERN PORTUGAL.

Scientific Name ^a	English ^a & Portuguese ^d	Main Prey ^b	Biotope ^b (study area)	Abundance ^a	Size ^b SVL ^e (mm)	Foraging Mode ^b	Activity ^b	Home Range ^b (ha)	Seasonal Activity ^b
Colubridae									
<i>Coronella girondica</i>	Southern Smooth Snake Cobra lisa bordalesa	Lizards Arthropods	Grassland Open woodlands Orchards Plantations Rocky areas Scrubland	Uncommon	496 (total length)	Active	Crepuscular Nocturnal	NA	Mar -Nov
<i>Hemorrhois hippocrepis</i>	Horseshoe Whip Snake Cobra de ferradura	Mammals Reptiles	Agricultural land Open spaces Riparian galleries Scrubland (low cover) Rocky areas or human structures	Common	891	Active	Diurnal Crepuscular Nocturnal (summer)	NA	
<i>Macroprotodon brevis</i>	False Smooth Snake Cobra de capuz	Reptiles	Mediterranean forests (e.g. Oak and pine) Pastureland (near water) Riparian galleries Scrublands	Uncommon	286	Sit and wait	Nocturnal	NA	Mar -Nov
<i>Rhinechis scalaris</i>	Ladder Snake Cobra de escada	Endothermic vertebrates	Agricultural land Oak woodlands and scrubland (field edges) Overgrown areas Riparian galleries Stone walls and ruins	Abundant	720	Active	Diurnal ^c Crepuscular Nocturnal (summer)	0.32 - 4.87	Apr -Oct
Natricidae									
<i>Natrix maura</i>	Viperine Snake Cobra de água viperina	Fish Amphibians	Ponds (in meadows and open woodland) Streams	Abundant	770	Sit and wait	Diurnal	0.7 - 5.8	Mar -Oct
<i>Natrix natrix</i>	Grass Snake Cobra de água de colar	Amphibians	Dense scrubland Grassland Oak and mixed forests (field edges) Riparian galleries	Abundant (rare in southern Portugal)	152 -900 (min - max)	Active	Diurnal	NA	Mar -Nov
Psammophiidae									
<i>Malpolon monspessulanus</i>	Montpellier Snake Cobra rateira	Mammals Reptiles	Agricultural land Open oak woodland Open spaces (e.g. grassland, meadows) Riparian galleries Ruins, parks, dumps Scrubland (low cover)	Common	723	Active	Diurnal	0.39 - 5.41	Feb -Nov

a -IUCN Red List of Threatened Species (IUCN 2013); b -Enciclopedia virtual de los vertebrados españoles (Carrascal & Salvador 2009); c -Exception in southwest Iberian Peninsula, it is generally nocturnal; ^dAtlas dos Anfíbios e Répteis de Portugal (Loureiro *et al.* 2010); ^e mean snout -vent length (SVL), except for *C. girondica* and *N. natrix*.

Response and Explanatory Variables

Several explanatory variables were analysed so as to understand the spatial behaviour of snakes that leads to crossing a road in a specific area. Variables including topographical (altitude and roughness), road type, land cover and landscape metrics variables were used for this purpose.

Thus, road lines were extracted from a digital aerial photo (source: Bing Maps aerial imagery web mapping service). For analytical purpose the selected roads were divided either in 250 or 500m segments. Each road segment had a centroid attributed that contained the roadkill numbers for every recorded snake species. These constituted the response variables. Despite initially dividing roads in 250 segments, these were not used because too many zeros were present in the species data. After extracting the response variables from the centroids in the 500m segmented roads, three snake species (e.g. *C. girondica*, *M. brevis* and *N. natrix*) were excluded from further analyses of individual species for not having enough data to be included in the statistical analysis. Besides the remaining four (snake) response variables, a fifth variable was created accounting for the snake community in the study area (but aquatic species were excluded).

I used digital layers with landscape classification available from previous studies included in the “MOVE” project. Before extracting the environmental variables, an optimum spatial scale had to be selected for this study area. To our knowledge, there is no study yet focusing on buffers in a roadkill framework for snakes. That being the case, we extracted variables at three spatial extents 250m, 500m and 1000m (Langen 2009) in order to select the most suited spatial scale for this study.

The altitude variables were gathered from the SRTM 90m digital elevation database v4.1 (Jarvis *et al.* 2008). In addition to extracting the “Mean Altitude”, a “Roughness Index” was created based on the standard deviation of the elevation. Roughness index variables have already been used in other wildlife studies (Rood, Ganie & Nijman 2010), including snakes (Fitzgerald *et al.* 2005).

Land uses were reclassified into eight main groups: “Agricultural Land” including olive groves, vineyards, exotic plantations (e.g. eucalyptus) and other types of cropland, “*Montado*” with oak tree cover >10%, “Open *Montado*” with oak tree cover <10%, “Open Area”, mostly comprised of fallow land and meadows, “Shrub Area” including all land use types covered with shrubs (e.g. *Montado* with shrubs), “Water Source” with permanent ponds, “Riparian Gallery” and “Human Influenced Area” comprising cities, villages and also areas with some human influence such as farmhouses.

Landscape metrics that could have biological meaning were extracted, namely: “Distance to Riparian Gallery”, a land use reported to have implications in some snake species roadkill (Pleguezuelos 2009b; Santos 2009) and “Distance to Water Source” which could be important for the aquatic snake species as it strongly depends on water. Distances were measured from each centroid to the nearest land cover feature without a spatial extent limit. Other landscape metrics that could describe snake habitat use included either fragmentation or field edges, more specifically in agricultural land (Pleguezuelos 2009b). For this purpose we extracted an “Agricultural Mean Patch Edge” variable.

All variables were obtained using ArcGIS 10.1 software (ESRI 2012). Altitude variables were extracted with the help of a modified version of the script “ACCRU tools” (Nielsen 2010) allowing its use in a more recent version of ArcGIS. This tool easily enabled calculations for overlapping buffers. The “Agricultural Mean Patch Edge” variable was extracted with the aid of the Patch analyst 5.1 extension for ArcGIS (Rempel, Kaukinen & Carr 2012).

Model Development and Selection

Generalized linear models with all variable combinations were built using a Poisson error distribution, with a log link function, which is the recommended distribution used for count data (Burnham & Anderson 2002; Zurr, Ieno & Smith 2007).

An 'all possible combinations' approach seemed more adequate as knowledge of the influence of spatial factors in snake roadkill is scarce, not allowing the construction of adequate a priori models at this stage. Hence, modelling was used as a tool to explore spatial factors influencing roadkill rather than to predict roadkill locations (Arnold 2010; Burnham & Anderson 2002).

Modelling procedures were used within information -theoretic framework. This approach is advantageous because it allows (Burnham & Anderson 2002):

- 1- the simultaneous comparison of the relative importance of multiple environmental factors;
- 2- to account for model selection uncertainty, drawing better inferences because parameter estimates are calculated with more precision and less bias through model averaging.

Regarding the criteria to validate the selection of models, among the Ecology forums are controversial debates focused on elucidating the pros and cons of using either the p -value or the Akaike Information Criterion (AIC), and the proper use of these two statistics in model selection. Lavine (2014) actually summarizes the common ground around these criteria:

- p -values, confidence intervals, and AIC are statistics based on the same statistical information;
- these statistics are descriptive and they should not be used as formal quantification of evidence;
- we should abandon the binary (accept/reject) declarations, whether it is based on p -values or AIC;
- we should be careful when interpreting a p -value or AIC as strength of evidence (the same p -value, say 0.01, in two problems may represent very different strength);

- above all, we should interpret the model based on plots and checks of assumption compliance.

But Burnham & Anderson (2014) vehemently rejected the defence of p -values and insisted that we should use AIC when choosing among multiple alternative models. They dismissed hypothesis testing as the 20th century statistical science, and proclaimed the use of AIC as the 21st century statistical science.

I am not able to discuss further with refined arguments the statistical ground bases around that controversy. Here I use the AIC as the appealing criteria for ecologists as one works with complex systems, though the correct model is often elusive. Thus, my model selection criteria was based in the Akaike Information Criterion adjusted to small sample sizes (AICc), which is mostly used when number of parameters exceeds $n/40$ (where n is sample size; Burnham & Anderson 2002; Johnson & Omland 2004).

Throughout the study, modelling procedures used one of the two model selection criteria, the ΔAICc or the AICc weights (w_i). While the ΔAICc compares each model with the best model (model with the lowest AICc),

$$\Delta_i \text{AICc} = \text{AICc}_i - \text{AICc}_{\min},$$

, therefore being useful in ranking models, the w_i quantifies the likelihood of each model being the best model,

$$w_i(\text{AICc}) = \frac{\exp\left[-\frac{1}{2} \times \Delta_i(\text{AICc})\right]}{\sum_{k=1}^K \exp\left[-\frac{1}{2} \times \Delta_k(\text{AICc})\right]},$$

, given the set of models (being K the set of models, Burnham & Anderson 2002).

Collinearity amongst explanatory variables may be problematic because it can lead to parameter bias and difficulties in determining true relationships (Dormann *et al.* 2013; Freckleton 2011; Grueber *et al.* 2011). Hence, prior to model development, collinearity between explanatory variables was checked using Spearman's rank correlation. If variables were correlated ($r > 0.7$) one of them was removed from analysis (Dormann *et al.* 2013; Zurr, Ieno & Smith 2007). "Mean Altitude" and

“Roughness Index” and also “Agricultural Land” and “Agriculture Mean Patch Edge” were strongly correlated so “Mean Altitude” and “Agriculture Mean Patch Edge” were discarded from further analysis. Twelve environmental variables remained containing land cover, landscape metrics and terrain features (Table 3).

It was not feasible to use all of the remaining environmental variables, as it would produce a huge number of models (2^k , k being the number of parameters). Therefore, after a careful review of the existing literature previously summarized in this study (Table 1; Fitzgerald *et al.* 2005; Pleguezuelos 2009b; Santos 2009), environmental variables that were perceived as less important snakes’ ecological requirements for snake community and chosen individual snake species were removed. Steps taken in model development, selection and multimodel inference were summarized in Table 2 and further explained below.

TABLE 2 - SEQUENTIAL MAIN STEPS APPLIED IN MODEL DEVELOPMENT, SELECTION AND MULTIMODEL INFERENCE WHETHER FOR THE FOUR INDIVIDUAL SPECIES (*R. scalaris*, *M. monspessulanus*, *N. maura*, *H. hippocrepis*) OR FOR THE SNAKE COMMUNITY RESPONSE VARIABLES.

1	Build 3 global models for each response variable representing the spatial extents to be examined;
2	Detect and add the autocovariate terms to global models with spatial autocorrelation;
3	Find curvilinear relationships between response and explanatory variable and add corresponding quadratic term to the global models;
4	Compare final global models of 3 spatial extents and select the ones within a $\Delta AICc$ of 2 units;
5	Use the 5 final global models to build models with all possible combinations of variables;
6	Calculate $AICc$, $\Delta AICc$, w_i and rank models;
7	Build model subsets by selecting models with a $\Delta AICc < 6$;
8	Employ model averaging to model subsets;
9	Recalculate w_i for models in the selected subsets;
10	Calculate the parameters variable relative importance in each model subset.

Spatial autocorrelation is a known issue in studies involving ecological data. Not dealing with spatial autocorrelation does in fact impact coefficient and inference results of statistical analysis (De Frutos, Olea & Vera 2007; Dormann 2007; Keitt *et al.* 2002). To address this issue, a Moran’s I analysis was performed to assess if spatial autocorrelation was present in the species data. If spatial autocorrelation was

detected, an autocovariate term was created for the corresponding response variable and forced into the model development phase (Augustin, Muggleston & Buckland 1996). Both the Moran's I and the autocovariate term were calculated through the "spdep" package for R v.3.0.2 software (Bivand 2014).

The relationship between response and environmental variables was checked comparing models. For each variable, a linear, a quadratic and a null model (including the autocovariate term when appropriate) were built and compared using the AICc weights as the model selection criteria. The shape of the fitted curves was visually checked (Pita, Mira & Beja 2013). Prior to exploring the curvilinear relationships, explanatory variables were centred and standardized. Centring controlled for collinearity problems that could arise with the use of quadratic terms and standardizing helped in the interpretation of upcoming results that included variables with different scales (Grueber *et al.* 2011). A spatial scale was selected by constructing global models only including variables of each spatial extent (250m, 500m and 1000m), besides the variables without spatial limit. Only models within an AICc of 2 units from the most supported model (lowest AICc) were selected (Burnham & Anderson 2002).

Model fit was confirmed by checking the final global models overdispersion for each response variable using the variance inflation factor (VIF), which should be lower than 2 (Burnham & Anderson 2002; Zurr, Ieno & Smith 2007). Variables in the final global models were the starting basis to develop models with all possible combinations of variables. When quadratic terms were present, the variable's linear and quadratic terms were always added simultaneously.

All models built were ranked from lowest to highest Δ AICc and a cutting point of Δ AICc=6 was used as a confidence set to assure that only models with the most supported evidence were selected (Grueber *et al.* 2011, Richards 2005, Richards 2008). Model development and selection was performed with the help of the "MuMIn" package for R v.3.0.2 software (Barton 2013; R Core Team 2013).

Multimodel Inference

Multimodel inference (MMI) is increasingly favoured over using only a single best model because inferences drawn from one best model can be relatively poor (Burnham & Anderson 2002). In this study, multimodel inference was used for model averaging and to assess the relative importance of variables. Thus, model averaging allowed investigating the direction and magnitude of effect size (Burnham & Anderson 2002) of multiple landscape features in snake roadkill. This technique calculates model averaged parameter estimates and corresponding unconditional standard errors for the chosen subset of models with suitable measures of precision (Burnham & Anderson 2002).

The variable relative importance (VRI) is calculated by summing the w_i over all models in the subset which include the given variable. The larger the VRI the more important is the variable relative to other variables and can therefore be ranked by importance (Burnham & Anderson 2002). For this purpose, the w_i of each response variable was calculated for all the selected subset of models. Since a variable relative importance (VRI) value of 0.40 or above has been suggested to have a good chance of indicating that a given variable has influence in the process at study (Converse, Block & White 2006), I chose to use this minimum value to select parameters most relevant to snake roadkill in this study. Model averaging was performed with the “MuMIn” package for R v.3.0.2 software (R Core Team 2013, Barton 2013) and variable relative importance was calculated using Microsoft Office Excel 2010.

TABLE 3- DESCRIPTION OF THE EXPLANATORY VARIABLES USED IN MODEL SELECTION AND MULTIMODEL INFERENCE.

Name	Code	Description (Unit)	Buffer Distance (m)	Mean ± SE	Range
Agricultural Land	AGR	Total area of crops and plantations (e.g. eucalyptus plantation, olive grove, vineyard) per road segment (ha)	250	3.2 ± 5.7	0 - 22
			500	8.2 ± 12.6	0 - 52
			1000	20.6 ± 21.5	0 - 75
Human Influenced Area	HUM	Total areas with higher human influence (e.g. city, village, farmhouse) per road segment (ha)	250	0.8 ± 2.3	0 - 15
			500	2.0 ± 5.0	0 - 35
			1000	6.0 ± 14.7	0 - 100
Montado	MONT	Total area of <i>Montado</i> with oak tree cover >10% per road segment (ha)	250	13.2 ± 12.5	0 - 45
			500	39.0 ± 32.6	0 - 128
			1000	128.4 ± 87.6	0 - 378
Open Area	OPA	Total area of pastureland, meadows and grasslands per road segment (ha)	250	19.6 ± 14.2	0 - 27
			500	56.1 ± 36.1	0 - 66
			1000	179.8 ± 96.2	0 - 166
Open Montado	OMONT	Total area of <i>Montado</i> with oak tree cover <10% per road segment (ha)	250	5.0 ± 6.4	0 - 27
			500	13.6 ± 13.9	0 - 66
			1000	42.7 ± 33.8	0 - 166
Riparian Gallery	RIP	Total area of riparian gallery per road segment (ha)	250	0.3 ± 0.6	0 - 3
			500	0.9 ± 1.4	0 - 7
			1000	3.5 ± 3.7	0 - 15
Shrub Area	SHR	Total area of shrubs per road segment (ha)	250	1.9 ± 4.3	0 - 21
			500	6.9 ± 11.7	0 - 56
			1000	27.7 ± 34.6	0 - 147
Water Source	WS	Total area of permanent ponds per road segment (ha)	250	0.1 ± 0.3	0 - 2
			500	0.6 ± 1.5	0 - 9
			1000	2.5 ± 3.3	0 - 17
Roughness Index	RI	Terrain mean roughness per road segment	250	6.4 ± 2.2	2 - 15
			500	9.5 ± 3.2	3 - 17
			1000	14.3 ± 5.6	5 - 32
Distance to Water Source	DWS	Distance to the nearest water source (m)	-	493.5 ± 276.8	28 - 1298
Distance to Riparian Gallery	DRIP	Distance to the nearest stream with riparian gallery (m)	-	795.2 ± 509.7	20 - 2007
Road Type	ROAD	ROADA - National road ROADB - Municipal road	-	-	-
Autocovariate Term	ATC	-	-	-	-

RESULTS

A total of 574 snakes comprising seven different species were killed in 2 years. Most snake roadkill data belonged to *R. scalaris* (n=281, 49%) followed by *M. monspessulanus* (n=158; 27.5%) accounting for 76.5% of the recorded data (Table 4).

TABLE 4 – SNAKE ROADKILL COUNT FOR FOUR ROADS SURVEYED IN THE STUDY AREA FROM 16 OF MARCH 2010 TO 15 OF MARCH 2012.

Snake species	N4	N114	M370	M529	Snake total	% total
Species not identified	6	11	0	0	17	3
Colubridae						
<i>Hemorrhois hippocrepis</i>	21	13	2	3	39	6.8
<i>Coronella girondica</i>	6	4	3	1	14	2.4
<i>Macroprotodon brevis</i>	3	7	4	4	18	3.1
<i>Rhinechis scalaris</i>	95	134	32	20	281	49
Natricidae						
<i>Natrix maura</i>	13	27	4	2	46	8
<i>Natrix natrix</i>	0	1	0	0	1	0.2
Psammophiidae						
<i>Malpolon monspessulanus</i>	50	74	17	17	158	27.5
Road total	194	271	62	47	574	100

Spatial autocorrelation was detected in the snake community, *R. scalaris* and *H. hippocrepis* response variables (Table 5). Environmental variables with a curvilinear relationship were also found (Table A1).

TABLE 5 - MORAN'S I, Z AND P VALUES FOR THE SNAKE COMMUNITY AND INDIVIDUAL SPECIES¹.

Response variable	Moran's I	Z	p -value
Snake community	0.327	3.399	<0.001
<i>H. hippocrepis</i>	0.282	3.297	<0.001
<i>R. scalaris</i>	0.255	2.690	<0.001
<i>N. maura</i>	0.095	1.231	0.109
<i>M. monspessulanus</i>	0.041	0.516	0.303

¹ -Significant Z and p values are in bold.

Models with a 1000 m spatial scale were selected for the snake community, *H. hippocrepis* and *R. scalaris*, with the exception of *N. maura* and *M. monspessulanus*, with a 250 m and 500 m spatial extent, respectively (Table 6).

TABLE 6 - BUFFER SIZE FOR THE SNAKE COMMUNITY AND INDIVIDUAL SPECIES.

Response variable	Buffer Distance (m)
Snake community	1000
<i>H. hippocrepis</i>	1000
<i>R. scalaris</i>	1000
<i>N. maura</i>	250
<i>M. monspessulanus</i>	500

The selected buffers' quadratic terms had a strong support of evidence towards selecting the quadratic models, with the exception of Riparian Gallery for *R. scalaris* and Open Area for *N. maura* and *H. hippocrepis* that had less obvious relationships (Table A1 in the final Appendices). Five final global models were obtained after selecting the models with most supported spatial extent variables (Table 7).

TABLE 7 - FINAL GLOBAL MODELS FOR THE SNAKE COMMUNITY AND RESPONSE VARIABLES OF FOUR SPECIES.

Response variable	Global model	VIF
Snake community	SNK~AGR+AGR ² +MONT+OMONT+OPA+HUM+SHR+RIP+RI+RI ² +DRIP+ROAD+ATC	1.52
<i>H. hippocrepis</i>	HH~AGR+OPA+OPA ² +SHR+RIP+HUM+HUM ² +RI+DRIP+DRIP ² +ROAD+ATC	1.77
<i>R. scalaris</i>	RS~AGR+AGR ² +MONT+OMONT+SHR+RIP+RIP ² +RI+RI ² +DRIP+ROAD+ATC	1.51
<i>N. maura</i>	NM~OMONT+OPA+OPA ² +WS+WS ² +RIP+RI+RI ² +DWS+DRIP+ROAD	1.63
<i>M. monspessulanus</i>	MM~AGR+OMONT+OPA+SHR+RIP+HUM+RI+RI ² +DRIP+ROAD	1.12

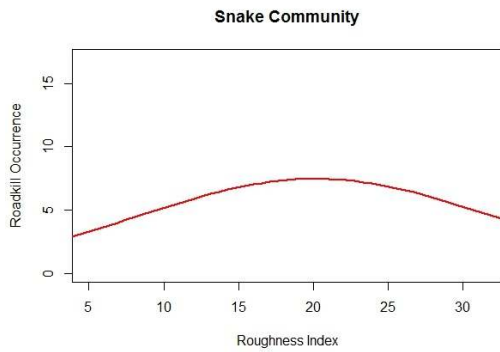
Snake community had 119 models selected for MMI (Table B1). Only the Distance to Riparian Gallery (DRIP) had relatively less support compared to all the other environmental variables. The Roughness Index (RI) was humped shaped (unimodal), having most impact in roadkill at intermediate levels and Agricultural Land (AGR) was mostly composed of a right sided curve, having relatively high roadkill impact up to intermediate levels (Figure 3). Also, *Montado* (MONT), Riparian Gallery (RIP) and Human Influenced Area (HUM) parameters were positively associated to roadkill. In contrast, Shrub (SHR), Road Type (ROAD), Open Area (OPA) and Open *Montado* (OMONT) were negatively associated to roadkill (Table 8).

TABLE 8 - MODEL AVERAGING AND VARIABLE RELATIVE IMPORTANCE (VRI) RESULTS FOR THE SNAKE COMMUNITY¹.

Explanatory Variable	Estimate	Unconditional SE	VRI%
RI²	- 0.114	0.044	99
RI	0.236	0.077	
MONT	0.191	0.452	79
SHR	- 0.269	0.180	79
ROAD	- 0.338	0.156	76
OPA	- 0.095	0.562	68
RIP	0.103	0.061	56
HUM	0.092	0.083	55
AGR²	- 0.125	0.065	53
AGR	0.020	0.163	
OMONT	- 0.198	0.195	52
DRIP	- 0.015	0.062	23
(Intercept)	1.887	0.154	-
(ATC)	- 0.010	0.020	-

1 -VRI most influential factors are in bold.

a)



b)

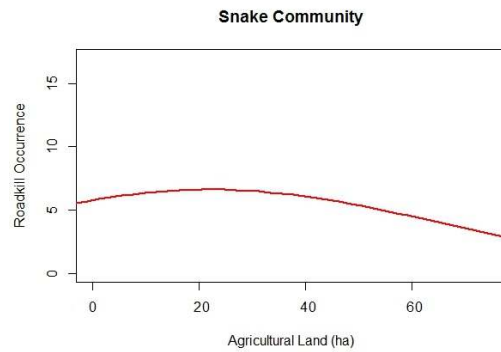


FIGURE 4 – SNAKE COMMUNITY RELATIONSHIPS BETWEEN ROADKILL OCURRENCE AND a) ROUGHNESS INDEX OR b) AGRICULTURAL LAND.

The horseshoe whip snake *H. hippocrepis* had 66 models selected (Table B2). Human influenced areas were highly influential followed by the Distance to Riparian Gallery. Human influenced areas had a noticeable positive association in roadkill and distance to riparian galleries had the most negative impact at intermediate distances. The Roughness Index had some relative importance and was negatively associated to roadkill. Several other variables had a low relative importance (ROAD, AGR, OPA, SHR and RIP) and were marginally negatively associated to roadkill, except for Shrub and Riparian gallery that had a marginal positive association (Table 9).

TABLE 9 - MODEL AVERAGING AND VARIABLE RELATIVE IMPORTANCE RESULTS FOR THE HORSESHOE WHIP SNAKE *Hemorrhhois hippocrepi*¹.

Explanatory Variable	Estimate	Unconditional SE	VRI
HUM²	- 0.103	0.063	100
HUM	1.153	0.336	
DRIP²	- 0.607	0.281	78
DRIP	0.050	0.294	
RI	- 0.313	0.262	38
ROAD	- 0.636	0.566	34
OPA²	0.048	0.215	24
OPA	- 0.407	0.248	
AGR	- 0.173	0.274	21
SHR	0.101	0.222	19
RIP	0.091	0.235	18
(Intercept)	- 0.692	0.374	-
(ATC)	- 0.269	0.194	-

1 - VRI most influential factors are in bold.

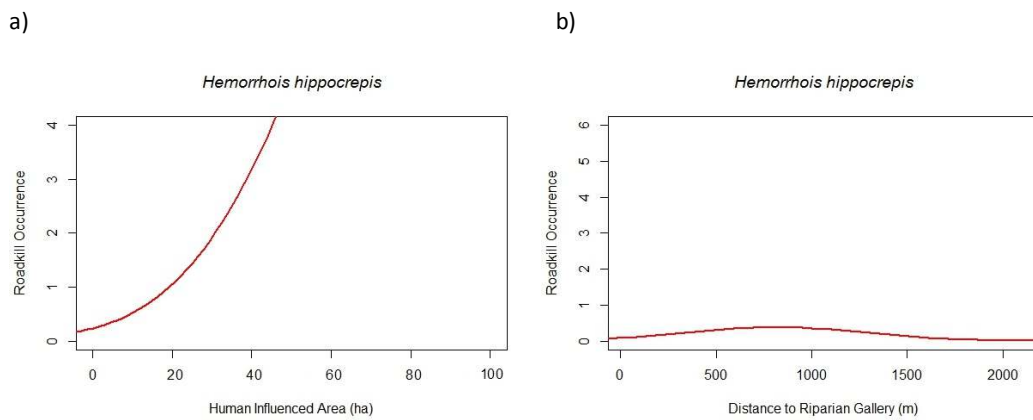


FIGURE 5 – *H. hippocrepi* RELATIONSHIPS BETWEEN ROADKILL OCCURRENCE AND a) HUMAN INFLUENCED AREA OR b) DISTANCE TO RIPARIAN GALLERY.

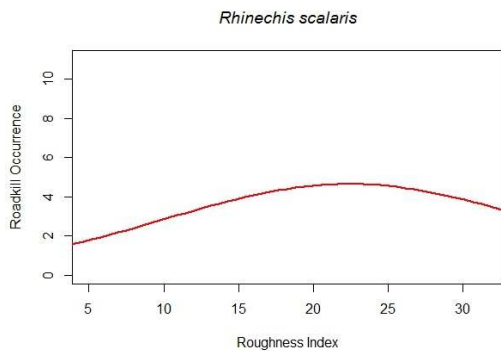
Twenty seven models were selected to analyse the environmental variables that influence the ladder snake *R. scalaris* (Table B3). Shrub, Road Type and Open *Montado* were negatively associated to roadkill, as opposed to the *Montado* variable that was positively associated. The Roughness Index and Agricultural Land were positively associated to roadkill up to intermediate levels, with a negative association after this threshold (Figure 4). The least important variables were the Distance to Riparian gallery and Riparian Gallery variables (Table 11).

TABLE 10 - MODEL AVERAGING AND VARIABLE RELATIVE IMPORTANCE RESULTS FOR THE LADDER SNAKE *Rhinechis scalaris*¹.

Explanatory Variable	Estimate	Unconditional SE	VRI%
SHR	- 0.318	0.096	100
MONT	0.311	0.077	100
RI²	- 0.102	0.059	91
RI	0.293	0.102	
AGR²	- 0.231	0.091	85
AGR	0.150	0.122	
ROAD	- 0.405	0.204	69
OMONT	- 0.147	0.090	52
DRIP	0.051	0.070	24
RIP²	0.105	0.065	23
RIP	- 0.077	0.104	
(Intercept)	1.364	0.185	-
(ATC)	- 0.040	0.040	-

1 -VRI most influential factors are in bold.

a)



b)

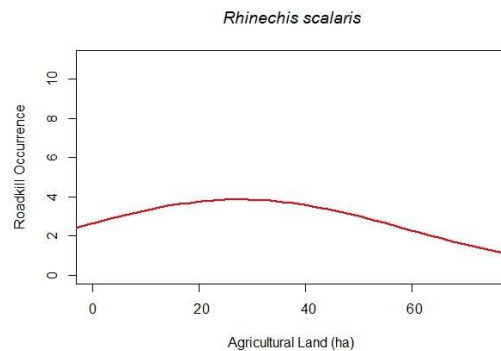


FIGURE 6 – *R. scalaris* RELATIONSHIPS BETWEEN ROADKILL OCURRENCE AND a) ROUGHNESS INDEX OR b) AGRICULTURAL LAND.

Model selection for the viperine snake *N. maura* resulted in 60 models (Table B4). Two highly influential variables were found, the Distance to Water Source (DWS) and Water Source (WS). Water source distance to roads was negatively associated to roadkill, as well as water source. In the first case, roadkill probability decreased as a water source became more distant from the road and in the second case the probability of a roadkill declined with increasing amount of water source (Figure 5). Open *Montado*, Open Area and Road Type were negatively associated to roadkill and still had a medium level influence in roadkill. The Roughness Index, Distance to

Riparian Gallery and Riparian Gallery showed a slight negative association to roadkill even though they were considered to have relatively low importance in the model set considered (Table 10).

TABLE 11 - MODEL AVERAGING AND VARIABLE RELATIVE IMPORTANCE RESULTS FOR THE VIPERINE SNAKE *Natrix maura*¹.

Explanatory Variable	Estimate	Unconditional SE	VRI
DWS	- 0.768	0.268	100
WS²	0.164	0.073	100
WS	- 0.559	0.382	
OMONT	- 0.425	0.257	63
OPA²	0.370	0.229	47
OPA	- 0.326	0.193	
ROAD	- 0.616	0.471	45
RI²	- 0.091	0.187	33
RI	- 0.320	0.220	
DRIP	- 0.140	0.181	29
RIP	- 0.080	0.200	25
(Intercept)	- 1.439	0.379	-

1 -VRI most influential factors are in bold.

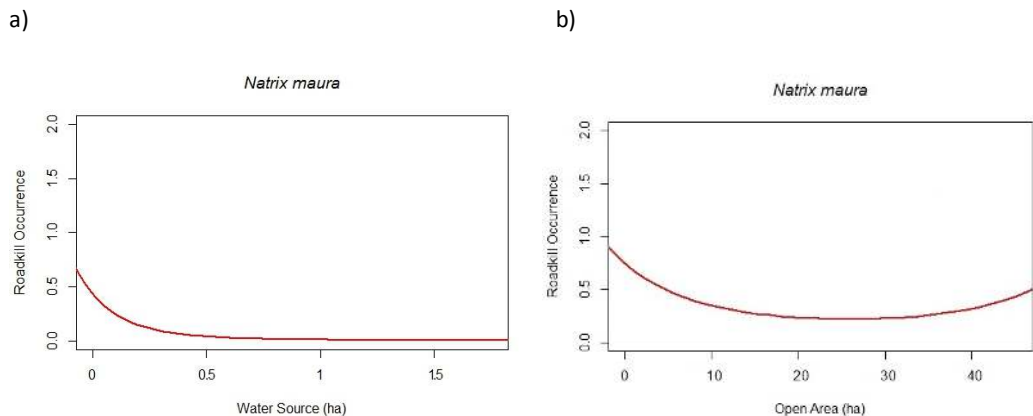


FIGURE 7 – *N. maura* RELATIONSHIPS BETWEEN ROADKILL OCCURENCE AND a) WATER SOURCE OR b) OPEN AREA.

A great number of models were generated for the rat snake *M. monspessulanus* showing some model uncertainty (Table B5). *M. monspessulanus* didn't have strongly influential landscape variables related to area amount or distance. However, the Roughness Index was considered an important variable with a hump shaped curve, leading to increased roadkill up to intermediate levels (Figure 6). Road

Type was also an important variable and was negatively associated to roadkill (Table 12).

TABLE 12 - MODEL AVERAGING AND VARIABLE RELATIVE IMPORTANCE RESULTS FOR THE RAT SNAKE *Malpolon monspessulanus*¹.

Explanatory Variable	Estimate	Unconditional SE	VRI%
ROAD	- 0.446	0.222	81
RI²	- 0.122	0.074	81
RI	0.260	0.107	
AGR	- 0.108	0.091	38
DRIP	- 0.091	0.088	33
SHR	- 0.100	0.099	33
OMONT	0.093	0.094	30
HUM	0.069	0.073	29
RIP	0.004	0.091	20
OPA	0.001	0.102	20
(Intercept)	0.620	0.112	-

1 -VRI most influential factors are in bold.

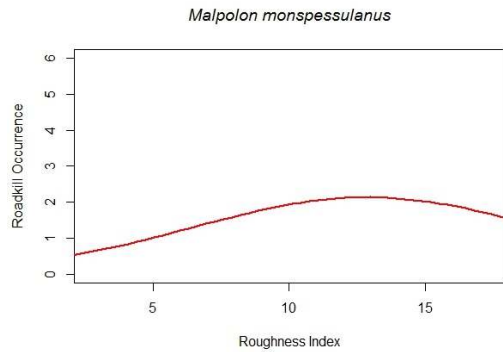


FIGURE 8 - *M. monspessulanus* RELATIONSHIP BETWEEN ROADKILL OCURRENCE AND ROUGHNESS INDEX.

DISCUSSION

Habitats influencing the movement of wildlife have been pointed as an influential characteristic for several vertebrates in determining roadkill locations (Clevenger, Chruszcz & Gunson 2003; Forman & Alexander 1998). And so the main objective of this study was to find connections and associated patterns between snake road crossing and snake habitat features in the roads surroundings that could influence roadkill events. For this purpose, landscape variables usually associated to snakes were used, plus a roughness index and a road type variable.

Since roadkill was recorded daily, one can expect that the endurance of snake carcasses on the pavement wasn't much influenced whether by scavenging or by tire removing in the road, which most likely varies across regions and habitats (Degregorio *et al.* 2011; Santos, Carvalho & Mira 2011). Indeed, Santos, Carvalho & Mira (2011) found that the persistence of snake carcasses in their study was around one day.

Most snake roadkill in the study area belonged to *R. scalaris* and *M. monspessulanus*, which are both considered to be abundant species (Loureiro *et al.* 2010; Malkmus 2004; Salvador & Pleguezuelos 2002). These snakes have a diurnal activity and are active feeders, increasing their chance to encounter vehicles as these are more frequent during the day. Moreover, small mammals are often relatively abundant in road verges which may attract snakes searching for prey (Ruiz-Capillas, Mata & Malo 2013), also in the study area (Sabino-Marques & Mira 2011). Snakes with the least records were *C. girondica*, *M. brevis* and *N. natrix*. The first two species are nocturnal with relatively low abundances in Southern Portugal (Malkmus 2004), which may explain their low roadkill numbers. Finally, *N. natrix* is a rare species in its southern distribution limits, possibly due to the suboptimal habitat characteristics (Santos *et al.* 2002), so it can be expected for roadkill counts to be scarce.

In general terms, habitat cover was an important factor influencing snake community roadkill, although results may be biased towards the most abundant species in the data set. *Montado*, riparian galleries and human influenced area cover were linked to a higher probability of roadkill while shrubs, open areas and open *Montado* cover were linked to a lower probability of roadkill in the snake community.

The *Montado* was the most important habitat cover influencing roadkill occurrence in snake community and second most important for *R. scalaris*. Even though other habitat types are important for snakes, a study has shown that oak woodland can be a crucial feature for Mediterranean snake communities and are often used in the hot and dry summer to avoid high temperatures (Filippi & Luiselli 2006). Also, the *Montado's* inherent diversity comprised of a mosaic of open area and woodland with different tree density provides a structurally complex habitat most favoured by Mediterranean snake communities (Luiselli & Filippi 2006).

Snake community results also showed that riparian galleries cover and distance had a medium relative importance, whereas individual species showed that other environmental factors are relatively more important. Riparian galleries have been considered an habitat used by many snake species in the study area (Feriche 2009; Pleguezuelos & Brito 2008; Pleguezuelos 2009a; Pleguezuelos 2009b) and have already been suggested as the main cause in roadkill events of some of these species (Pleguezuelos 2009b, Santos 2009). Nevertheless, one suspects that perhaps other features associated to riparian galleries may be more important than cover or distance alone. Riparian galleries are usually long and thin and consequently have an extensive interface with adjacent habitats. The structural complexity that riparian galleries and their surroundings offer could be more meaningful than the riparian gallery alone, for example. In spite of most individual species showing a relative weak importance compared to other factors, the snake *H. hippocrepis* was an exception showing a higher roadkill probability at medium distances of riparian galleries, around 800 m.

The increase in human influenced cover increased roadkill probability for snake community and highly increased the chances of a roadkill happening for *H. hippocrepis*. Human influenced areas may be used by some snake species (*R. scalaris*, *M. monspessulanus*), but to a lesser extent compared with *H. hippocrepis* which adapts well to these environments (Feriche 2009). It seems that to a certain degree snakes have commensal liaisons with man activities, particularly with activities that directly favour rodent commensal populations (Malkmus 2004; Salvador & Pleguezuelos 2002). This may explain why this factor could be crucial in determining roadkill impact. As for *H. hippocrepis*, this species prefers rocky areas, so it uses human constructions as a

substitute and may even be encountered in more urban environments (Feriche 2009). Due to such a strong dependency on human structures, the expansion of human development and roads may greatly increase *H. hippocrepis* roadkill numbers, which is considered the most anthropophilic snake in the Iberian Peninsula (Salvador & Pleguezuelos 2002).

Conversely, agricultural land had medium importance in snake community roadkill, slightly increasing roadkill probability up to 20 ha of cover and greatly decreasing after this threshold. Agricultural land may offer favourable prey availability which explains why snakes may be killed while foraging for food in these areas. Results were similar for *R. scalaris* showing a slightly higher turning point at 25 ha of cover. In Portugal, *R. scalaris* is well adapted to traditional agricultural areas (with a mosaic pattern) where it can easily find places to hide and hunt animals, such as small mammals (Pleguezuelos 2009b). On the other hand, areas with intensified agriculture may be avoided because they are overly simplified and use too many pesticides.

In general terms, snake community had a lower probability of roadkill if the cover of open areas and open *Montado* was higher in the study area. A similar relationship was also shown for *R. scalaris* in open *Montado*. Even though open spaces may be attractive for basking, an increased extent of these areas may endanger snakes survival. Without the presence of hiding features snakes may be exposed to a greater risk of predation (e.g. birds of prey) and tend to avoid open terrain (Andrews, Gibbons & Jochimsen 2006). Open *Montado* as characterized in this study was composed of sparsely dispersed oak trees with less than 10% tree cover probably offering similar conditions of those present in open spaces.

Similarly, shrubs were also considered an important factor with a higher cover leading to lower roadkill for snake community and *R. scalaris*. Another study also found that snake mortality rate was lower in shrub habitat (Pragatheesh & Rajvanshi 2013). Perhaps the increase of shrub cover may lead to a structurally simplified habitat which can be considered unsuitable habitat for snakes. Actually, a Mediterranean snake species elsewhere was mostly associated to bushes when interspaced with open

grassy fields (Capula *et al.* 1997), so a similar behaviour could be expected from other Mediterranean snakes.

Indeed, the majority of terrestrial snake species (*H. hippocrepis*, *M. monspessulanus* and *R. scalaris*) have a generalist behaviour occupying a wide variety of niches (Malkmus 2004, Salvador & Pleguezuelos 2002). I suggest that the weak relationship that *M. monspessulanus* had with landscape factors may be due to being the most generalist species within the snake community. Fortunately, because of its huge plasticity and annual rising temperatures, it is less likely that roadkill is having a negative impact in its populations. Actually, an article has even mentioned an increase in populations for the studied area, as opposed to other snakes (Segura *et al.* 2007). We should expect the same trend for *R. scalaris*, however roadkill numbers in Portugal are very high and it is already suspected that population numbers are declining (Pleguezuelos 2009b). Consequently, roads are considered one of the biggest threats for this species.

Despite *M. monspessulanus* roadkill not showing influential landscapes, the roughness index was highly influential in determining roadkill. Likewise, snake community and terrestrial snakes studied were all associated to a roughness index with relatively high importance. Roadkill for snake community, *R. scalaris* and *M. monspessulanus* was higher at medium levels of roughness and, in the case of *H. hippocrepis*, roadkill probability decreased as terrain got rougher. Taking into account topographic features such as the roughness index or even other related features, as for instance slope or mean altitude, may be an important addition in finding spatial patterns that lead to snake roadkill, even more so for habitat generalist species.

Other parameters such as water source cover and distance were considered crucial factors in determining *N. maura* roadkill. *Natrix maura* is an aquatic species that is strongly dependent on aquatic features (Malkmus 2004, Santos 2009). Findings in our study verify this strong dependency, as *N. maura* roadkill showed a strong link to water source distance and cover. Here, this species may have no links to terrestrial habitats due to its aquatic habits and is quite adaptable too any kind of water source. It has even been seen in water sources altered by agricultural activities (Santos 2009),

even though mass population declines have been reported for polluted aquatic sources (Santos 2008).

Roads in the study area differ mostly because of their traffic volume. The national roads reach up to 10000 vehicles per day compared to municipal roads that have less than 4000 vehicles per day. We found that snakes mortality was higher in national roads than in municipal roads. Other studies have already discovered that snake roadkill is closely linked to traffic volumes (Colino-Rabanal & Lizana 2012; Pragatheesh & Rajvanshi 2013; Szerlag & McRobert 2006) adding support to our results. There are several reasons to why snake roadkill can be influenced by traffic patterns. Snake's movement is slower in smoother road surfaces compared to other surfaces (Bonnet, Naulleau & Shine 1999; Roe, Gibson & Kingsbury 2006). Also, drivers have been reported to intentionally kill snakes due to aversion to them (Andrews, Gibbons & Jochimsen 2006; Row, Blouin-Demers & Weatherhead 2007). In Portugal, that is a common human behaviour.

This study has shown that landscape features can be used to identify spatial patterns in roadkill events. Another study involving snake spatial patterns in roadkill also showed this relationship (Pragatheesh & Rajvanshi 2013). More importantly, landscapes influencing roadkill differed from species to species revealing the importance of considering individual species in these studies. In brief, all the individual species seem to have distinctive landscape features that could certainly be influencing roadkill. To begin with, *H. hippocrepis* roadkill was higher with the increase of human influenced areas, then *R. scalaris* had a higher roadkill chance in landscapes that can be structurally more complex such as the *Montado* and possible traditional agricultural land, *N. maura* roadkill also was mostly associated to aquatic features and finally *M. monspessulanus* roadkill was mostly influenced by terrain roughness and had a general weak relationship with other landscape factors.

In the meantime, knowledge about the relationship between habitat and snake road mortality has a long way to go. Models can still include other variables that may improve our understanding on how habitat surroundings influence roadkill. For example, habitat selection in snakes is strongly correlated to prey's resource

distribution (Luiselli & Filippi 2006). Also, some habitat characteristics such as rocky areas or shrub height were not incorporated in this study, possibly missing important snake habitat requirements.

Finally, models could also take into account snakes' ecological differences such as age, sex or seasonal activity that can present shifts in habitat spatial use (Luiselli & Filippi 2006). Studies have already shown population declines in several snake species (Reading *et al.* 2010) and even for some snake species in the Iberian Peninsula, including Portugal (Pleguezuelos & Brito 2008; Santos 2008). Also, roads have been pointed as one of the main sources of mortality for several snake species in Portugal. Identifying major roadkill areas and related landscape features is an essential step to incorporate adequate management measures into road planning and mitigation implementation.

CONCLUDING REMARKS

This study revealed that roadkill events can be influenced by landscape factors. Individual species data showed that most important landscape features requirements were quite different between them, so important information could be missed when modelling snake species altogether.

If roadkill was more prominent in snake species that forage actively and have a diurnal behaviour, which agrees with another study (Bonnet *et al.* 1999), than it is still unclear how spatial patterns influence some of the less common snake species. Studying influences at the landscape level has shown important relationships with snake roadkill, but site specific characteristics may also have an important input in roadkill events. Variables selected at a finer scale may improve our knowledge about the role of habitat features in roadkill events. For example, spiny shrubs have been associated to the presence of snakes in the Mediterranean region as they function as a source of prey while also protecting against predators (Luiselli & Filippi 2006). Also, the height of shrubs or rocky features may be an important factor in determining habitat use, as *H. hippocrepis* and *M. monspessulanus* are found in areas with shrubs of low

height (Feriche 2009; Pleguezuelos 2009a). Similarly, it may also be appropriate to take into account age or sex differences. For example, juveniles' dispersion may show irregular patterns which may confound results when age differences are not taken into consideration.

A single scale approach was adopted in this study. But it is possible that some variables become more important at other scales (Graf *et al.* 2005), a multiscale approach can help understand if these differences are pertinent in snake roadkill studies. Moreover, model selection and multimodel inference are limited by the model set considered (Burnham & Anderson 2002). Problems go from the limited number of variables that can be included in models due to statistical issues and software limitations, to collinearity issues mostly between area and fragmentation variables. This is apparent when model development involves small data sets and generalist species that usually have several habitat preferences. Also, because interactions are considered extra parameters in model procedures, important relationships may have been missed. For example, *N. maura* models could have had the inclusion of interaction terms between water sources and terrestrial landscapes in order to better understand the importance of these landscapes, as these only have meaning if a water source is present.

Although model selection and multimodel inference with an information theoretic approach posed some difficulties, the possibility of examining several competing hypotheses simultaneously to identify the best set of models through AIC proved advantageous over traditional null hypothesis testing.

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APPENDIX

APPENDIX A – ENVIRONMENTAL VARIABLES RESPONSE CURVES FOR SNAKE COMMUNITY AND INDIVIDUAL SPECIES RESPONSE VARIABLES.

TABLE A1 - AKAIKE WEIGHTS (w_i) OF UNIVARIATE MODELS USED TO EXPLORE ALTERNATIVE RESPONSE CURVES IN SNAKE COMMUNITY AND FOR EACH SNAKE SPECIES (ENVIRONMENTAL VARIABLES OF EACH BUFFER AND LANDSCAPE METRICS WITHOUT A BUFFER LIMIT).

Snake Community									
Land Cover									
Buffer Distance	250m			500m			1000m*		
Explanatory Variables	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model
AGR	0.35	0.14	0.52 (n)	0.35	0.15	0.50 (n)	0.30	0.14	0.55 (n)
MONT	0.05	0.71 (+)	0.25	0.01	0.72 (+)	0.26	0.02	0.65 (+)	0.33
OMONT	0.50	0.34 (-)	0.16	0.21	0.46 (-)	0.33	0.14	0.64 (-)	0.22
OPA	0.31	0.48 (-)	0.22	0.27	0.54 (-)	0.19	0.18	0.53 (-)	0.29
SHR	0.63	0.25 (-)	0.12	0.43	0.22	0.35 (n)	0.35	0.37 (-)	0.28
RIP	0.42	0.16	0.42 (n)	0.67	0.23 (+)	0.10	0.52	0.31 (+)	0.17
HUM	0.68	0.24 (+)	0.08	0.66	0.25 (+)	0.09	0.52	0.36 (+)	0.13
RI	0.01	0.01	0.97 (n)	0.01	0.11	0.88 (n)	0.10	0.07	0.83 (n)
Landscape Metrics									
Explanatory Variables	Null Model			Linear Model			Quadratic Model		
DRIP	0.34			0.47 (-)			0.18		

<i>Hemorrhhois hippocrepis</i>									
Land Cover									
Buffer Distance	250m			500m			1000m*		
Explanatory Variables	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model
AGR	0.49	0.30 (+)	0.21	0.57	0.32(+)	0.11	0.09	0.68 (+)	0.23
OPA	0.64	0.22 (+)	0.14	0.54	0.21	0.25(n)	0.50	0.25	0.25 (n)
SHR	0.63	0.28 (+)	0.10	0.67	0.24(+)	0.08	0.50	0.35 (-)	0.16
RIP	0.01	0.55 (+)	0.44	0.03	0.64(+)	0.33	0.01	0.73 (+)	0.26
HUM	0.03	0.01	0.96 (n)	0.00	0.01	0.99(n)	0.00	0.13	0.87 (n)
RI	0.32	0.51 (+)	0.17	0.35	0.38(+)	0.27	0.53	0.30 (-)	0.17
Landscape Metrics									
Explanatory Variables	Null Model			Linear Model			Quadratic Model		
DRIP	0.12			0.21			0.67 (n)		

(A1 continued)

Rhiznechis scalaris

Land Cover									
Buffer Distance	250m			500m			1000m*		
Explanatory Variables	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model
AGR	0.28	0.10	0.63(η)	0,18	0.07	0.75(η)	0.12	0.04	0.84 (η)
MONT	0.02	0.65(+)	0.32	0,01	0.66(+)	0.33	0.00	0.50 (+)	0.49
OMONT	0.36	0.28	0.36(η)	0,08	0.48(-)	0.43	0.32	0.50 (-)	0.18
SHR	0.45	0.14	0.40(η)	0,19	0.16	0.65(η)	0.29	0.40 (-)	0.31
RIP	0.63	0.26(-)	0.11	0,62	0.28(-)	0.10	0.57	0.20	0.23 (η)
RI	0.00	0.00	0.99(η)	0,03	0.15	0.82(η)	0.25	0.18	0.57 (η)
Landscape Metrics									
Explanatory Variables	Null Model			Linear Model			Quadratic Model		
DRIP	0.59			0.26 (-)			0.16		

Natrix maura

Land Cover									
Buffer Distance	250m*			500m			1000m		
Explanatory Variables	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model
OMONT	0.03	0.67 (-)	0.29	0.05	0.71 (-)	0.25	0.14	0.62 (-)	0.24
OPA	0.40	0.29	0.31 (η)	0.65	0.24 (+)	0.12	0.63	0.26 (-)	0.12
RIP	0.60	0.27 (-)	0.13	0.17	0.50 (-)	0.33	0.54	0.33 (+)	0.13
WS	0.00	0.27	0.73 (η)	0.06	0.16	0.78 (η)	0.58	0.21 (-)	0.21
RI	0.21	0.28	0.51 (η)	0.46	0.22	0.32 (η)	0.19	0.08	0.73 (η)
Landscape Metrics									
Explanatory Variables	Null Model			Linear Model			Quadratic Model		
DWS	0.00			0.73 (-)			0.27		
DRIP	0.62			0.26 (-)			0.12		

Malpolon monspessulanus

Land Cover									
Buffer	250m			500m*			1000m		
Explanatory Variables	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model	Null Model	Linear Model	Quadratic Model
AGR	0.55	0.23(-)	0.22	0.62	0.25 (-)	0.13	0.33	0.30	0.37(η)
OMONT	0.63	0.23(-)	0.14	0.68	0.24 (+)	0.09	0.38	0.46(-)	0.16
OPA	0.60	0.29(-)	0.10	0.58	0.30 (-)	0.12	0.65	0.26(-)	0.09
SHR	0.66	0.25(-)	0.09	0.64	0.26 (-)	0.10	0.57	0.30(-)	0.13
RIP	0.58	0.21(+)	0.20	0.59	0.26 (+)	0.15	0.08	0.68(+)	0.24
HUM	0.40	0.27	0.33(η)	0.59	0.26 (+)	0.15	0.24	0.51(+)	0.25
RI	0.32	0.39(+)	0.29	0.05	0.30	0.65 (η)	0.13	0.18	0.70(η)
Landscape Metrics									
Explanatory Variables	Null Model			Linear Model			Quadratic Model		
DRIP	0.39			0.39 (-)			0.22		

NOTES: Types of association are presented as: (+) positive, (-) negative and (η) unimodal;* quadratic terms used in final global models.

APPENDIX B – MODELS, RANKING AND CALCULATIONS OF MODELS GENERATED AFTER MODEL SELECTION.

TABLE B1 - MODELS SELECTED FOR THE SNAKE COMMUNITY WITH A $\Delta AICc < 6$ AND EXPLAINED DEVIANCE (D2), AICc AND $\Delta AICc$ VALUES.

Rank	Models	D2	AICc	$\Delta AICc$
1	SNK~OPA+MONT+RIP+HUM+ROAD+RI+sqRI+ATC	0.35	507	0.00
2	SNK~OMONT+OPA+RIP+SHR+AGR+RI+sqAGR+sqRI+ATC	0.35	508	0.58
3	SNK~MONT+RIP+SHR+ROAD+RI+sqRI+ATC	0.33	508	0.83
4	SNK~OMONT+OPA+MONT+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	508	0.84
5	SNK~OMONT+OPA+RIP+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	508	1.03
6	SNK~OPA+MONT+RIP+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	508	1.04
7	SNK~OMONT+MONT+RIP+SHR+ROAD+RI+sqRI+ATC	0.34	508	1.13
8	SNK~MONT+SHR+HUM+ROAD+RI+sqRI+ATC	0.33	508	1.24
9	SNK~OPA+MONT+RIP+SHR+HUM+ROAD+RI+sqRI+ATC	0.35	509	1.31
10	SNK~OMONT+OPA+MONT+SHR+AGR+RI+sqAGR+sqRI+ATC	0.35	509	1.46
11	SNK~MONT+SHR+ROAD+RI+sqRI+ATC	0.32	509	1.48
12	SNK~OPA+MONT+RIP+HUM+AGR+RI+sqAGR+sqRI+ATC	0.35	509	1.71
13	SNK~OMONT+OPA+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	509	1.72
14	SNK~OMONT+OPA+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	509	1.72
15	SNK~MONT+RIP+SHR+HUM+ROAD+RI+sqRI+ATC	0.34	509	1.75
16	SNK~OMONT+OPA+MONT+RIP+HUM+ROAD+RI+sqRI+ATC	0.35	509	1.78
17	SNK~OPA+MONT+SHR+HUM+ROAD+RI+sqRI+ATC	0.34	509	1.84
18	SNK~OPA+MONT+HUM+ROAD+RI+sqRI+ATC	0.33	509	1.87
19	SNK~OMONT+OPA+MONT+RIP+SHR+AGR+RI+sqAGR+sqRI+ATC	0.36	509	2.00
20	SNK~OPA+MONT+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	509	2.24
21	SNK~OMONT+MONT+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	509	2.27
22	SNK~OMONT+OPA+RIP+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.36	510	2.40
23	SNK~OMONT+OPA+MONT+RIP+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	510	2.42
24	SNK~OPA+MONT+RIP+HUM+DRIP+ROAD+RI+sqRI+ATC	0.35	510	2.46
25	SNK~OMONT+MONT+SHR+ROAD+RI+sqRI+ATC	0.33	510	2.47
26	SNK~OMONT+OPA+RIP+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	510	2.49
27	SNK~OPA+MONT+RIP+SHR+ROAD+RI+sqRI+ATC	0.34	510	2.49
28	SNK~OMONT+MONT+RIP+SHR+HUM+ROAD+RI+sqRI+ATC	0.35	510	2.53
29	SNK~MONT+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.34	510	2.56
30	SNK~OMONT+MONT+SHR+HUM+ROAD+RI+sqRI+ATC	0.33	510	2.58
31	SNK~MONT+SHR+DRIP+ROAD+RI+sqRI+ATC	0.32	510	2.61
32	SNK~OMONT+MONT+RIP+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	510	2.67
33	SNK~OMONT+OPA+SHR+ROAD+RI+sqRI+ATC	0.32	510	2.70
34	SNK~OMONT+OPA+MONT+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.35	510	2.71
35	SNK~OMONT+MONT+RIP+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.35	510	2.92
36	SNK~OMONT+OPA+MONT+HUM+ROAD+RI+sqRI+ATC	0.33	510	2.95
37	SNK~OMONT+MONT+RIP+SHR+AGR+RI+sqAGR+sqRI+ATC	0.34	510	2.99
38	SNK~OMONT+OPA+RIP+SHR+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.35	510	3.01
39	SNK~OPA+MONT+RIP+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	510	3.06
40	SNK~OPA+MONT+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	510	3.12

(B1 continued)

41	SNK~OMONT+MONT+RIP+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	510	3.13
42	SNK~OMONT+OPA+SHR+AGR+RI+sqAGR+sqRI+ATC	0.33	510	3.14
43	SNK~MONT+SHR+HUM+DRIP+ROAD+RI+sqRI+ATC	0.33	510	3.15
44	SNK~OPA+MONT+HUM+DRIP+ROAD+RI+sqRI+ATC	0.33	510	3.20
45	SNK~MONT+RIP+SHR+DRIP+ROAD+RI+sqRI+ATC	0.33	510	3.22
46	SNK~OMONT+OPA+MONT+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	510	3.24
47	SNK~OMONT+MONT+RIP+SHR+RI+sqRI+ATC	0.32	510	3.27
48	SNK~OMONT+MONT+SHR+DRIP+ROAD+RI+sqRI+ATC	0.33	510	3.28
49	SNK~OMONT+OPA+MONT+RIP+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	511	3.31
50	SNK~OMONT+OPA+MONT+SHR+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	511	3.40
51	SNK~OMONT+OPA+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.34	511	3.42
52	SNK~OMONT+OPA+SHR+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	511	3.49
53	SNK~OMONT+MONT+RIP+SHR+DRIP+ROAD+RI+sqRI+ATC	0.34	511	3.55
54	SNK~OPA+MONT+RIP+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	511	3.57
55	SNK~OMONT+OPA+RIP+SHR+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	511	3.59
56	SNK~OMONT+OPA+MONT+RIP+SHR+ROAD+RI+sqRI+ATC	0.34	511	3.60
57	SNK~OPA+MONT+SHR+HUM+DRIP+ROAD+RI+sqRI+ATC	0.34	511	3.61
58	SNK~OMONT+OPA+RIP+SHR+ROAD+RI+sqRI+ATC	0.33	511	3.64
59	SNK~MONT+RIP+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	511	3.68
60	SNK~OPA+MONT+SHR+ROAD+RI+sqRI+ATC	0.32	511	3.76
61	SNK~OMONT+OPA+MONT+RIP+SHR+HUM+ROAD+RI+sqRI+ATC	0.35	511	3.83
62	SNK~OPA+MONT+RIP+ROAD+RI+sqRI+ATC	0.32	511	3.83
63	SNK~OPA+MONT+RIP+SHR+HUM+DRIP+ROAD+RI+sqRI+ATC	0.35	511	3.83
64	SNK~OMONT+OPA+MONT+SHR+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.35	511	3.96
65	SNK~OMONT+OPA+SHR+DRIP+ROAD+RI+sqRI+ATC	0.33	511	3.98
66	SNK~OPA+MONT+RIP+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.35	511	4.03
67	SNK~OMONT+OPA+MONT+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	511	4.06
68	SNK~OPA+MONT+RIP+HUM+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.35	511	4.07
69	SNK~OPA+MONT+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	511	4.11
70	SNK~OMONT+OPA+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	511	4.13
71	SNK~MONT+RIP+SHR+HUM+DRIP+ROAD+RI+sqRI+ATC	0.34	511	4.22
72	SNK~OMONT+OPA+MONT+RIP+HUM+AGR+RI+sqAGR+sqRI+ATC	0.35	511	4.23
73	SNK~OMONT+MONT+SHR+HUM+DRIP+ROAD+RI+sqRI+ATC	0.34	511	4.27
74	SNK~OMONT+OPA+MONT+RIP+HUM+DRIP+ROAD+RI+sqRI+ATC	0.35	511	4.28
75	SNK~OMONT+OPA+RIP+SHR+RI+sqRI+ATC	0.32	511	4.28
76	SNK~OMONT+OPA+MONT+SHR+HUM+ROAD+RI+sqRI+ATC	0.34	512	4.31
77	SNK~OMONT+OPA+MONT+RIP+SHR+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.36	512	4.34
78	SNK~MONT+RIP+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.34	512	4.37
79	SNK~OMONT+OPA+MONT+RIP+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.36	512	4.39
80	SNK~OMONT+MONT+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.34	512	4.47
81	SNK~OMONT+OPA+MONT+SHR+ROAD+RI+sqRI+ATC	0.33	512	4.51
82	SNK~OMONT+MONT+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	512	4.60
83	SNK~OMONT+MONT+SHR+HUM+AGR+RI+sqAGR+sqRI+ATC	0.34	512	4.61
84	SNK~OMONT+OPA+MONT+HUM+DRIP+ROAD+RI+sqRI+ATC	0.34	512	4.67
85	SNK~OMONT+MONT+RIP+SHR+HUM+RI+sqRI+ATC	0.33	512	4.68
86	SNK~MONT+SHR+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.33	512	4.70
87	SNK~OMONT+OPA+SHR+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.34	512	4.71
88	SNK~OPA+MONT+SHR+DRIP+ROAD+RI+sqRI+ATC	0.33	512	4.74
89	SNK~OMONT+OPA+RIP+SHR+HUM+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.36	512	4.76
90	SNK~OPA+MONT+RIP+SHR+DRIP+ROAD+RI+sqRI+ATC	0.34	512	4.92

(B1 continued)

91	SNK~OMONT+OPA+MONT+RIP+SHR+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	512	4.95
92	SNK~MONT+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	512	4.97
93	SNK~OPA+SHR+ROAD+RI+sqRI+ATC	0.31	512	5.01
94	SNK~OMONT+OPA+SHR+HUM+ROAD+RI+sqRI+ATC	0.32	512	5.02
95	SNK~OMONT+OPA+RIP+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	512	5.03
96	SNK~OMONT+MONT+RIP+SHR+HUM+DRIP+ROAD+RI+sqRI+ATC	0.35	512	5.05
97	SNK~OMONT+OPA+MONT+RIP+SHR+HUM+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	512	5.06
98	SNK~OMONT+OPA+MONT+SHR+AGR+sqAGR+ATC	0.31	512	5.07
99	SNK~OMONT+OPA+MONT+RIP+SHR+RI+sqRI+ATC	0.32	512	5.19
100	SNK~OMONT+MONT+RIP+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.37	512	5.22
101	SNK~OMONT+OPA+MONT+SHR+HUM+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.35	513	5.29
102	SNK~OMONT+MONT+RIP+SHR+HUM+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.35	513	5.31
103	SNK~OPA+MONT+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	513	5.37
104	SNK~OMONT+OPA+RIP+SHR+AGR+sqAGR+ATC	0.31	513	5.44
105	SNK~OMONT+OPA+MONT+SHR+HUM+AGR+sqAGR+ATC	0.32	513	5.49
106	SNK~OMONT+MONT+RIP+SHR+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.34	513	5.51
107	SNK~OMONT+OPA+MONT+SHR+ROAD+AGR+sqAGR+ATC	0.32	513	5.57
108	SNK~OPA+MONT+HUM+AGR+RI+sqAGR+sqRI+ATC	0.32	513	5.57
109	SNK~OMONT+OPA+MONT+SHR+DRIP+ROAD+RI+sqRI+ATC	0.33	513	5.59
110	SNK~OMONT+MONT+SHR+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.34	513	5.62
111	SNK~OPA+MONT+RIP+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	513	5.63
112	SNK~OMONT+OPA+SHR+HUM+DRIP+AGR+RI+sqAGR+sqRI+ATC	0.34	513	5.67
113	SNK~OMONT+MONT+RIP+SHR+DRIP+RI+sqRI+ATC	0.32	513	5.68
114	SNK~OMONT+MONT+RIP+SHR+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.35	513	5.70
115	SNK~OMONT+OPA+MONT+RIP+SHR+AGR+sqAGR+ATC	0.32	513	5.77
116	SNK~OMONT+OPA+RIP+SHR+DRIP+ROAD+RI+sqRI+ATC	0.33	513	5.86
117	SNK~OMONT+OPA+MONT+SHR+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	513	5.88
118	SNK~OMONT+OPA+MONT+RIP+HUM+DRIP+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.36	513	5.89
119	SNK~OMONT+OPA+SHR+RI+sqRI+ATC	0.30	513	5.90

TABLE B2 - MODELS SELECTED FOR THE HORSE WHIP SNAKE *Hemorrhoids hippocrepis* WITH A $\Delta AICc < 6$ AND EXPLAINED DEVIANCE (D2), AICc AND $\Delta AICc$ VALUES.

Rank	Models	D2	AICc	$\Delta AICc$
1	HH~HUM+DRIP+sqHUM+sqDRIP+ATC	0.37	145	0.00
2	HH~RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	146	1.12
3	HH~ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	146	1.24
4	HH~RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.40	146	1.45
5	HH~AGR+HUM+DRIP+sqHUM+sqDRIP+ATC	0.37	147	2.14
6	HH~SHR+HUM+DRIP+sqHUM+sqDRIP+ATC	0.37	147	2.14
7	HH~HUM+sqHUM+ATC	0.32	147	2.20
8	HH~RIP+HUM+DRIP+sqHUM+sqDRIP+ATC	0.37	147	2.26
9	HH~OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.39	147	2.39
10	HH~RI+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.41	148	2.84
11	HH~AGR+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	148	2.84
12	HH~SHR+RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	148	2.85
13	HH~SHR+RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.41	148	2.97
14	HH~OPA+HUM+sqOPA+sqHUM+ATC	0.35	148	3.01
15	HH~AGR+RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.41	148	3.05
16	HH~AGR+RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	148	3.39
17	HH~RIP+RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	148	3.40
18	HH~SHR+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	148	3.41
19	HH~RI+OPA+HUM+sqOPA+sqHUM+ATC	0.36	148	3.47
20	HH~ROAD+HUM+sqHUM+ATC	0.32	148	3.50
21	HH~RIP+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	149	3.61
22	HH~RI+HUM+sqHUM+ATC	0.32	149	3.76
23	HH~RIP+RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.40	149	3.87
24	HH~RIP+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.40	149	3.92
25	HH~AGR+HUM+sqHUM+ATC	0.32	149	4.03
26	HH~ROAD+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.40	149	4.12
27	HH~RI+ROAD+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.42	149	4.22
28	HH~RIP+RI+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.42	149	4.28
29	HH~AGR+SHR+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	149	4.30
30	HH~SHR+HUM+sqHUM+ATC	0.32	149	4.32
31	HH~RIP+HUM+sqHUM+ATC	0.32	149	4.35
32	HH~AGR+SHR+RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.42	149	4.39
33	HH~AGR+RIP+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	149	4.41
34	HH~RIP+SHR+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	149	4.41
35	HH~AGR+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.40	149	4.41
36	HH~RI+ROAD+HUM+sqHUM+ATC	0.33	150	4.52
37	HH~RIP+OPA+HUM+sqOPA+sqHUM+ATC	0.35	150	4.55
38	HH~SHR+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.39	150	4.70
39	HH~ROAD+OPA+HUM+sqOPA+sqHUM+ATC	0.35	150	4.71
40	HH~AGR+ROAD+HUM+sqHUM+ATC	0.33	150	4.80

(B2 continued)

41	HH~SHR+OPA+HUM+sqOPA+sqHUM+ATC	0.35	150	4.87
42	HH~AGR+OPA+HUM+sqOPA+sqHUM+ATC	0.35	150	4.88
43	HH~RIP+RI+OPA+HUM+sqOPA+sqHUM+ATC	0.37	150	4.90
44	HH~AGR+SHR+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	150	4.97
45	HH~RI+ROAD+OPA+HUM+sqOPA+sqHUM+ATC	0.37	150	4.99
46	HH~AGR+RI+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.41	150	5.04
47	HH~RIP+SHR+RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	150	5.11
48	HH~AGR+SHR+RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	150	5.15
49	HH~AGR+RIP+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	150	5.24
50	HH~SHR+RI+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.41	150	5.30
51	HH~RIP+SHR+RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.41	150	5.43
52	HH~AGR+RIP+RI+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.41	150	5.49
53	HH~AGR+RI+OPA+HUM+sqOPA+sqHUM+ATC	0.37	151	5.55
54	HH~SHR+RI+HUM+sqHUM+ATC	0.32	151	5.61
55	HH~AGR+ROAD+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.41	151	5.63
56	HH~SHR+ROAD+HUM+sqHUM+ATC	0.32	151	5.67
57	HH~AGR+RIP+RI+HUM+DRIP+sqHUM+sqDRIP+ATC	0.39	151	5.69
58	HH~AGR+RI+HUM+sqHUM+ATC	0.32	151	5.73
59	HH~AGR+RIP+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.41	151	5.74
60	HH~RIP+ROAD+HUM+sqHUM+ATC	0.32	151	5.76
61	HH~SHR+RI+OPA+HUM+sqOPA+sqHUM+ATC	0.36	151	5.77
62	HH~RIP+SHR+ROAD+HUM+DRIP+sqHUM+sqDRIP+ATC	0.38	151	5.82
63	HH~AGR+RI+ROAD+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.43	151	5.83
64	HH~AGR+RI+ROAD+HUM+sqHUM+ATC	0.34	151	5.89
65	HH~RIP+RI+HUM+sqHUM+ATC	0.32	151	5.90
66	HH~RIP+ROAD+OPA+HUM+DRIP+sqOPA+sqHUM+sqDRIP+ATC	0.40	151	5.99

TABLE B3 - MODELS SELECTED FOR THE LADDER SNAKE *Rhinechis scalaris* WITH A $\Delta AICc < 6$ AND EXPLAINED DEVIANCE (D2), AICc AND $\Delta AICc$ VALUES.

Rank	Models	D2	AICc	$\Delta AICc$
1	RS~SHR+MONT+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.31	415	0.00
2	RS~OMONT+SHR+MONT+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.32	415	0.00
3	RS~OMONT+SHR+MONT+AGR+RI+sqAGR+sqRI+ATC	0.31	415	0.04
4	RS~SHR+MONT+ROAD+RI+sqRI+ATC	0.29	416	1.30
5	RS~SHR+MONT+DRIPCS+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.32	416	1.60
6	RS~SHR+MONT+ROAD+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.33	417	1.80
7	RS~OMONT+SHR+MONT+DRIPCS+ROAD+AGR+RI+sqAGR+sqRI+ATC	0.33	417	1.84
8	RS~OMONT+SHR+MONT+DRIPCS+AGR+RI+sqAGR+sqRI+ATC	0.31	417	2.04
9	RS~OMONT+SHR+MONT+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.32	417	2.45
10	RS~OMONT+SHR+MONT+ROAD+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.34	417	2.46
11	RS~SHR+MONT+AGR+RI+sqAGR+sqRI+ATC	0.29	418	2.87
12	RS~OMONT+SHR+MONT+ROAD+RI+sqRI+ATC	0.29	418	3.19
13	RS~SHR+MONT+DRIPCS+ROAD+RI+sqRI+ATC	0.29	418	3.22
14	RS~OMONT+SHR+MONT+ROAD+AGR+sqAGR+ATC	0.28	419	3.79
15	RS~OMONT+SHR+MONT+AGR+sqAGR+ATC	0.27	419	4.01
16	RS~SHR+MONT+DRIPCS+ROAD+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.33	419	4.22
17	RS~OMONT+SHR+MONT+DRIPCS+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.33	419	4.52
18	RS~OMONT+SHR+MONT+ROAD+RIP+AGR+sqRIP+sqAGR+ATC	0.30	419	4.59
19	RS~SHR+MONT+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.30	419	4.61
20	RS~SHR+MONT+ROAD+AGR+sqAGR+ATC	0.27	420	4.62
21	RS~SHR+MONT+DRIPCS+AGR+RI+sqAGR+sqRI+ATC	0.29	420	4.69
22	RS~SHR+MONT+ROAD+RIP+AGR+sqRIP+sqAGR+ATC	0.29	420	4.83
23	RS~OMONT+SHR+MONT+RIP+AGR+sqRIP+sqAGR+ATC	0.29	420	4.83
24	RS~OMONT+SHR+MONT+DRIPCS+ROAD+RIP+AGR+RI+sqRIP+sqAGR+sqRI+ATC	0.34	420	4.84
25	RS~SHR+MONT+ROAD+RIP+RI+sqRIP+sqRI+ATC	0.29	420	4.85
26	RS~OMONT+SHR+MONT+DRIPCS+ROAD+RI+sqRI+ATC	0.29	420	5.24
27	RS~SHR+MONT+ROAD+ATC	0.24	421	5.65

TABLE B4 - MODELS SELECTED FOR THE VIPERINE SNAKE *Natrix maura* WITH A $\Delta AICc < 6$ AND EXPLAINED DEVIANCE (D2), AICc AND $\Delta AICc$ VALUES.

Rank	Models	D2	AICc	$\Delta AICc$
1	NM~OMONT+DWS+OPA+WS+sqOPA+sqWS	0.35	170	0.00
2	NM~OMONT+DWS+WS+sqWS	0.31	170	0.24
3	NM~OMONT+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.36	171	0.75
4	NM~OMONT+DWS+ROAD+WS+sqWS	0.32	171	0.84
5	NM~OMONT+DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.37	171	0.91
6	NM~DWS+WS+sqWS	0.29	171	1.16
7	NM~DWS+ROAD+WS+sqWS	0.31	171	1.32
8	NM~OMONT+DRIP+DWS+WS+sqWS	0.32	172	1.65
9	NM~OMONT+DRIP+DWS+OPA+WS+sqOPA+sqWS	0.35	172	1.70
10	NM~OMONT+DWS+ROAD+OPA+RI+WS+sqOPA+sqRI+sqWS	0.39	172	1.71
11	NM~DWS+ROAD+OPA+WS+sqOPA+sqWS	0.33	172	1.87
12	NM~OMONT+DWS+RI+WS+sqRI+sqWS	0.33	172	1.89
13	NM~OMONT+DWS+ROAD+RI+WS+sqRI+sqWS	0.35	172	2.02
14	NM~DWS+ROAD+RI+WS+sqRI+sqWS	0.33	172	2.04
15	NM~DWS+OPA+WS+sqOPA+sqWS	0.32	172	2.06
16	NM~OMONT+RIP+DWS+WS+sqWS	0.31	172	2.34
17	NM~OMONT+RIP+DWS+OPA+WS+sqOPA+sqWS	0.35	172	2.36
18	NM~OMONT+DRIP+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.36	173	2.48
19	NM~OMONT+DRIP+DWS+ROAD+WS+sqWS	0.33	173	2.56
20	NM~DRIP+DWS+WS+sqWS	0.30	173	2.59
21	NM~DWS+RI+WS+sqRI+sqWS	0.31	173	2.60
22	NM~OMONT+RIP+DWS+ROAD+WS+sqWS	0.33	173	2.86
23	NM~DRIP+DWS+ROAD+WS+sqWS	0.31	173	3.02
24	NM~DWS+ROAD+OPA+RI+WS+sqOPA+sqRI+sqWS	0.36	173	3.02
25	NM~OMONT+RIP+DRIP+DWS+WS+sqWS	0.32	173	3.10
26	NM~OMONT+RIP+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.36	173	3.17
27	NM~RIP+DWS+WS+sqWS	0.29	173	3.20
28	NM~RIP+DWS+ROAD+WS+sqWS	0.31	173	3.24
29	NM~DRIP+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.34	173	3.29
30	NM~OMONT+DRIP+DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.37	173	3.30
31	NM~OMONT+RIP+DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.37	173	3.37
32	NM~DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.34	173	3.44
33	NM~DRIP+DWS+OPA+WS+sqOPA+sqWS	0.32	174	3.54
34	NM~OMONT+DRIP+DWS+RI+WS+sqRI+sqWS	0.34	174	3.86
35	NM~OMONT+RIP+DRIP+DWS+ROAD+WS+sqWS	0.34	174	3.87
36	NM~RIP+DRIP+DWS+WS+sqWS	0.30	174	3.93
37	NM~OMONT+RIP+DRIP+DWS+OPA+WS+sqOPA+sqWS	0.35	174	3.98
38	NM~RIP+DWS+ROAD+RI+WS+sqRI+sqWS	0.34	174	3.99
39	NM~OMONT+RIP+DWS+RI+WS+sqRI+sqWS	0.33	174	4.13
40	NM~RIP+DRIP+DWS+ROAD+WS+sqWS	0.32	174	4.14
41	NM~OMONT+DRIP+DWS+ROAD+OPA+RI+WS+sqOPA+sqRI+sqWS	0.39	174	4.17
42	NM~OMONT+RIP+DWS+ROAD+RI+WS+sqRI+sqWS	0.35	174	4.20
43	NM~DRIP+DWS+ROAD+RI+WS+sqRI+sqWS	0.33	174	4.23
44	NM~OMONT+RIP+DWS+ROAD+OPA+RI+WS+sqOPA+sqRI+sqWS	0.39	174	4.23
45	NM~RIP+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.33	174	4.23
46	NM~OMONT+DRIP+DWS+ROAD+RI+WS+sqRI+sqWS	0.35	174	4.27
47	NM~RIP+DWS+OPA+WS+sqOPA+sqWS	0.32	174	4.38
48	NM~DRIP+DWS+RI+WS+sqRI+sqWS	0.31	175	4.51
49	NM~RIP+DWS+RI+WS+sqRI+sqWS	0.31	175	4.69
50	NM~OMONT+RIP+DRIP+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.36	175	4.77

(B4 continued)

51	NM~DRIP+DWS+ROAD+OPA+RI+WS+sqOPA+sqRI+sqWS	0.36	175	5.23
52	NM~RIP+DRIP+DWS+ROAD+OPA+WS+sqOPA+sqWS	0.34	175	5.41
53	NM~RIP+DWS+ROAD+OPA+RI+WS+sqOPA+sqRI+sqWS	0.36	175	5.43
54	NM~DRIP+DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.34	176	5.60
55	NM~RIP+DRIP+DWS+ROAD+RI+WS+sqRI+sqWS	0.34	176	5.64
56	NM~RIP+DRIP+DWS+OPA+WS+sqOPA+sqWS	0.32	176	5.69
57	NM~OMONT+RIP+DRIP+DWS+RI+WS+sqRI+sqWS	0.34	176	5.69
58	NM~OMONT+RIP+DRIP+DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.38	176	5.76
59	NM~RIP+DWS+OPA+RI+WS+sqOPA+sqRI+sqWS	0.34	176	5.81
60	NM~OMONT+DWS+ROAD+OPA+RI+sqOPA+sqRI	0.32	176	5.94

TABLE B5 - MODELS SELECTED FOR THE RAT SNAKE *Malpolon monspessulanus* WITH A $\Delta AICc < 6$ AND EXPLAINED DEVIANCE (D2), AICc AND $\Delta AICc$ VALUES.

Rank	Models	D2	AICc	$\Delta AICc$
1	MM~ROAD+RI+sqRI	0.08	343	0.00
2	MM~AGR+ROAD+RI+sqRI	0.09	343	0.45
3	MM~DRIP+ROAD+RI+sqRI	0.09	343	0.84
4	MM~OMONT+ROAD+RI+sqRI	0.09	343	0.95
5	MM~SHR+ROAD+RI+sqRI	0.09	344	1.07
6	MM~AGR+SHR+ROAD+RI+sqRI	0.10	344	1.15
7	MM~HUM+ROAD+RI+sqRI	0.08	344	1.27
8	MM~AGR+DRIP+ROAD+RI+sqRI	0.10	344	1.56
9	MM~AGR+HUM+ROAD+RI+sqRI	0.10	344	1.67
10	MM~OMONT+SHR+ROAD+RI+sqRI	0.10	344	1.75
11	MM~OMONT+AGR+ROAD+RI+sqRI	0.09	344	1.86
12	MM~ROAD	0.04	344	1.90
13	MM~RI+sqRI	0.06	344	1.91
14	MM~OMONT+DRIP+ROAD+RI+sqRI	0.09	345	2.01
15	MM~SHR+RI+sqRI	0.07	345	2.10
16	MM~RIP+ROAD+RI+sqRI	0.08	345	2.12
17	MM~OMONT+HUM+ROAD+RI+sqRI	0.09	345	2.15
18	MM~OPA+ROAD+RI+sqRI	0.08	345	2.19
19	MM~AGR+ROAD	0.05	345	2.23
20	MM~HUM+RI+sqRI	0.07	345	2.28
21	MM~SHR+DRIP+ROAD+RI+sqRI	0.09	345	2.28
22	MM~DRIP+RI+sqRI	0.07	345	2.33
23	MM~OMONT+AGR+SHR+ROAD+RI+sqRI	0.11	345	2.37
24	MM~AGR+RIP+ROAD+RI+sqRI	0.09	345	2.56
25	MM~DRIP+ROAD	0.05	345	2.57
26	MM~HUM+DRIP+ROAD+RI+sqRI	0.09	345	2.65
27	MM~OPA+AGR+ROAD+RI+sqRI	0.09	345	2.66
28	MM~AGR+SHR+DRIP+ROAD+RI+sqRI	0.10	345	2.70
29	MM~SHR+HUM+ROAD+RI+sqRI	0.09	345	2.75
30	MM~OMONT+ROAD	0.05	345	2.84
31	MM~AGR+SHR+HUM+ROAD+RI+sqRI	0.10	345	2.85
32	MM~OMONT+OPA+ROAD+RI+sqRI	0.09	345	2.92
33	MM~OPA+DRIP+ROAD+RI+sqRI	0.09	345	2.99
34	MM~RIP+DRIP+ROAD+RI+sqRI	0.09	346	3.03
35	MM~OMONT+AGR+HUM+ROAD+RI+sqRI	0.10	346	3.06
36	MM~SHR+DRIP+RI+sqRI	0.07	346	3.07
37	MM~OMONT+AGR+DRIP+ROAD+RI+sqRI	0.10	346	3.10
38	MM~OPA+SHR+ROAD+RI+sqRI	0.09	346	3.13
39	MM~AGR+DRIP+ROAD	0.06	346	3.14
40	MM~OMONT+RIP+ROAD+RI+sqRI	0.09	346	3.19
41	MM~SHR+HUM+RI+sqRI	0.07	346	3.23
42	MM~OMONT+SHR+DRIP+ROAD+RI+sqRI	0.10	346	3.23
43	MM~OPA+AGR+SHR+ROAD+RI+sqRI	0.10	346	3.24
44	MM~AGR+HUM+DRIP+ROAD+RI+sqRI	0.10	346	3.30
45	MM~RIP+SHR+ROAD+RI+sqRI	0.09	346	3.32
46	MM~HUM+ROAD	0.05	346	3.34
47	MM~OMONT+SHR+HUM+ROAD+RI+sqRI	0.10	346	3.40
48	MM~AGR+SHR+RI+sqRI	0.07	346	3.42
49	MM~AGR+RIP+SHR+ROAD+RI+sqRI	0.10	346	3.43
50	MM~RIP+HUM+ROAD+RI+sqRI	0.09	346	3.47

(B5 continued)

51	MM~HUM+DRIP+RI+sqRI	0.07	346	3.50
52	MM~RIP+RI+sqRI	0.06	346	3.53
53	MM~OPA+HUM+ROAD+RI+sqRI	0.08	346	3.53
54	MM~AGR+RI+sqRI	0.06	346	3.57
55	MM~AGR+HUM+ROAD	0.06	346	3.60
56	MM~OMONT+AGR+ROAD	0.06	346	3.62
57	MM~OPA+ROAD	0.04	346	3.70
58	MM~OPA+AGR+DRIP+ROAD+RI+sqRI	0.10	346	3.73
59	MM~OMONT+HUM+DRIP+ROAD+RI+sqRI	0.10	346	3.76
60	MM~OMONT+DRIP+ROAD	0.06	346	3.76
61	MM~AGR+HUM+RI+sqRI	0.07	346	3.81
62	MM~OMONT+OPA+DRIP+ROAD+RI+sqRI	0.10	346	3.84
63	MM~AGR+RIP+DRIP+ROAD+RI+sqRI	0.10	346	3.85
64	MM~OMONT+OPA+AGR+ROAD+RI+sqRI	0.10	346	3.89
65	MM~SHR+ROAD	0.04	346	3.92
66	MM~OPA+SHR+RI+sqRI	0.07	346	3.95
67	MM~AGR+RIP+HUM+ROAD+RI+sqRI	0.10	346	3.95
68	MM~OPA+AGR+HUM+ROAD+RI+sqRI	0.10	346	3.97
69	MM~RIP+ROAD	0.04	347	4.00
70	MM~OMONT+RI+sqRI	0.06	347	4.01
71	MM~OPA+RI+sqRI	0.06	347	4.05
72	MM~OMONT+OPA+SHR+ROAD+RI+sqRI	0.10	347	4.05
73	MM~OMONT+RIP+SHR+ROAD+RI+sqRI	0.10	347	4.06
74	MM~OMONT+AGR+SHR+DRIP+ROAD+RI+sqRI	0.11	347	4.08
75	MM~OMONT+AGR+SHR+HUM+ROAD+RI+sqRI	0.11	347	4.08
76	MM~OMONT+AGR+RIP+ROAD+RI+sqRI	0.10	347	4.11
77	MM~RIP+SHR+RI+sqRI	0.07	347	4.11
78	MM~OMONT+HUM+ROAD	0.05	347	4.13
79	MM~OPA+AGR+ROAD	0.05	347	4.13
80	MM~OMONT+SHR+RI+sqRI	0.07	347	4.14
81	MM~AGR+SHR+ROAD	0.05	347	4.16
82	MM~AGR+DRIP+RI+sqRI	0.07	347	4.16
83	MM~OMONT+RIP+DRIP+ROAD+RI+sqRI	0.09	347	4.17
84	MM~OMONT+RIP+HUM+ROAD+RI+sqRI	0.09	347	4.23
85	MM~OMONT+OPA+HUM+ROAD+RI+sqRI	0.09	347	4.25
86	MM~OMONT+HUM+RI+sqRI	0.07	347	4.30
87	MM~SHR+HUM+DRIP+ROAD+RI+sqRI	0.09	347	4.32
88	MM~AGR+RIP+ROAD	0.05	347	4.34
89	MM~OPA+RIP+ROAD+RI+sqRI	0.08	347	4.36
90	MM~OPA+DRIP+RI+sqRI	0.07	347	4.39
91	MM~RIP+SHR+DRIP+ROAD+RI+sqRI	0.09	347	4.45
92	MM~HUM+DRIP+ROAD	0.05	347	4.48
93	MM~OPA+HUM+RI+sqRI	0.07	347	4.49
94	MM~RIP+HUM+RI+sqRI	0.07	347	4.49
95	MM~AGR+SHR+HUM+RI+sqRI	0.08	347	4.50
96	MM~RIP+DRIP+ROAD	0.05	347	4.50
97	MM~OMONT+DRIP+RI+sqRI	0.07	347	4.50
98	MM~RIP+HUM+DRIP+ROAD+RI+sqRI	0.09	347	4.50
99	MM~RIP+DRIP+RI+sqRI	0.07	347	4.53
100	MM~OPA+SHR+DRIP+ROAD+RI+sqRI	0.09	347	4.56

(B5 continued)

101	MM~OPA+DRIP+ROAD	0.05	347	4.62
102	MM~AGR+SHR+DRIP+RI+sqRI	0.08	347	4.64
103	MM~OMONT+AGR+DRIP+ROAD	0.06	347	4.69
104	MM~SHR+HUM+DRIP+RI+sqRI	0.08	347	4.70
105	MM~SHR+DRIP+ROAD	0.05	347	4.70
106	MM~OMONT+OPA+AGR+SHR+ROAD+RI+sqRI	0.11	347	4.71
107	MM~AGR+SHR+HUM+DRIP+ROAD+RI+sqRI	0.11	347	4.72
108	MM~OMONT+AGR+RIP+SHR+ROAD+RI+sqRI	0.11	347	4.73
109	MM~OMONT+SHR+ROAD	0.05	347	4.76
110	MM~OMONT+AGR+HUM+DRIP+ROAD+RI+sqRI	0.10	347	4.82
111	MM~OPA+AGR+RIP+ROAD+RI+sqRI	0.09	347	4.83
112	MM~OPA+SHR+HUM+ROAD+RI+sqRI	0.09	347	4.86
113	MM~OMONT+AGR+HUM+ROAD	0.06	347	4.89
114	MM~OPA+HUM+DRIP+ROAD	0.09	347	4.91
115	MM~RIP+SHR+HUM+ROAD+RI+sqRI	0.09	347	4.95
116	MM~OMONT+OPA+ROAD	0.05	347	4.96
117	MM~AGR+HUM+DRIP+ROAD	0.06	347	4.99
118	MM~OPA+AGR+SHR+HUM+ROAD+RI+sqRI	0.10	348	5.00
119	MM~OPA+AGR+SHR+DRIP+ROAD+RI+sqRI	0.10	348	5.00
120	MM~AGR+RIP+SHR+DRIP+ROAD+RI+sqRI	0.10	348	5.01
121	MM~OMONT+OPA+AGR+DRIP+ROAD+RI+sqRI	0.10	348	5.01
122	MM~OMONT+RIP+ROAD	0.05	348	5.01
123	MM~OPA+HUM+ROAD	0.05	348	5.01
124	MM~AGR+RIP+RI+sqRI	0.06	348	5.10
125	MM~OPA+SHR+HUM+RI+sqRI	0.08	348	5.13
126	MM~AGR+RIP+SHR+HUM+ROAD+RI+sqRI	0.10	348	5.15
127	MM~OPA+RIP+DRIP+ROAD+RI+sqRI	0.09	348	5.20
128	MM~OMONT+SHR+HUM+RI+sqRI	0.07	348	5.20
129	MM~OMONT+SHR+DRIP+RI+sqRI	0.07	348	5.20
130	MM~AGR+HUM+DRIP+RI+sqRI	0.07	348	5.21
131	MM~OMONT+OPA+RIP+ROAD+RI+sqRI	0.09	348	5.22
132	MM~OMONT+OPA+AGR+HUM+ROAD+RI+sqRI	0.10	348	5.22
133	MM~AGR+SHR+DRIP+ROAD	0.06	348	5.23
134	MM~OPA+SHR+DRIP+RI+sqRI	0.07	348	5.23
135	MM~AGR+RIP+DRIP+ROAD	0.06	348	5.24
136	MM~OMONT+SHR+HUM+DRIP+ROAD+RI+sqRI	0.10	348	5.24
137	MM~OPA+AGR+DRIP+ROAD	0.06	348	5.25
138	MM~OMONT+AGR+RIP+HUM+ROAD+RI+sqRI	0.10	348	5.27
139	MM~OPA+AGR+SHR+RI+sqRI	0.07	348	5.29
140	MM~OMONT+RIP+SHR+DRIP+ROAD+RI+sqRI	0.10	348	5.31
141	MM~RIP+SHR+DRIP+RI+sqRI	0.07	348	5.33
142	MM~AGR+RIP+HUM+DRIP+ROAD+RI+sqRI	0.10	348	5.34
143	MM~OMONT+RIP+HUM+DRIP+ROAD+RI+sqRI	0.10	348	5.34
144	MM~OPA+SHR+ROAD	0.05	348	5.36
145	MM~OPA+AGR+HUM+ROAD	0.06	348	5.38
146	MM~RIP+HUM+ROAD	0.05	348	5.39
147	MM~OMONT+AGR+RIP+DRIP+ROAD+RI+sqRI	0.10	348	5.39
148	MM~AGR+RIP+SHR+RI+sqRI	0.07	348	5.40
149	MM~OMONT+RIP+SHR+HUM+ROAD+RI+sqRI	0.10	348	5.43
150	MM~OPA+RIP+SHR+ROAD+RI+sqRI	0.09	348	5.43

(B5 continued)

151	MM~OMONT+AGR+SHR+ROAD	0.06	348	5.46
152	MM~SHR+HUM+ROAD	0.05	348	5.48
153	MM~RIP+SHR+HUM+RI+sqRI	0.07	348	5.48
154	MM~OMONT+HUM+DRIP+ROAD	0.06	348	5.57
155	MM~OMONT+OPA+SHR+DRIP+ROAD+RI+sqRI	0.10	348	5.57
156	MM~OPA+AGR+SHR+ROAD	0.06	348	5.58
157	MM~OPA+AGR+RIP+SHR+ROAD+RI+sqRI	0.10	348	5.58
158	MM~RIP+HUM+DRIP+RI+sqRI	0.07	348	5.58
159	MM~OPA+AGR+HUM+DRIP+ROAD+RI+sqRI	0.10	348	5.60
160	MM~OMONT+RIP+DRIP+ROAD	0.06	348	5.60
161	MM~OMONT+HUM+DRIP+RI+sqRI	0.07	348	5.62
162	MM~OMONT+AGR+SHR+RI+sqRI	0.07	348	5.65
163	MM~OMONT+RIP+RI+sqRI	0.06	348	5.68
164	MM~AGR+SHR+HUM+ROAD	0.06	348	5.70
165	MM~OPA+HUM+DRIP+RI+sqRI	0.07	348	5.71
166	MM~OPA+RIP+RI+sqRI	0.06	348	5.72
167	MM~OPA+AGR+RI+sqRI	0.06	348	5.73
168	MM~AGR+RIP+HUM+ROAD	0.06	348	5.74
169	MM~OMONT+OPA+HUM+DRIP+ROAD+RI+sqRI	0.10	348	5.75
170	MM~OMONT+OPA+SHR+HUM+ROAD+RI+sqRI	0.10	348	5.77
171	MM~OMONT+OPA+AGR+ROAD	0.06	348	5.78
172	MM~OMONT+AGR+RI+sqRI	0.06	348	5.78
173	MM~OPA+RIP+HUM+ROAD+RI+sqRI	0.09	348	5.78
174	MM~OMONT+AGR+RIP+ROAD	0.06	348	5.82
175	MM~OPA+RIP+ROAD	0.04	348	5.83
176	MM~OMONT+SHR+DRIP+ROAD	0.06	348	5.85
177	MM~OMONT+OPA+RIP+DRIP+ROAD+RI+sqRI	0.10	348	5.91
178	MM~OMONT+RIP+HUM+ROAD	0.06	348	5.97
179	MM~OMONT+OPA+DRIP+ROAD	0.06	348	5.98
180	MM~RIP+HUM+DRIP+ROAD	0.06	349	5.99