Universidade de Aveiro Departamento de Biologia
Ano 2018

Manuela Cordeiro Sales

Drivers of vertebrates' richness and diversity in Baixo Vouga Lagunar region

Determinantes da riqueza específica e diversidade de vertebrados na região do Baixo Vouga Lagunar

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Ecologia Aplicada, realizada sob a orientação científica do Prof. Doutor Luís Miguel do Carmo Rosalino, Investigador Auxiliar do Departamento de Biologia e do Centro de Estudos do Ambiente e do Mar (CESAM) da Universidade de Aveiro e Professor Auxiliar Convidado do Departamento de Biologia Animal da Faculdade de Ciências da Universidade de Lisboa

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Palavras-chave Baixo Vouga Lagunar, *Hotspots*, medidas de diversidade, modelação ecológica, paisagem em mosaico, vertebrados, zonas húmidas

Resumo A identificação dos fatores que determinam as variações de riqueza e diversidade de espécies na paisagem tem um papel fundamental em ecologia e nos planos de conservação da biodiversidade. Neste estudo, focamos a nossa atenção em diferentes *taxas* de vertebrados terrestres presentes no Baixo Vouga Lagunar (BVL) e definimos como objetivo a identificação de *hotspots* de biodiversidade nesta região portuguesa. Para atingir o objetivo, revimos os estudos ecológicos centrados nos *taxa* modelo deste trabalho e que abrangiam a área do BVL e usamos os seus dados como base para o nosso estudo. De seguida, recolhemos variáveis ambientais com importância ecológica e estabelecemos três hipóteses (H_1: Composição da paisagem; H_2: Perturbação antrópica; H_3: Presença de água), contendo essas variáveis de forma a testar quais os fatores que restringem ou promovem os padrões de riqueza e diversidade dos vertebrados no BVL. Assim, recorrendo a uma abordagem de modelação ecológica e depois, baseando-nos nesses fatores estimamos os valores de riqueza e diversidade de espécies para toda a área de estudo. Era expectável conseguirmos identificar os hotspots de riqueza e diversidade de vertebrados terrestres no BVL, que seriam uma ferramenta crucial para gerir eficazmente esta área e assegurar a manutenção dos seus valores de biodiversidade. No entanto, deparamo-nos com uma limitação de dados, que se revelou um problema na construção dos modelos, resultando numa baixa precisão e consequentemente numa limitada capacidade de predição do modelo. Portanto, a nossa projeção da métrica para o BVL não permitiu identificar hotspots. No futuro, é necessária uma amostragem melhor delineada e um esforço de amostragem mais intenso para abranger um leque mais vasto de pontos de amostragem e promover assim a recolha de um maior volume de dados que permitam a construção de modelos mais robustos.

Key words Baixo Vouga Lagunar, Hotspots, diversity measures, ecological modelling, mosaic landscape, vertebrates, wetlands

Abstract

The identification of the factors driving species richness and diversity variations in a landscape has key role in ecology and in biodiversity conservation plans. In this study, we focused our attention on different vertebrates' *taxa* present in the Baixo Vouga Lagunar (BVL) and aimed to identify biodiversity hotspots in this Portuguese region. To achieve that goal, we reviewed ecological studies that targeted terrestrial vertebrates inhabiting the BVL and used their datasets as a basis for our study. Then, we collected ecologically relevant environmental variables, established three ecological hypotheses encompassing those variables (H_1: Landscape composition; H_2: Anthropic disturbance; H_3: Water presence), and tested them to assess which drivers can restrain or promote the BVL vertebrates' biodiversity patterns (species richness and diversity).The test of those hypotheses was implemented using an ecological modeling approach (Generalized Linear Mixed Models - GLMM) and later, based on the identified drivers, we forecasted species richness and diversity values to the study area. We expected to be able to identify vertebrates' richness and diversity hotspots in the BVL, which would be a crucial tool to efficiently manage this area and assure the maintenance of its biodiversity values. Unfortunately, we faced data limitations, which affected model building robustness, resulting in low accuracy, and consequently in limited feasibility of the models' predictive capacity. Therefore, in our forecasted map we could not define specific areas as hotspots, which is unrealistic. In the future, a well-defined sample design and more intense sample effort is needed in order to encompass a broader range of sampling points and promote a more robust model.

LIST OF CONTENTS

LIST OF FIGURES...IV

LIST OF TABLES...V

1 INTRODUCTION 1

2 METHODS.. 4

2.1 Study area 4

2.2 Wildlife data.. 6

2.3 Landscape data.. 8

2.4 Data analysis 17

3 RESULTS.. 19

3.1 Species Richness 19

3.2 Species Diversity 25

3.3 Forecasted richness and diversity patterns...................................... 29

4 DISCUSSION 32

4.1 Species Richness 32

4.2 Species Diversity 33

4.3 Forecasted Species richness and diversity 35

4.4 Data limitation 35

5 CONCLUSION 36

6 REFERENCES 38

7 APPENDICES 47

LIST OF FIGURES

Figure 1 Study area location with a 500m grid overlapped and spatial distribution of sampling points (each letter corresponds to the different habitats sampled and the numbers associated, represents sample replicate).. 5

Figure 2 Land use classes represented in the study area and spatial distribution of sampling points. (See **Table 1** for categories description). 10

Figure 3 Map with the predicted values of species diversity distribution on the study area. Darker areas represent zones where probably the higher species diversity is enhanced. Black dots represents each sampling point... 31

LIST OF TABLES

Table 1 Variables used to test vertebrate's richness and abundance hypotheses (H_1, H_2 and H_3) 15

Table 2 Best GLMM models constructed with Poisson distribution (*i.e*. ΔAICc<2) explaining vertebrate's richness in Baixo Vouga Lagunar. Results were presented per working hypothesis, for both scales tested and models ranked by increasing AICc. 20

Table 3 Best GLMM models constructed with Negative Binomial distribution (*i.e.* ΔAICc<2) explaining vertebrates richness in Baixo Vouga Lagunar. Results presented per working hypothesis, for both scales tested and ranked by increasing AICc.......... 23

Table 4 Variables included in the best models of the more supported hypothesis (landscape composition (H_1) and water presence (H_3) for the 500m scale explaining species richness variability. 25

Table 5 Best GLMM models built with Gaussian distribution (i.e. ΔAICc<2) explaining vertebrate's diversity in Baixo Vouga Lagunar. Results were presented per working hypothesis, for both scales tested and models ranked by increasing AICc. 27

Table 6 Variables included in the best models of the more supported hypothesis (Mixed hypothesis (H_4) for the 500m scale and Water presence hypothesis (H_3) for the 2000m scale) for explaining diversity variability. 29

Table 7 Land use and land cover categories presented in COS 2010 and the aggrupation in broader categories. 47

Table 8 Overdispersion of the best models built with Poisson distribution. Significant values are underlined. 50

1.
INTRODUCTION

Human welfare and sustainable development rely on the conservation of biodiversity and wise use of ecosystems (Alcamo, 2003; Bennett *et al.,* 2015). With the aim of promoting a better management of ecosystems, it's important to identify the factors that endorse modifications on their dynamics (Pereira *et al.*, 2009). According to the Millennium Ecosystem Assessment (2006), those factors are called 'drivers of change' and could be direct or indirect. Direct drivers have an immediate effect on the ecosystem and are predominantly physical, chemical or biological (*e.g*. modifications in land cover climate change, air and water pollution, exotic and/or invasive species income). An indirect driver influences direct drivers, not the ecosystem itself (Alcamo, 2003). For example, the demography (*e.g.* population size and their spatial distribution) and the economy (*e.g.* economic policies) – which are indirect drivers - of a country, will affect resources consumption (Alcamo, 2003; Pereira *et al.*, 2009).

The increase in number and distribution of human population over the last century (United Nations, 2014) imperil ecosystems and limit their services. Besides from diminishing the capacity of ecosystems to feed an increasing demand for their services (Pereira *et al.,* 2009), human practices led to a conversion of natural landscapes into anthropic environments (Foley *et al.,* 2005; Barnosky *et al*., 2012). Those land use changes became more intense in the past few decades and have negatively affected our coexistence with other living beings, both by habitat loss and fragmentation among other ecological processes (Rogan & Lacher, 2018).

Habitat loss refers specifically to a decrease in available habitat area while fragmentation occurs when a certain continuous habitat becomes patchy (Fahrig, 2003). Although habitat loss can occur in a landscape without necessarily fragmenting it, when a landscape is broken in patches, a removal of habitat area happens necessarily (Fahrig, 2003). Despite being different processes, they are correlated (Didham *et al.*, 2012; Villard & Metzger, 2014) and generally have negative effects for wildlife populations and communities: i) population size decline (Koskimäki *et al.,* 2014), ii) reduction in species richness (Murphy & Romanuk, 2014), iii) rearrangement and contraction of population physical distribution (Morrison *et al.,* 2007), and iv) consequent loss of genetic diversity (Morrison *et al.,* 2007). These processes could also affect population growth rate (Bascompte *et al.*, 2002) and breeding success (Kurki *et al*., 2000). Notwithstanding, the effects of these processes are contingent on specific animal traits and vary widely among landscapes (Didham *et al*., 2012).

Wetlands are very productive areas characterized for being moist throughout a large part of the year. They have features from both terrestrial and aquatic ecosystems and are presently seen as important ecological services providers (Woodward & Wui, 2001). Among other services, they offer habitat for aquatic and semi-aquatic species, defence against floods, purified water and leisure opportunities (Finlayson *et al.,* 2018). In the past, they were considered as non-useful land, or even harmful landscapes (*e.g.* sources of plagues such as mosquitos) therefore people frequently used to drain and destroy wetlands to 'improve' their land (Woodward & Wui, 2001). Because of that, losses in wetland areas have been severe throughout history (Hook, 1993) and, by the 80's circa 65% of European wetlands were lost (Finlayson *et al.,* 2018), mainly for conversion in dry farming lands and urban areas (Hook, 1993), but also due to the development of economic activities (Eppink *et al.*, 2004). The remaining wetlands were often restricted to a mosaic landscape where wetland environments were interspersed by productive lands.

Within a mosaic-shaped landscape, resource availability varies at finer- scales. Consequently, spatial heterogeneity may affect the presence and dispersal patterns of organisms, as well as their foraging behaviour. (Milne *et al.,* 1992). The response of an organism to spatial heterogeneity rests on its taxonomic group, its dispersion skills and its perception of the nearby habitat (Malanson & Cramer, 1999; Tews *et al.,* 2003). Habitat loss and fragmentation jeopardise wetlands (Hook, 1993) making these ecosystems connectivity unfeasible and consequently inhibiting species dispersal (Finlayson *et al.,* 2018.) which is indirectly one of the most significant causes for vertebrate biodiversity loss (Millennium Ecosystem Assessment, 2006).

Baixo Vouga Lagunar (Lower Vouga Lagoon System, hereafter, BVL) is a wetland and a human-altered region typical of Mediterranean ecosystems, that has been shaped by human activities as well as natural disturbances for centuries (Caraveli, 2000). This region is characterized by a heterogeneous landscape that resulted from a complex spatial matrix with fragments of remnant natural habitats, semi-natural (*e.g.* agricultural crops, pastoral production lands, etc.) and human-made (*e.g.* urban areas) habitats that closely contact with an estuarine coastal lagoon (Lillebø *et al.,* 2015). This wetland has unique features and holds a rich biodiversity (Andresen & Curado, 2005; Sumares & Fidelis, 2015; Lillebø *et al.,* 2015) because of the high numbers of available niches and resources that promote the coexistence of different taxa (habitat heterogeneity hypothesis by MacArthur & MacArthur, 1961). Therefore, the BVL arbour a great ecologic importance as it allows purification, storage and posterior drainage of water, besides establishing shelter, breeding and feeding zones for different species (DGADR, 2018). Although being considered a Special Protection Area (SPA) and a Site of Community Importance (SCI) in the Natura 2000 network, little is known about animal populations' dynamic and few has been done to promote the conservation of biodiversity and other natural values within this important area. In addition, there is a gap in knowledge about what drivers may impose menaces to those values.

In this context, the project "Human and nature in *Baixo Vouga Lagunar*: promote synergies and resilience in a global changes scenario" ("*Homem e Natureza no Baixo Vouga Lagunar: promover sinergias e resiliência num cenário de alterações globais*", original title) arises. The project globally aims: i) to balance biodiversity and Ecosystems Services with human activities, namely agriculture and ii) the promotion of a better management and more effective conservation of the BVL. More specifically, the objectives of this project are i) to identify vertebrates' biodiversity hotspots and with that ii-a) identify priority areas for conservation; ii-b) encourage local communities to get involved in conservation and ii-c) predict possible impacts in biodiversity values due to landscape changes. Thus, the current study is an integral part of this project that aims to respond to the first specific objective. In order to achieve that, in an initial phase we purpose to evaluate which factors can restrain or promote the BVL vertebrates' biodiversity patterns. To fulfill these goals, we formulated three hypotheses to be tested:

H_1: Landscape composition influence vertebrates' richness and diversity values once different habitats can provide various ecological niches and access to diverse resources (*e.g.* food). Therefore, there are some landscape units more favorable than others (Andrén, 1994; Atauri & de Lucio, 2001).

H_2: Anthropic disturbances affect negatively vertebrates' richness and diversity values due to their general sensitivity regarding manmade infrastructures (*e.g.* roads, houses, etc.) which preclude some species of using particular areas. (Murphy & Romanuk, 2014; Fahrig & Rytwinski, 2009).

H_3: The predominance of aquatic elements has a positive effect on vertebrates' richness and diversity values; since all organisms depend on waterbodies whether as breeding or feeding sites or just as a freshwater source (Korine *et al.,* 2016; Lintott *et al.,* 2016; Amorim *et al.,* 2018; Hoverman & Johnson, 2012; Torres *et al.,* 2016)

On a second phase, from those hypotheses and using ecological modeling, we want to assess what factors do better explain richness and diversity and then, based on the identified drivers forecast species richness and diversity to the entire BVL region. After that, we will be able to identify vertebrates' richness and diversity hotspots in the BVL, which will be a crucial tool to efficiently manage this nature conservation area and assure the maintenance of its biodiversity values.

2. METHODS

2.1 Study area

The study was carried out in the Central-North Portuguese coast, in a region located in Aveiro district. It encompasses part of the municipalities of Aveiro, Estarreja, Murtosa, Albergaria–a-Velha and Ovar, which are included in a region known as Baixo Vouga Lagunar (BVL). The study area had approximately 42,500 ha; it is limited in the west by Atlantic Ocean and in the south by the Vouga River (**Figure 1**).

Most of the BVL area is classified as a Special Protection Area (SPA) and a Site of Community Importance (SCI) under the Natura 2000 network (Ref. PTCON0061), because of its high diversity of living organisms and its ecologically delicate agricultural area. Among the important wildlife species that can be found in BVL, golden-striped salamander (*Chioglossa lusitanica*, Vulnerable -VU), palmate newt (*Triturus helveticus*, VU), greater mouse-eared bat (*Myotis myotis*, VU) and lesser mouse-eared bat (*Myotis blythii*, VU) are important natural values of the area due to their high threatened status (Cabral *et al.,* 2005). This classification is an important tool to guarantee the preservation of ecosystem integrity and the conservation of biodiversity values (Andresen & Curado, 2005; Sumares & Fidelis, 2015; Lillebø *et al*., 2015). However, despite the recognised importance of this area to preserve the regional natural values, no data is yet available regarding the identification of the geographical location of potential biodiversity hotspots.

The BVL region, besides being a transitional system between terrestrial, freshwater and brackish water systems, is also a complex manmade and highly heterogeneous landscape that includes natural, semi-natural and completely human-altered habitats therefore creating a mosaic of habitats. As a coastal wetland, it embraces some typical habitats, such as salt marshes, sea rushes and reed beds, while freshwater marshes, forests, open fields and *bocage* (Sumares & Fidelis, 2015; Lillebø, 2015) characterize some upstream areas. The latest has on BVL its unique representation on the Portuguese territory. *Bocage* characterizes for being a complex system where small patches of agricultural or grazing areas are surrounded by hedges. These landscapes are very important for biodiversity preservation due to their high multifunctionality (DGT, 2013).

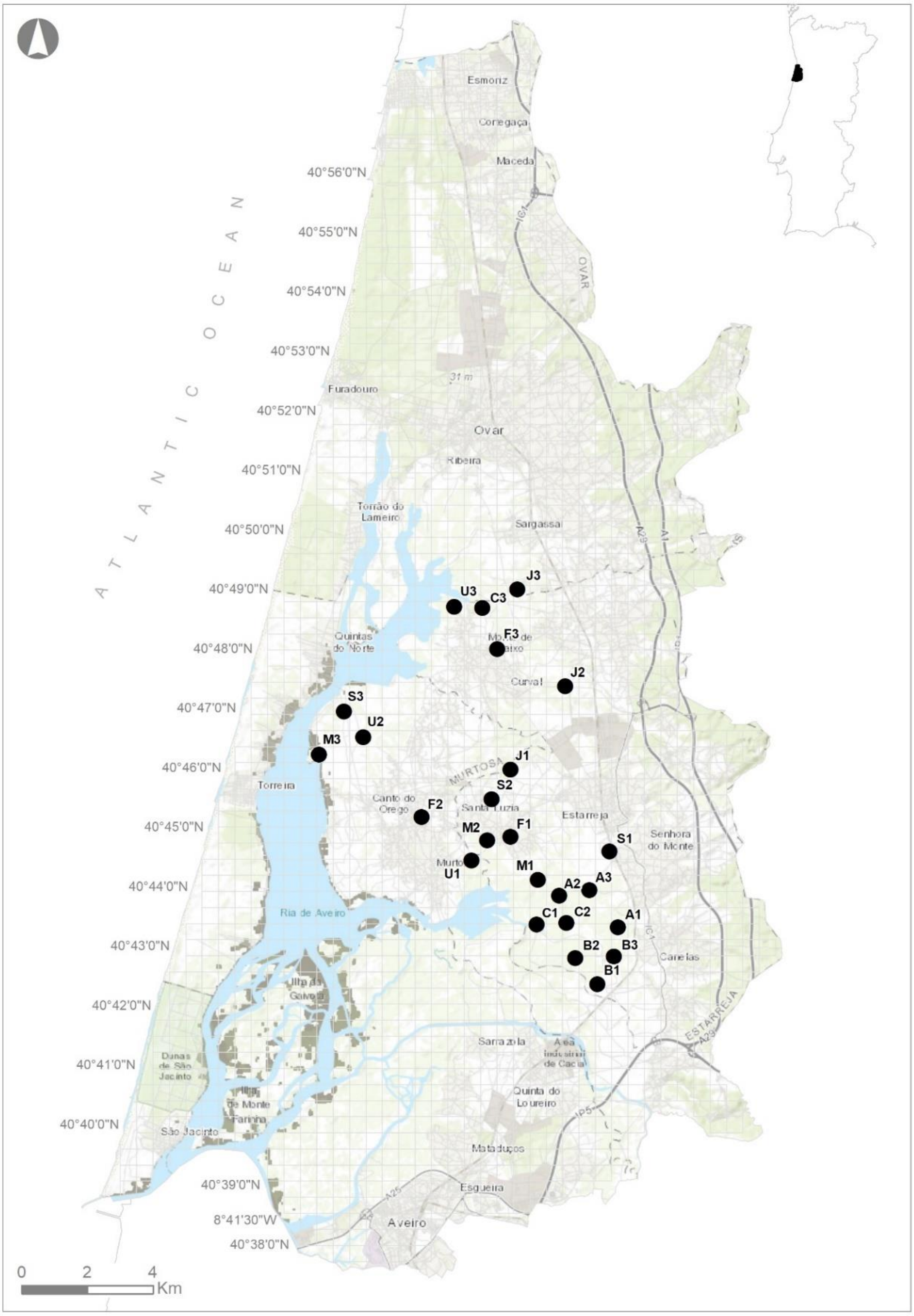

Figure 1 Study area location with a 500m grid overlapped and spatial distribution of sampling points (each letter corresponds to the different habitats sampled and the numbers associated, represents sample replicate).

2.2 Wildlife data

We reviewed all ecological studies implemented in the study area that targeted the model taxa (*i.e.* amphibians, reptiles and mammals), using ISI Web of Science (https://apps.webofknowledge.com), Scopus (https://www.elsevier.com/solutions/scopus) databases, and the Google Scholar search engine. We searched for the follow terms within article title, abstract and keywords: 'amphibians', 'reptiles', 'mammals', 'Baixo Vouga' and 'BVL', as isolated and as combined terms. All the published studies we gathered corresponded to University of Aveiro Master dissertations (*e.g.* Torres, 2013; Marques, 2013; Mendes, 2013), and thus we focused our data collection on those data sources. The data used on these master theses were collected in the course of a project entitled "Factors that affect the seasonal and spatial patterns of vertebrate diversity and activity in different habitat types of the humanized landscape of Baixo Vouga Lagunar". Thus, we gathered presence and abundance data of amphibians and reptiles from Torres (2013) dissertation, and mammalians data from Marques (2013) and Mendes (2013) studies. From each of these studies we were able to retrieve individual geographical locations of specimens of each *taxon* detected or trapped, mostly acquired on predefined sampling sites (see **Figure 1)**.

Torres (2013) aimed to understand which factors influence the distribution and diversity of amphibians in BVL. A wide variety of sampling methodologies were implemented (*e.g.,* nocturnal itineraries, waterbody's sampling, pitfall traps with drift fences, arboreal pipe refuges and aquatic funnel traps). Sampling was carried out between October 2011 and September 2012. Itineraries were prospected at evening/night in an extent of 500m and 2,5m for both sides during 30min. In October and November of 2011, itineraries took place twice a month and from December on, one of the itineraries, was substituted for waterbodies sampling with the same sample effort, using fishnets with a 4mm mesh. When sampling points do not have waterbodies, those points were prospected with walking transepts. During March, April and May (breeding season) a supplementary daytime waterbody sample was carried out for each sampling point. Six arboreal refugees, two aquatic funnel traps and four pitfall traps with drift fences were installed per sampling point, every two months and were verified during five consecutive days. For more details regarding the methodological approach please see Torres, 2013.

In this study, the target habitats were those considered typical of the landscape mosaic of the study area, namely *bocage*, forest, maize fields, marshland, reed beds, rice fields and sea rushes. For each one of these habitats, three replicates were used, in twenty-one sampling points.

During the implementation of the fieldwork, the numbers of amphibians in the larval phase and as adults were registered in each of the sampling occasions per habitat type and sampling period. Although reptiles were not the target taxa of that study, the number of reptiles detected as well as its geographical location were also registered. Torres (2013) compiled two type of datasets: the species presence/absence and the abundance of each species per sampling point.

Sara Marques master dissertation (Marques, 2013) focused the study on the community of terrestrial mammals, as well as the predator-prey interaction, targeting carnivores and small mammals. The major goal of this dissertation was to recognize and understand patterns of terrestrial mammal species richness and abundance in the heterogeneous landscape of the BVL. Seven representative habitats present in the BVL (the same ones mentioned above that were used for sampling amphibians) were sampled using also three replicates for each habitat type (totalizing again 21 sampling points, scattered through the study area). Different methodologies were adopted to detect the various mammal species present in the area which differ in bio-ecological characteristics and tend to explore the landscape in different spatial scales (*e.g.* carnivores home-range can be 370x wider than those of small mammals; *e.g*. European badgers, *Meles meles vs* wood mouse, *Apodemus sylvaticus*; (Rosalino *et al*., 2004; Rosalino *et al.*, 2011)); Small mammals were sampled using 30 Sherman ^{TM} traps disposed in line in each sampling point during five consecutive days, every two months between November 2011 and October 2012.

A 1km^2 square was used as standard sampling unit size to catalogue carnivores' distribution in the BVL. This size was chosen considering species home range as a compromise between small (Weasel, *Mustela nivalis*; 0.24 km^2 – Jedrzejewski *et al*., 1995) and larger (European badger, Meles meles; 4.5 km^2 – Rosalino *et al.,* 2004) size species. To detect carnivores, diurnal linear transepts were set to detect signs of presence (scats, footprints, dens, etc.), which were complemented with the installation of camera-traps (Bushnell® Trophy XLT cameras with a movement sensor).

The survey for carnivores' presence signs consisted in evenly distributed transepts in every sampling unit, with all land uses being represented. Each transept, which was 500m long, was prospected once, during 15 minutes by two people (total effort = 30min) between November 2011 and April 2012. All signs of presence were identified to species level and their geographical location were recorded; Prospection with camera traps was carried out among January 2012 and June 2013 in randomly selected 1km^2 squares to diminish autocorrelation (spatial and temporal). A total of 72 sampling sites were searched during 15 consecutive days. Methodological details regarding mammal sampling are described in Marques (2013).

The study of bat assemblages, implemented by Mendes (2013), intended to assess the main drivers affecting the activity and diversity of bats in BVL. For that, he based his fieldwork on acoustic monitoring of bats during walking transepts. Sampling was performed twice a month between October 2011 and September 2012, except in April and July, which were only surveyed once each month due to unfavourable weather conditions. Acoustic survey was carried out in the first 2.5h-3h after nightfall in 15 minutes walking transepts of about 500m length. Those transepts were implemented in eight characteristic habitats of the region (for his study, Mendes (2013) considered the same habitats as Torres (2013) and Marques (2013), but included one more: urban), which were sampled three times each, therefore totalizing 24 sites. During bat sampling, individuals' presence was identified using an ultrasound detector (Pettersson D240x, Pettersson Elektronik AB™, Uppsala, Sweden) and a digital sound recorder (Edirol R-09, Roland Corp., Shizuoka, Japan) that allowed to detect bat calls and stored those data for later identification (for more details regarding bat's data gathering see Mendes, 2013).

2.3 Landscape data

The present study analysis (see below) was based on landscape drivers. Thus, we used information available from the "Land use and land cover map of continental Portugal - COS2010" (DGT, 2010) to assess the land cover composition of each grid cells used as the sampling unit in our analysis (**Figure 2**). We also accessed information of roads and rail network from the "OpenStreetMap" database (www.geofabrik.de) in order to calculate distances from the sampling points to the nearest man-made infrastructure. In addition, we assessed "*Sistema National de Informação de Recursos Hídricos*" (SNIRH; www.snirh.apambiente.pt) to obtain waterbodies distribution in the BVL region and therefore estimate distance to the nearest waterbody.

Using the COS2010 land cover information as the keystone data we built an Eco-Geographical Information System (Eco-GIS), based on the ArcMap software (version 10.5). This Eco-GIS allowed us to extract the environmental variables for each of the sampling points that were considered important and influential drivers of local species richness and diversity, allowing us to test the three pre-defined hypotheses.

First, we built two distinct grids representing the two scales of analysis: 500m x 500 meters and 2000m x 2000m. These two scales were selected due to the fact that they represent two different scales of space used by wildlife. They were used to match the compiled wildlife data, that included species that have wider home ranges (*e.g*. carnivores, as badger whose home range can reach 4.5km^2 (Rosalino *et al.*, 2004)) and those with a more restricted scale of habitat use (*e.g*. amphibians, reptiles and small mammals). Both grids were limited by the BVL limits and were overlaid on the land cover map, on the roads and rail network map and on waterbodies distribution map.

The land cover categories presented in the original version of COS2010 were too detailed, therefore we choose to group some of the original categories not only in order to reduce it number (see **Table 7** in the Appendices), but also to adapt it to the local study area characteristics. Thus, we pooled all manmade infrastructures: horizontal/vertical and/or continuous/discontinuous urban fabric; infrastructures for energy production or for waste/water-waste treatment; asphalted roads (includes highways, national and municipal roads); rail network and other manmade constructions, in one category named "Urban". This category embraces a huge spectrum of infrastructures whose construction implied habitat changes (Beebee, 2013). This transforms natural spaces in anthropic ones (urbanization), therefore reducing habitat and changing the remain of it, which affects vertebrates use of space (Hamer & Parris, 2011). More specifically, for example roads are very harmful for amphibians (Beebee, 2013), reptiles (Jochimsen *et al.,* 2004) and non-volant mammals (Oxley *et. al.,* 1974), because of the risk of death due to vehicle trampling.

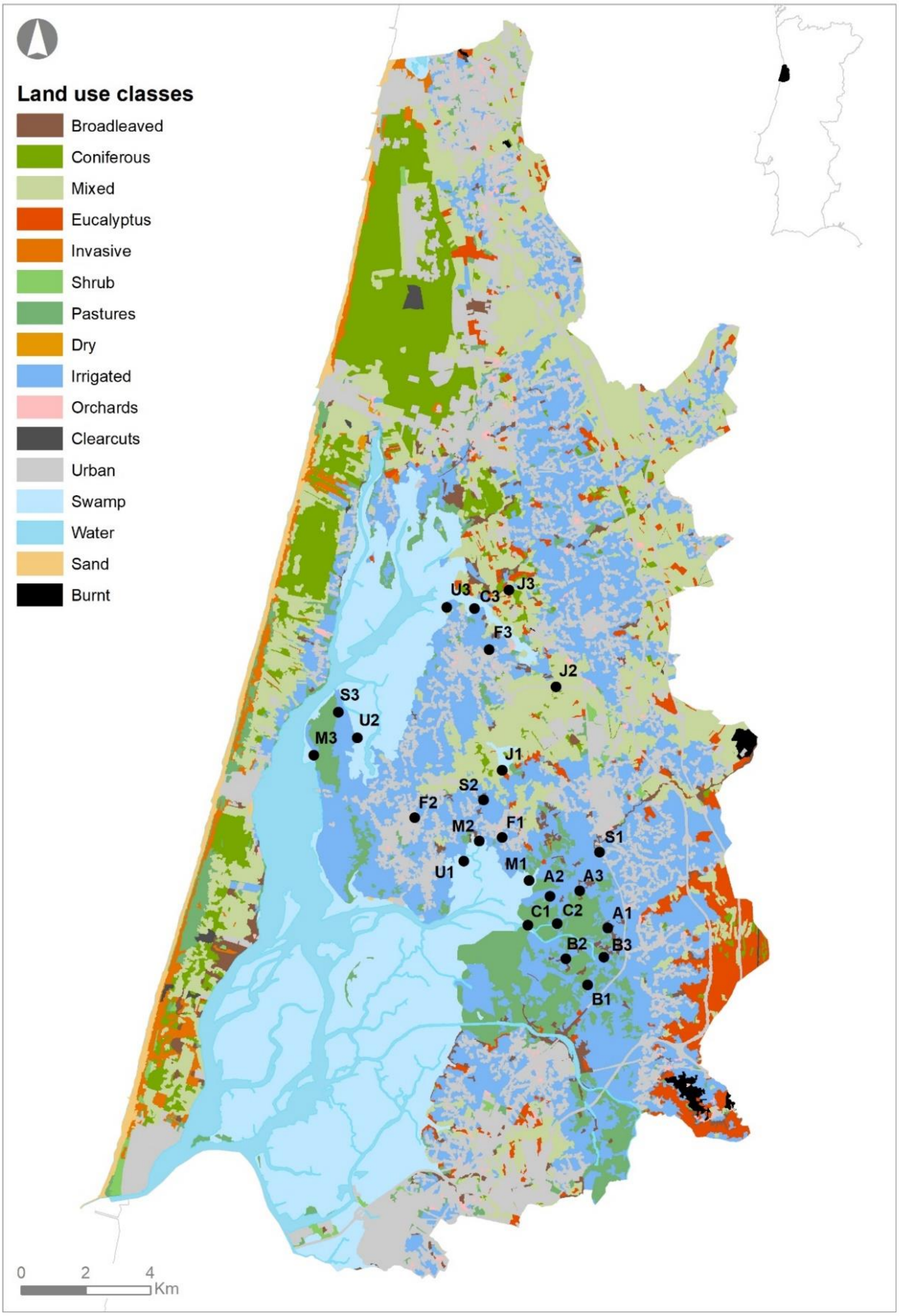

Figure 2 Land use classes represented in the study area and spatial distribution of sampling points. (See **Table 1** for categories description).

Regarding habitat changes, there are some species (*e.g.* bats), who's feeding activity and social behavior is positively influenced by urban sites (Mendes, 2013). Notwithstanding, some species are strictly associated with specific habitat types, but many bat species are generalists; hence, they can use diverse existing habitats (Lookingbill *et al.,* 2010). They often depend on multiple location to fulfill their needs and accede their life-cycle requirement habitats (Lookingbill *et al.,* 2010), and this way, the mosaic of habitats characterizing BVL, represents great opportunities for these chiropter species.

Although human population and their infrastructures generally have negative effects in wildlife, constructions built for water retention can have positive effects on amphibian species (Laan & Verboom, 1990). Besides that, amphibian's presence is influenced by the existence of temporary waterbodies, used as breeding habitat (Torres *et al.,* 2016). Carnivore and small mammals richness are positively influenced by landscape features like freshwater lines (Marques, 2013; Santos *et al.,* 2011). For those reasons, we cluster in "Water" category all natural and artificial watercourses, natural and artificial lakes and lagoons, reservoirs, puddles and other fresh water related structures.

In the BVL region, most water channels are salty or brackish, making fresh water a scarce resource for carnivores. Therefore, the "Swamp" category was also considered plausible for explaining richness and diversity in our study. Swamps, marshlands, saltpans and the intertidal zone were grouped on that category. That class is also important for reptiles and amphibians because many times they are searched for food and breeding (Wells, 2007). Agriculture-based landscapes in wetlands are known for being significant foraging habitats for bats (Sirami *et al.,* 2013).

A negative correlation amongst amphibians' diversity and agricultural areas have been established by many authors (Beja & Alcazar, 2003; Pellet *et al.,* 2004) and amphibians' richness is also negatively related with more arid agricultural environments (Atauri & De Lucio, 2001). Similar results were shown to reptiles richness: they are negatively related with irrigated and unirrigated crops (Atauri & De Lucio, 2001).On the other hand, moderate pastoralism preserves low vegetation, hence allowing amphibians and reptiles' dispersion (Plăiasu *et al*., 2010). Thus, we decided to segregate agriculture related lands in different categories accordingly to their characteristics. Dry farming lands correspond to "Dry"; irrigated farming zones such as rice fields and temporary irrigated farming associated with vineyards/orchards/olive groves were congregated in "Irrigated"; all land areas destined to fruit production were gathered in the "Orchards" category and "Pasture" is the category that includes not only permanent pasture land, but also agricultural lands with grass zones and natural grass fields.

Regarding vegetation cover, the presence of shrub plays an important role for carnivore diversity and abundance in Mediterranean landscapes by providing shelter (Rosalino *et al.,* 2009). “Shrub” is one of the categories we consider and refers to dense sclerophyll vegetation. The existence of forest cover is an important driver for amphibian’s richness and diversity because forests provide them shelter outside the breeding season (Hamer & McDonnell, 2008). Patches of Mediterranean forest are important habitats for non-volant mammals due to provisioning protection from predators for small mammals and shelter for carnivores (Virgós, 2001). In our study area, *Eucalyptus* sp. and *Pinus pinaster* dominate forest cover and composition. As monocultural plantations, is expected the harbour of few animals (Proença *et al.,* 2010). Hence, we classified this land use in seven categories: “Coniferous” when referring to *Pinus pinaster* , *Pinus pinea* and other softwoods forests; “Broadleaved” when lands are occupied by oaks and other broadleaved tree species; “Eucalyptus” when forests are mainly composed by eucalyptus; “Invasive” when invasive species dominate the forest (*e.g. Acacia longifolia*); “Mixed” when more than one of the tree species included in previous categories, are present; “Clearcuts” when trees were cut, no matter which one of previous categories they belong and “Burnt” in areas that went through wildfires (this one also include non-forested areas).

”Sand” include interior and coastal beaches, dunes and sands (see **Table 1** for more elucidation about the categories).

These last two categories (“Burnt” and “Sand”), although being present in this mosaic of habitats, don´t have representativeness on sampled cells. For this reason, they do not appear in **Table 1** and were not included in the produced models.

Each sampling point was assigned to a cell in the 2000m x 2000m and 500m x 500m grid to associate the ecological wildlife data with the environmental characteristics of the area. The environmental variables were extracted for both scales (500m x 500m and 2000m x 2000m), and the land use information collected for each cell was: percentage of each type of soil use, and distance, in meters, from the sampling points to the closest waterbodies, roads (streets, municipal and national roads and high ways are encompassed), railway, and other manmade infrastructures.

We then merged this matrix containing the landscape characteristics of each cell (in both scales) to which we add wildlife data, with that containing the wildlife information for the correspondent cell.

For each of the cell that we manage to collect wildlife data we also estimated species richness and a diversity index. The first one was estimated by summing the number of species that were detected in each of those cells and we chose to calculate the Shannon-Wiener Index (H'; Zar, 2010), using the following equation:

$$H' = \sum_{i=1}^{S} p\,i * \ln(pi) \ ,$$

where *S* is the species richness and *pi* is the proportion of individuals that belong to specie *i*.

Table 1 Variables used to test vertebrate's richness and abundance hypotheses (H1, H2 and H3)

Hypotheses	Variable	Description	Type	Scale 500m	2000m
H_1 Landscape composition	Bleaved[(a)]	Percentage of area covered by broadleaved trees species (*e.g.*: Oak; Chestnut) in each sampled cell	Continuous	✓	✓
	Conif [(a)]	Percentage of area covered by coniferous tree species (*e.g.*: *Pinus pinaster*; *Pinus pinea*; other softwoods) in each sampled cell	Continuous	✓	✓
	Eucalypt[(a)]	Percentage of area covered by *Eucalypts* plantations in each sampled cell	Continuous	✓	✓
	Irrigat [(a)]	Percentage of area covered by temporary or permanent irrigated farming (*e.g*. irrigated vineyards, orchards or olive groves; rice fields) in each sampled cell	Continuous	✓	✓
	Mixed [(a)]	Percentage of area covered by forests of more than one tree species in each sampled cell	Continuous	✓	✓
	Orchard [(a)]	Percentage of area covered by fruit tree species (includes vineyards) in each sampled cell	Continuous	✓	✓
	Pasture [(a)]	Percentage of area covered by pasture lands in each sampled cell	Continuous	✓	✓
	Shrub2[(a)]	Percentage of area covered by shrubs and other vegetation in each sampled cell	Continuous		✓
H_2 Anthropic disturbances	Urban [(a)]	Percentage of area covered by manmade infrastructures (*e.g.*: houses; buildings; recreational facilities) in each sampled cell	Continuous	✓	✓

	DistUrban[(b)]	Distance in meters from each sampling point (included in a sampled cell) to the nearest man-made infrastructure (*e.g*. Houses, buildings, parks, sports facilities)	Continuous	✓	✓
	DistRway[(b)]	Distance in meters from each sampling point to the nearest railway	Continuous	✓	✓
	DistHWay[(b)]	Distance in meters from each sampling point to the nearest highway	Continuous	✓	✓
	DistResid[(b)]	Distance in meters from each sampling point to the nearest street	Continuous	✓	✓
	DistNation[(b)]	Distance in meters from each sampling point to the nearest national road	Continuous	✓	✓
H_3 Water presence	Swamp [(a)]	Percentage of area coved by temporary waterbodies in each sampled cell	Continuous	✓	✓
	Water [(a)]	Percentage of area coved by permanent waterbodies in each sampled cell	Continuous	✓	✓
	DistWater[(c)]	Distance in meters from each sampling point to the nearest waterbody	Continuous	✓	✓

Data collected from: (a) COS 2010 DGT (Direcção Geral do Território) (2010) Carta de Uso e Ocupação do Solo de Portugal continental para 2010 (COS 2010) WMS. Direção de Serviços de Geodesia, Cartografia e Informação Geográfica, Direção-Geral do Território, Lisboa; (b) Open street maps database, accessed at https://www.geofabrik.de/ on January 2018 and (c) https://snirh.apambiente.pt/ accessed on January 2018. In terms of nomenclature, 2000m x 2000m scale variables differ from 500m x 500m scale variables by adding a “2” in the end of the word (*e.g.* Shrub2).

2.4 Data analysis

To test our working hypotheses, we grouped the variables extracted from the Eco- GIS. Thus, we divided the variables into three clusters corresponding to the three ecological hypotheses defined *a priori*: Landscape Composition Hypothesis (H_1); Anthropic Disturbance Hypothesis (H_2) and Water Presence Hypothesis (H_3) (**Table 1**).

The first phase of the data analysis focused on exploring the dataset. All the environmental variables collected in the data processing phase will be used as explanatory variables to test what factors determined richness (*i.e.* number of species) and diversity (H') variations, using an ecological model approach. We first standardized the variables in order to convert data from different sources into the same scale; hence allowing comparisons that otherwise could not occur (Mackenzie *et al*., 2006). We then tested the existence of spatial autocorrelation within our richness and diversity datasets, throughout the estimation of Moran Index (I; Legendre, 1993), which assesses how well objects correlate with other nearby objects across a spatial area. Moran Index was estimated in R software (version1.0.143, R Core Team, 2017) using the package "ape" (Paradis *et al.,* 2004).

Furthermore, correlation between independent variables may affect the fitness of the models, leading to greater standard errors of coefficients, and consequently to type II errors (*i.e*. Failure to reject a false hypothesis; Zar, 2010). Thus, it was necessary to test associations between the explanatory variables through the calculation of the Variance Inflation Factors (VIF; Zuur *et al*., 2007). As suggested by Zuur *et al*. (2007) we excluded from the modelling procedures all variables with VIF > 2, because of the suspicion of existence of multicollinearity. VIF estimations were produced using the package "*fmsb*" (Nakazawa, 2014), in R software.

After the definition of the candidate predictors (variables with VIF<2), we implemented an ecological model approach to test our working hypothesis. To the extent that no spatial autocorrelation was detected for any of the scales of analysis, we applied a Generalized Linear Models (GLMMs) approach, with Poisson distribution (for the richness dataset, as the dependent variable was the number/count of species present (Zuur *et al.,* 2007)) and with Gaussian distribution for the diversity dataset (Zuur *et al.,* 2007).

For each scale of analysis and type of dataset (*i.e.* richness and diversity), we applied the following procedure: in each hypothesis under test, we built models corresponding to all combinations of the candidate variables considered to each hypothesis (see **Table 1**).

These models' combinations were implemented using the package "*MuMIn*" (Barton, 2018). Models produced for each hypothesis were ranked according the Akaike Information Criterion, with a correction for small sample sizes (AICc) (Burnham & Anderson, 2002). Those models with ΔAICc < 2 were considered the ones that can better explain the variability in the response variables for each hypothesis (*i.e*. best models). The best models for every hypothesis were then averaged and the variables coefficients were calculated using a 95% confidence interval (95% CI). Those variables, whose 95% CI of the coefficient did not include zero, were considered candidate variables for a possible fourth hypothesis (H4), the mixed hypothesis (*i.e.* vertebrates' diversity and richness variations are determined by a combination of landscape, disturbance and aquatic element drivers). Models for this hypothesis were also built by combining all the selected variables and were ranked according to the AICc. We then compared the AICc of all models produced and selected the hypothesis that best explained the data variability, as that corresponding to the models with the lowest AICc. Then, we calculated the relative importance of each variable as the sum of the Akaike weights of all models that included the variable (Arnold, 2010).

After selecting the overall best models for the richness data sets (*i.e.* count data), we tested for overdispersion (using the package "AER" in R software; Kleiber & Zeileis, 2008), to evaluate whether the empirical variance in the data is greater than the one predicted by the model, thus affecting the model performance (Zuur *et al.,* 2007). In the cases where overdispersion was significant (i.e. $p<0.05$), the models were redone resorting to a Negative Binomial (NB) distribution, that was implemented using the package "MASS" (Venables & Ripley, 2002). Finally, we compared the performance (*i.e.* it fit) between the models with both types of distribution using a goodness of fit test to assess which of the models built using NB or Poisson distribution was better fitted to the data.

Since R^2 informs us about the total variance explained for a model, we calculated it for the overall best models found using the package "rsq" (Zhang, 2018)

The primary motive for our model selection was to identify a model that could be used for prediction. If a single model is clearly supported, then the prediction can be done using it; if more than one model is supported, model averaging should be used before extrapolation (Johnson, 2004).

The prediction of our response variables' patterns was based on model averaging. We used the best previous models to extrapolate results for the entire study area using the package "xlsx" (Dragulescu & Arendt, 2018). This allowed us to predict values of diversity on non-sampled cells trough computation of the estimated variables in the final model (Lee *et al.,* 2006). We then mapped those predicted values using ArcMap.

3. RESULTS

3.1 Species Richness

No significant spatial autocorrelation (Moran I= - 0.057 for both scales; p=0.778) was detected for species richness data.

In the landscape composition hypothesis (H_1), to avoid type II errors, we acceded collinearity between independent variables through VIF calculation and posterior exclusion of the variables with VIF<2, as recommended by Zuur *et al.* (2007). The results led us to remove "Conif" (VIF= 62.036) from the 500m scale model process and "Conif2" (VIF= 137.001), "Eucalyp2" (VIF= 8.450) and "Mixed2" (VIF= 2.708) from the 2000m scale procedure. We applied a Generalized Linear Mixed Models (GLMMs) approach, with Poisson distribution and obtained models combining the remaining variables for each scale. From those, we found two plausible models (ΔAICc <2; see **Table 2**) for each scale for explaining species richness considering the land cover hypothesis. Regarding anthropic disturbance (H_2) we removed from the models: "DistRway" (VIF=105.153) and "DistNation" (VIF=3.946) from the 500m scale model procedure and "DistRWay2" (VIF=101.302) and "DistUrban2" (VIF=3.861) from the 2000m scale model process. Therefore, we obtained three acceptable models for the 500m scale and four for the 2000m scale (ΔAICc <2; see **Table 2**) for the richness explanation taking into account anthropic disturbance. Finally, considering water presence hypothesis (H_3), none of the component variables presented collinearity and, consequently, all of them were used for model building. As a result, we obtained four models (ΔAICc <2) for the 500m scale as well as for the 2000m scale (consult **Table 2**)

Table 2 Best GLMM models constructed with Poisson distribution (*i.e*. ΔAICc<2) explaining vertebrate's richness in Baixo Vouga Lagunar. Results were presented per working hypothesis, for both scales tested and models ranked by increasing AICc.

Scale	Hypotheses	Df	LogLik	AICc	ΔAICc	W	Total ΔAICc for each scale
	H_1: Landscape composition						
500m	FULL MODEL: (Bleaved + Eucalypt + Irrigat + Mixed + Orchard + Pasture, family = poisson)						
	• Bleaved + Pasture	3	-70.283	147.8	0.00	0.165	0.00
	• Bleaved + Eucalypt + Pasture	4	-69.769	149.6	1.88	0.064	1.80
	H_2: Anthropic disturbances						
	FULL MODEL: (Urban + DistUrban + DistHWay + DistResid, family = poisson)						
	• Null model	1	-75.924	154.0	0.00	0.310	6.20
	• DistUrban	2	-75.542	155.7	1.63	0.137	7.90
	• DistHWay	2	-75.713	156.0	1.97	0.116	8.20
	H_3: Water presence						
	FULL MODEL: (Swamp + Water + DistWater, family = poisson)						
	• DistWater + Water	3	-72.888	153.0	0.00	0.258	5.2
	• Water	2	-74.479	153.5	0.55	0.196	5.7
	• DistWater	2	-74.564	153.7	0.72	0.180	5.9
	• Null model	2	-75.924	154.0	1.05	0.152	6.2

	H_1: Landscape composition						
2000m	FULL MODEL: (Bleaved2 + Irrigat2 + Orchard2 + Pasture2 + Shrub2, family = poisson)						
	• Bleaved2	2	-74.095	152.8	0.00	0.235	0.00
	• Null model	1	-75.924	154.0	1.27	0.125	1.20
	H_2: Anthropic disturbances						
	FULL MODEL: (Urban2 + DistHWay2 + DistResid2 + DistUrban2, family = poisson)						
	• Null model	1	-75.924	154.0	0.00	0.310	1.20
	• DistUrban2	2	-75.542	155.7	1.63	0.137	1.20
	• DHWay2	2	-75.713	156.0	1.97	0.116	3.20
	H_3: Water presence						
	FULL MODEL: (Swamp2 + Water2 + DistWater2, family = poisson)						
	• DistWater2 + Water2	3	-72.888	153.0	0.00	0.258	0.20
	• Water2	2	-74.479	153.5	0.55	0.196	0.70
	• DistWater2	2	-74.564	153.7	0.72	0.180	0.90
	• Null model	1	-75.924	154.0	1.05	0.152	1.20

Df Degrees of freedom; **LogLik** log-likelihood of the GLMM model; **AICc** Akaike Information Criteria corrected for small sample sizes; **∆AICc** difference between the model AICc and the lowest AICc of all models built for that specific hypothesis scale of analysis; **W** model weight; **Total ∆AICc for each scale** is the difference between the model AICc and the lowest AICc of all models built for that specific scale of analysis. The models with more statistical support are underlined. Variables' description is presented in **Table 1**

After that, we tested the models' overdispersion (*i.e.* larger variance than the model assumes; Meyer, 2018) and we found it significant in the 2000m scale for land cover hypothesis, in both scales for anthropic disturbance hypothesis and in some models for the 2000m scale regarding water presence hypotheses (consult **Table 8** in the Appendices). All other models presented non-significate overdispersion (see **Table 8**). An overdispersed Poisson model would promote understated standard errors, which also leads to incorrect conclusions (Meyer, 2018). Therefore, we remade the models using a Negative Binomial distribution and obtained seven models with ΔAICc <2 for H_1, one for H_2 and four for H_3 at the 500m scale (see **Table 3**). Considering the 2000m scale, two, one and three models fulfilled that criteria, respectively for H_1, H_2 and H_3 (ΔAICc <2; **Table** 3). Then, we compared the models' goodness of fit for each distribution using the Likelihood Ratio test (Satorra & Saris 1985). In general, this resulted in a better fit from Negative Binomial (NB) distribution, and a significant statistical adequacy for all scales and hypotheses except one: for the landscape composition hypothesis at 500m scale, the NB distribution fitted better than Poisson (*i.e.* LogLik >1) but the difference had no statistical significance (LogLik = 7.483424, p= 0.006).

Table 3 Best GLMM models constructed with Negative Binomial distribution (*i.e.* ΔAICc<2) explaining vertebrates richness in Baixo Vouga Lagunar. Results presented per working hypothesis, for both scales tested and ranked by increasing AICc.

Scale	Hypotheses	Df	LogLik	AICc	ΔAICc	W	ΔAICc for each scale
	H_1 :Landscape composition						
500m	FULL MODEL: (Bleaved + Eucalypt + Irrigat + Mixed + Orchard + Pasture, family = Negative Binomial)						
	• <u>Bleaved + Pasture</u>	<u>4</u>	<u>-68.871</u>	<u>147.9</u>	<u>0.00</u>	<u>0.092</u>	<u>0.00</u>
	• Bleaved	3	-70.513	148.2	0.38	0.076	0.40
	• Null model	2	-71.887	148.4	0.50	0.072	0.60
	• Mixed	3	-70.583	148.4	0.52	0.071	0.60
	• Irrigated	3	-70.954	149.1	1.26	0.049	1.30
	• Pasture	3	-70.979	149.2	1.31	0.048	1.40
	• Bleaved + Mixed	4	-69.635	149.4	1.53	0.043	1.60
	H_2 : Anthropic disturbances						
	FULL MODEL: (Urban + DistUrban + DistHWay + DistResid, family = Negative Binomial)						
	• Null model	1	-71.887	148.3	0.00	0.374	0.50
	H_3 : Water presence						
	FULL MODEL: (Swamp + Water + DistWater, family = Negative Binomial)						
	• <u>Swamp</u>	<u>3</u>	<u>-70.349</u>	<u>147.9</u>	<u>0.00</u>	<u>0.251</u>	<u>0.00</u>
	• <u>DistWater + Swamp</u>	<u>4</u>	<u>-68.898</u>	<u>147.9</u>	<u>0.00</u>	<u>0.251</u>	<u>0.00</u>
	• Null model	2	-71.887	148.3	0.45	0.201	0.50

	• DistWater	3	-71.228	149.7	1.76	0.104	1.90
	H_1 :Landscape composition						
2000m	FULL MODEL: (Bleaved2 + Irrigat2 + Orchard2t + Pasture2 + Shrub2, family = Negative Binomial)						
	• Null model	2	-71.887	148.3	0.00	0.235	0.00
	• Bleaved2	3	-71.033	149.3	0.92	0.148	1.00
	H_2 : Anthropic disturbances						
	FULL MODEL: (Urban2 + DistHWay2 + DistResid2 + DistNation2, family = Negative Binomial)						
	• Null model	1	-71.887	148.3	0.00	0.367	0.00
	H_3 : Water presence						
	FULL MODEL: (Swamp2 + Water2 + DistWater2, family = Negative Binomial)						
	• Null model	2	-71.887	148.3	0.00	0.335	0.00
	• Water2	3	-71.156	149.5	1.17	0.187	1.20
	• DistWater2	3	-71.228	149.7	1.31	0.174	1.40

Df Degrees of freedom; **LogLik** log-likelihood of the GLMM model; **AICc** Akaike Information Criteria corrected for small sample sizes; ∆**AICc** difference between the model AICc and the lowest AICc of all models built for that specific hypothesis scale of analysis; **W** model weight; ∆**AICc** for each scale is the difference between the model AICc and the lowest AICc of all models built for that specific scale of analysis. The models with more statistical support are underlined. Variables' description is presented in Table 1.

Regarding 500m scale analysis, all 95% CI of the variables' coefficients integrating the group of best models crossed zero, therefore no mixed hypothesis could be constructed (see **Table 4**). The landscape composition hypothesis presented the lowest AICc of all generated models, thus sustaining that this hypothesis is the one with more statistical support (**Table 3)**. Again, none of the variables from the 2000m scale hypotheses respected the criteria of being in the group of best models and their 95% CI of the variables' coefficients did not including the zero, hence it was not possible to elaborate a mixed hypothesis. Furthermore, the best model for each hypothesis (*i.e.* ΔAICc = 0.00) is the null model in all cases (confirm in **Table 3**). Consequently, no 95% CI of the variables coefficient is presented in **Table 4**.

Table 4 Variables included in the best models of the more supported hypothesis (landscape composition (H_1) and water presence (H_3) for the 500m scale explaining species richness variability.

Scale	**Variables**	**β**	**SE**	**z value**	***P***	**CI 95%**	**RI**
	(Intercept)	2.488	0.080	29.133	<0.001***	2.312/2.645	
	Bleaved	-0.073	0.099	0.722	0.470	-0.340/0.029	0.570
500m	Pasture	-0.043	0.079	0.533	0.594	-0.312/0.034	0.310
	(Intercept)	2.470	0.075	33.018	<0.001***	2.322/2.615	
	DistWater	0.140	0.077	1.809	0.071 .	-0.013/0.291	0.355
	Swamp	0.170	0.072	2.358	0.018*	-0.026/0-313	0.502

β is the variable coefficient; **SE** represents the Standard Error associated; ***P*** (with its significance codes: 0 - '***'; 0.001 - '**'; 0.01 - '*'; 0.05 - '.'; 0.1 - ' ') is the p-value that corresponds to the ***z* value**; Confidence Interval (**CI 95%)** for each variable is presented as 2.5%/97.5% ; and their Relative Importance (**RI**).

3.2 Species Diversity

Species diversity data did not presented a significant autocorrelation (Moran I= -0.111 for both scales; p=0.142).

For H_1, the VIF calculation implied the disposal of the variables "Conif", (VIF=62.036); "Conif2", (VIF=137.001); "Eucalypt2", (VIF=8.450) and "Mixed2", (VIF= 2.708). The application of GLMMs with Gaussian distribution to the candidate landscape composition variables allow us to identify two models satisfying the criterion for best model (ΔAICc < 2;

see **Table 5**) for the 500m scale and five for the 2000m scale. For H_2 we identify several collinear variables: “DistRway”, (VIF=101.302); “DistUrban” (VIF=3.860); “DistRWay2”, (VIF=105.153) and “DistNation2”, (VIF=3.946). With the removal of these variables, and combining all the remaining in several GLMM models, we were able to obtain two best models (ΔAICc <2) for the 500m scale and four for the 2000m scale (see **Table 5**). The analysis of the third hypothesis comprehended the set of variables designated previously (**Table 1**), without needing to exclude any (*i.e.* no collinearity). From the built models, associated to the 500m scale, only one had ΔAICc < 2 and for the 2000m scale, three models were considered good (access **Table 5**).

From the variables included in the best models for each hypothesis, those whose CI 95% of their coefficients did not included zero, were incorporated in H_4 (mixed hypothesis). For the 500m scale, four variables prized the criteria: percentage of area covered by broadleaved forests and by mixed forest, and the distance to the nearest highway and national road (see **Table 5**). Applying again the GLMMs approach, from the 16 mixed models generated for this H_4, two had ΔAICc < 2 (see **Table 5**). Distance to the nearest highway did not entered the best models produced on the mixed hypothesis. Despite we could built a mixed hypothesis, the model with the lowest AICc does not belong to this hypothesis, but to landscape composition hypothesis (confirm on **Table 5**).

Regarding the 2000m scale, as the distance to the nearest waterbody 95% CI of its coefficient did not included the zero, this was the only variable from H_1, H_2 e H_3 that could be used to produce H_4 models. However, this corresponded to a H3 model and therefore no mixed hypothesis model was produced. For this scale, the water presence hypothesis was the more supported by our data (**Table 5**).

Table 5 Best GLMM models built with Gaussian distribution (i.e. ΔAICc<2) explaining vertebrate's diversity in Baixo Vouga Lagunar. Results were presented per working hypothesis, for both scales tested and models ranked by increasing AICc.

Scale	Hypothesis	Df	LogLik	AICc	∆AICc	W	Total ∆AICc for each scale
	H_1 :Landscape composition						
500m	FULL MODEL: (Bleaved + Eucalypt + Irrigat + Mixed + Orchard + Pasture, family = gaussian)						
	• Bleaved + Eucalypt + Mixed	5	23.112	-32.9	0.00	0.367	0.00
	• Bleaved + Mixed	4	20.872	-31.6	1.25	0.196	1.30
	H_2 : Anthropic disturbances						
	FULL MODEL: (Urban + DistHWay + DistResid + DistNation, f amily = gaussian)						
	• DistHWay + DistNation	4	17.828	-25.6	0.00	0.419	7.30
	• DistHWay + DistNation + Urban	5	18.485	-23.6	1.91	0.161	9.30
	H_3 : Water presence						
	FULL MODEL: (Swamp + Water + DistWater, family = gaussian)						
	• DistWater	3	15.410	-23.6	0.00	0.468	9.30
	$H_{4:}$ Mixed (Best variables from previous hypotheses**)**						
	FULL MODEL: (Bleaved + Mixed + DistHWay + DistNation, family = gaussian)						
	• Bleaved + Mixed	4	20.872	-31.6	0.00	0.72	1.30
	• Bleaved + DistNation + Mixed	5	21.554	-29.8	1.86	0.28	3.10
2000m	**H_1 :Landscape composition**						

FULL MODEL: (Bleaved2 + Irrigat2 + Orchard2 + Pasture2 + Shrub2, family = gaussian)						
• Pasture2	3	14.677	-22.2	0.00	0.149	1.40
• Null model	2	13.002	-21.4	0.72	0.104	2.20
• Pasture2 + Shrub2	4	15.700	-21.3	0.86	0.097	2.30
• Orchard2	3	14.143	-21.1	1.07	0.088	2.50
• Orchard2 + Pasture2	4	15.238	-20.4	1.79	0.061	3.20
H_2 : Anthropic disturbances						
FULL MODEL: (Urban2 + DistUrban2 + DistHWay2 + DistResid2 , family = gaussian)						
• DistHWay2 + DistUrban2	4	15.960	-21.8	0.00	0.195	1.80
• DistHWay2	3	14.318	-21.4	0.38	0.162	2.20
• Null model	2	13.002	-21.4	0.38	0.161	2.20
• DistUrban2	3	14.131	-21.1	0.75	0.134	2.50
H_3 : Water presence						
FULL MODEL: (Swamp2 + Water2 + DistWater2, family = gaussian)						
• <u>DistWater2</u>	<u>3</u>	<u>15.410</u>	<u>-23.6</u>	<u>0.00</u>	<u>0.347</u>	<u>0.00</u>
• DistWater2 + Swamp2	4	16.205	-22.3	1.32	0.180	1.30
• DistWater2 + Water2	4	16.062	-22.0	1.60	0.156	1.60

Df Degrees of freedom; **LogLik** log-likelihood of the GLMM model; **AICc** Akaike Information Criteria corrected for small sample sizes; **∆AICc** difference between the model AICc and the lowest AICc of all models built for that specific hypothesis scale of analysis; **W** model weight; **Total ∆AICc for each scale** is the difference between the model AICc and the lowest AICc of all models built for that specific scale of analysis. The models with more statistical support are underlined.

Bearing in mind 500m scale and its variables, our best model indicates that "Bleaved" and "Mixed" patches seem to have a negative influence on diversity (β = -0. 088, β=-0.068,respectively; all p<0.01). Furthermore, distance to national roads presented a positive effect on diversity (β=0.007) but as the 95% CI of it coefficient included the zero we cannot be sure of its directional influence. Thus, "Bleaved" and "Mixed" patches could be considered good predictors of 500m scale diversity (see **Table 6**). Regarding 2000m scale, DistWater showed significant negative influence (β=-0.061, *P*=0.038) (**Table 6**) on diversity.

We obtained a R^2= 0.432 for the best model at the 500m scale and a R^2= 0.145 for the 2000m scale.

Table 6 Variables included in the best models of the more supported hypothesis (Mixed hypothesis (H_4) for the 500m scale and Water presence hypothesis (H3) for the 2000m scale) for explaining diversity variability.

Scale	**Variables**	**β**	**SE**	**z value**	***P***	**CI 95%**	**RI**
500m	(Intercept)	0.486	0.022	20.719	<0.001***	0.440/0.532	
	Bleaved	-0.088	0.023	3.528	<0.001***	-0.136/-0.039	0.952
	Mixed	-0.068	0.024	2.688	0.007**	-0.118/-0.018	0.849
	DistNation	0.007	0.017	0.409	0.682	-0.024/0.075	0.350
2000m	(Intercept)	0.486	0.027	17.916	<0.001***	0.429/0.544	
	DistWater	-0.061	0.028	-2.211	0.038*	-0.119/-0.004	0.749

β is the variable coefficient; **SE** represents the Standard Error associated; ***P*** (with its significance codes: 0 - '***'; 0.001 - '**'; 0.01 - '*'; 0.05 - '.'; 0.1 - ' ') is the p-value that corresponds to the ***z* value**; Confidence Interval (**CI 95%)** for each variable is presented as 2.5%/97.5% ; and their Relative Importance (**RI**).

3.3 Forecasted richness and diversity patterns

With regard to species richness, we could not predict values for the entire area, since more than one model belonging to different hypothesis presented statistical support, but then again, the variables included in them did not allowed a single model building (*i.e.* all crossed zero on their 95% CI, thus halting a mixed hypothesis construction).

We used the 500m scale best model (because it presented the higher R^2) built to explain species diversity variability to predict vertebrate diversity throughout BVL. We mapped the predicted values for each 500m cell, creating the map showed in **Figures 3**. This map shows higher values – *i.e.* diversity hotspots - near wetland areas (see **Figures 3** and **Figure 2**).

Our forecasted map of vertebrate diversity shows the majority of the study area as a hotspot, which is not realistic assumption and probably resulted from an imprecise prediction due to the low R^2 value. The diversity patterns forecasted by our models to BVL areas were blurrier, with several areas scattered throughout BVL reaching the highest values, but without a clear pattern. A huge area, located on the southern region of BVL, was assigned with high diversity values, but as it corresponds mostly to a region flooded most of the year, it may be the result of an analytical bias associated with the lower model prediction abilities (i.e. low R^2 values).

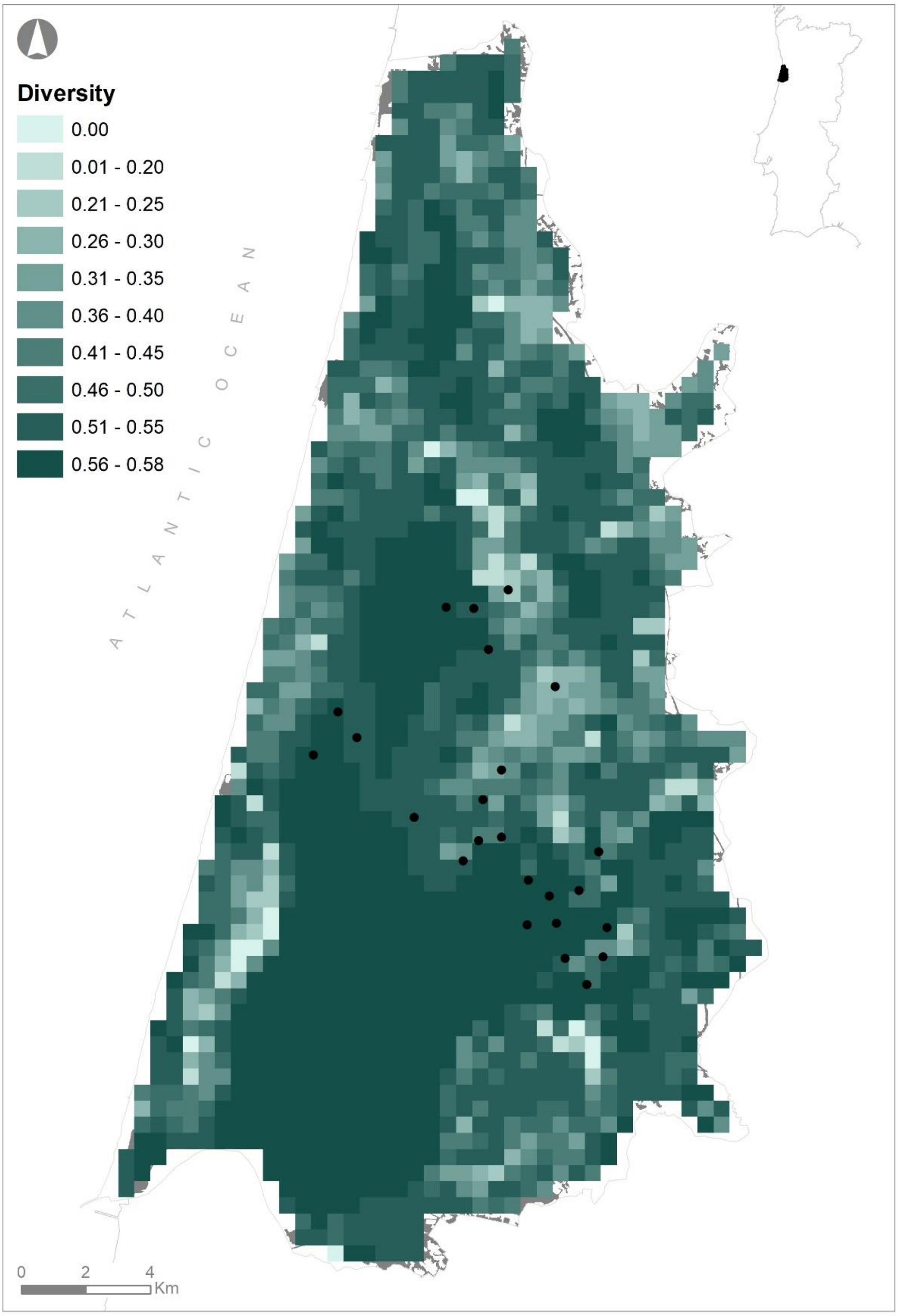

Figure 3 Map with the predicted values of species diversity distribution on the study area. Darker areas represent zones where probably the higher species diversity is enhanced. Black dots represents each sampling point.

4. DISCUSSION

We tested three complementary hypotheses and, when relevant, a fourth mixed one, that comprehends the best explanatory variables from the previous hypotheses, to shed light on the ecological and anthropogenic mechanisms underlying the richness and diversity patterns of amphibians, reptiles, non-volant mammals and chiropters in the Baixo Vouga Lagunar.

4.1 Species Richness

Our results showed that the most supported models were the ones correspondent to the landscape composition and the water presence hypotheses, in which the variables capable of explaining species richness variation were related with ecological. Such results indicate that vertebrates' richness is dependent of the synergistic effect of different origin drivers, *i.e*. landscape composition and aquatic elements. We testified that patches of broadleaved forests had a negative effect on vertebrate's species richness, which is somewhat the opposite of what we expected, since several studies identified these areas as key for foraging, shelter and roosting for different vertebrate *taxa* (Quine *et al.,* 2004; Rainho, 2007; Sattler *et al.,* 2007; Baldwin *et al.*, 2006; Rinehart *et al.,* 2009; Alexandre, 2017) and as important landscape connectivity providers (*e.g.* Hazell *et al.,* 2001). To the extent that broadleaved forest cover reached no statistical significance, and the 95% CI of its coefficient included the zero (*i.e*. we could not assess if it had a positive or negative effect on vertebrate richness), this result neither confirm nor reject our hypotheses (*i.e.* no significant effect was detected) and this lack of significance could be due to the low representativeness of the habitat on the study area. Pastures also showed a negative influence on vertebrates' richness, which could be a result of smaller animals avoiding this kind of lands trampled by cattle, because of the risk of being easily predated. Some changes in food availability are caused by alterations in vegetation assembly as a result of cattle grazing, and soil trample which results in compaction of its upper layer. This could restrain small animals of excavating burrows in order to avoid predation, or just diminish their food gathering efficiency, justifying the avoidance of reptile and small mammal populations of such areas, with the consequent reduction in species richness (Torre *et al.,* 2007; Pafilis *et al.,* 2013). Although many studies revealed the inconsistence of the effects of cattle presence on amphibians, this may be a consequence of different species sensitivity and the same could occur with other vertebrates. For instance, several studies have showed that European badgers (*Meles meles*) avoid pastures due to cattle disturbance (Drewe *et al.,* 2013; Mullen *et al.*, 2013). This variable did not reach statistical significance, and the 95% CI of its coefficient included the zero. Despite that, its coefficient presented a negative value (β= -0.043), which indicates that it has at least a slightly negative effect on richness, probably due to the disturbance caused by the use of those patches by cattle. The importance of water to all living organisms is considerable, especially for amphibians that are dependent of its presence to reproduce. Species richness increased in the presence of swamp areas (positive and significant effect), which agrees with other studies' results (Scott *et al.,* 2008; Sirami *et al*., 2013). Nevertheless, its 95%CI included the zero, thus supporting the assumption that this variable has a positive but limited effect on richness. Such pattern could be due to the fact that hydroperiods affect the time the land is flooded. Consequently, the capacity of vertebrates to use those areas is restricted or enhanced, depending on the sampling period, and the recolonization ability of each taxa (Cherry, 2011). Therefore, the hydroperiod of swamps must be defined before sampling (which we could not since our data was collected from previously implemented studies; see above) to allow a proper and concrete assessment of the positive or negative effect. Regarding the distance to water, our models registered a positive but non-significant effect of this variable. Thus, we could not corroborate the positive effect of the presence of water sources as promoter of richness, due to the increase of ecological niches and resources availability (*e.g.* Rosalino *et al.,* 2009).

Considering the 2000m scale, the best model for each hypothesis (*i.e.* lower AICc values; see **Table 3**) was always the null one (*i.e.* no variables included in the model). These results suggest that the diversity pattern could be better explained with no variables, which means that it can be a result of randomness, or variables not tested in our study are determining the detected pattern.

4.2 Species Diversity

Modelling species diversity at 500m scale showed that the mixed hypotheses produced the best model, which indicates that diversity is dependent on the influence of distinct origin factors combined: land cover and anthropic disturbance. Two of the best predictor variables were related with landscape composition (broadleaved and mixed forests) and the other with anthropic disturbance (distance to the nearest national road). As mentioned for species richness, we found that broadleaved forest cover had a negative effect on explaining species diversity at smaller scales (500m grid), and this time it reached statistical significance. Mixed forest cover followed the same patterns, also showing a negative and significant impact on species diversity. Both results were unexpected, because some authors have showed that these land covers can provide appropriate terrestrial microhabitats for foraging as well as a place where the smaller vertebrates could hide from their predators under the fallen leaves (*e.g.* Kret & Poirazidis, 2014). Furthermore, the presence of those smaller vertebrates can also motivate the use of these patches by their predators, thus enhancing diversity. However, the results of our study seem to reveal an opposite pattern and such result is difficult to interpret. Nonetheless, we believe that the landscape composition of the study area, together with the sample points' locations, could have induced such output. These patches (*i.e.* broadleaved and mixed forests) are scarce in the study area, and many of our sampling points did not include them. Thus, if a specific point containing these patches, due to any stochastic event, presents lower species richness and diversity, and few points (N= 3) were covered at least partially by them, the resulting model may be biased. Further research should be implemented to highlight the local effects of broadleaved and mixed forest, using a more stratified sampling scheme (which we could not, as we were limited to the areas where sample had been already implemented). DistNation had a positive effect on vertebrates' diversity, indicating that the greater the distance to the national road, the greater the diversity of vertebrates. This result agrees with our hypotheses that postulated a negative influence of anthropic infrastructures on vertebrates' diversity, but the lack of significance of this predictor, plus the fact that the 95% CI included zero, doesn't allow us to clearly state that it corroborates that hypothesis. Again, we believe that we need a more thorough sampling scheme to assess in a more robust way the effectiveness of the detected patterns. Despite these limitations in our results, many authors have already established a negative effect of roads network on vertebrates' populations, trough disrupting movements among breeding sites in amphibians (Ray *et al*., 2002) and promoting mortality of individuals of all types of *taxa* (Oxley *et al.,* 1974; Trombulak & Frissell, 2000; Jochimsen *et al.,* 2004; Beebee, 2013).

Regarding 2000m scale, the only variable included in the best model was distance to water (DistWater), with a negative and significant effect. However, the fact that its 95% CI only included negative values, indicates that this factor has a weak but consistent negative effect on vertebrates' diversity. The negative effect of this variable means that areas closer to waterbodies have a higher probability of reaching higher diversity values. The same reasoning used for the interpretation of the influence of water bodies on species richness can also be extended to this diversity results. The presence of water sources increases the ecological niches and resources availability for most vertebrates (*e.g.* mammals (Rosalino *et al*., 2009; Marques *et al.,* 2015)), and creates the conditions allowing other to reproduce (*e.g*., amphibians; Semlitsch, 2002).

4.3 Forecasted Species richness and diversity

We based our prediction values only on species diversity data for the 500m scale of analysis, because this was the scale that presented the higher R^2 value. Although it was the higher, it was still a low value (R^2=0.432); therefore, their graphical representation (**Fig. 3**) identified almost the entire area as a species diversity hotspot, which seems unrealistic. These results led us to state that our forecasted diversity map has low reliability and applicability.

4.4 Data limitation

The precision of environmental variables mapping may bias some variables' values in particular squares therefore influencing the results for certain grid cell scales. However, the overall picture can be considered reliable (Moody & Woodcock, 1995; Smith *et al.,* 2003).

Our data derived from small sample size sources (*i.e.* samples with n<30 are considered small (Wisz *et al.,* 2008) and we only had a maximum of eight habitats sampled three times each, totalizing a low sample effort (n=24)). Data scarcity is a problem due the influence that the number of records has on model building (Hernandez *et al*., 2006). It could result in low model accuracy and high variability across species and between models (Wisz *et al.,* 2008). Despite regression models (*i.e.* the ones we used) perform better than almost any other class of models at large sample sizes, no algorithm could predict consistently well with small sample size (Wisz *et al.*, 2008).

This small number of records limited the feasibility of the models' predictive capacity, as it is illustrated by the low R^2 values accomplished by the built models. Thus, if future studies aim to define and evaluate biodiversity hotspots, they need to be careful in the sample design: a more intense sample effort is needed in order to encompass a broader range of sampling points and promote a more robust model. Furthermore, the low predictive capacity was worsened by the fact that we defined a study area bigger that the considered in the studies from which we retrieved our datasets.

5. CONCLUSION

A relation between environmental variables and the presence or abundance of species was stablished in this study although in some cases that relation did not presented strong statistical support. Our distribution models failed to attempt a robust forecast of species diversity distribution and a clear definition of hotspots. Even so, we may assume that the water bodies scattering throughout the study area are very important for reaching the higher values of diversity because in the forecasted map (**Figure 3**) we can observe a pattern of darker areas (*i.e.* higher diversity) close to wetlands. It is rather surprising that the number of species and their abundance showed not to be influenced by urban areas and manmade infrastructures with the exception of the positive effect of distance to national roads on the 500m scale for explaining diversity variations. This pattern is probably due to a low intense urbanization of the study area as a whole. It is even more astonishing that relatively natural ecosystems such as broadleaved and mixed forests presented negative influence on vertebrates' richness and diversity, which could only be explained by their low representativeness in BVL and a consequent bias in the sampling scheme.

We are conscious of the drawbacks associated with the dataset used, which apart from being scarce is also highly heterogeneous, due to the ecological and behavioural differences between the diverse *taxa* considered. Thus, some of the bias observed may be a result of a non-equal influence of the variables on different vertebrates' *taxa* (*e.g.* bats *vs* other mammal species and reptiles *vs* amphibians). Additionally, for conservation planning purposes, the majority of the management efforts are mainly directed to well-known *taxa* (*i.e.* vertebrates) (Ramsar Convention, 2006) although the main factors that determine their distribution patterns cannot always be generalized to other faunal groups (Bonn & Gaston, 2005; Rodrigues & Brooks, 2007). Thus, even if we were been able to perform good forecasted maps, the hotspots that would have been identified, would correspond to vertebrates hotspots and then, the conservation priorities efforts would have to be complemented with other faunal information in order to minimize the overall biodiversity loss driven by land use changes.

In conclusion, although recognising that our outputs are limited and affected by different bias, we also believe that this exercise demonstrates the need to implement a well-designed sampling, which will overcome the bias effected that we faced here, when using data collected for other purposes. Furthermore, the hotspot approach despite some of the critics that could be pointed out, is a key tool to determine priority conservation areas-Nevertheless, it does not mean that the remain area should be excluded from conservation plans.

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7. APPENDICES

Table 7 Land use and land cover categories presented in COS 2010 and the aggrupation in broader categories.

COS 2010 categories	Grouped categories
1.1.1.01.1 Tecido urbano contínuo predominantemente vertical	Urban
1.1.1.02.1 Tecido urbano contínuo predominantemente horizontal	Urban
1.1.1.03.1 Áreas de estacionamentos e logradouros	Urban
1.1.2.01.1 Tecido urbano descontínuo	Urban
1.1.2.02.1 Tecido urbano descontínuo esparso	Urban
1.2.1.01.1 Indústria	Urban
1.2.1.02.1 Comércio	Urban
1.2.1.03.1 Instalações agrícolas	Urban
1.2.1.04.1 Equipamentos públicos e privados	Urban
1.2.1.05.1 Infraestruturas de produção de energia renovável	Urban
1.2.1.05.2 Infraestruturas de produção de energia não renovável	Urban
1.2.1.06.1 Infraestruturas de captação, tratamento e abastecimento de águas para consumo	Urban
1.2.1.07.1 Infraestruturas de tratamento de resíduos e águas residuais	Urban
1.2.2.01.1 Rede viária e espaços associados	Urban
1.2.2.02.1 Rede ferroviária e espaços associados	Urban
1.2.3.01.1 Terminais portuários de mar e de rio	Urban
1.2.3.02.1 Estaleiros navais e docas secas	Urban
1.2.3.03.1 Marinas e docas pesca	Urban
1.2.4.02.1 Aeródromos	Urban
1.3.1.02.1 Pedreiras	Urban
1.3.2.01.1 Aterros	Urban
1.3.2.02.1 Lixeiras e Sucatas	Urban
1.3.3.01.1 Áreas em construção	Urban
1.3.3.02.1 Áreas abandonadas em territórios artificializados	Urban
1.4.1.01.1 Parques e jardins	Urban
1.4.1.02.1 Cemitérios	Urban
1.4.2.01.1 Campos de golfe	Urban
1.4.2.01.2 Outras instalações desportivas	Urban
1.4.2.02.1 Parques de campismo	Urban
1.4.2.02.2 Outros equipamentos de lazer	Urban
1.4.2.03.1 Equipamentos culturais e zonas históricas	Urban
2.1.1.01.1 Culturas temporárias de sequeiro	Dry
2.1.1.02.1 Estufas e Viveiros	Orchards
2.1.2.01.1 Culturas temporárias de regadio	Irrigated
2.1.3.01.1 Arrozais	Irrigated
2.2.1.01.1 Vinhas	Orchards
2.2.1.02.1 Vinhas com pomar	Orchards
2.2.1.03.1 Vinhas com olival	Orchards
2.2.2.01.1 Pomares de frutos frescos	Orchards

2.2.2.01.3 Pomares de castanheiro	Orchards
2.2.2.01.5 Pomares de citrinos	Orchards
2.2.2.01.6 Outros pomares	Orchards
2.2.2.02.6 Outros pomares com vinha	Orchards
2.2.3.01.1 Olivais	Orchards
2.2.3.02.1 Olivais com vinha	Orchards
2.3.1.01.1 Pastagens permanentes	Pastures
2.4.1.01.3 Culturas temporárias de sequeiro associadas a olival	Dry
2.4.1.02.1 Culturas temporárias de regadio associadas a vinha	Irrigated
2.4.1.02.2 Culturas temporárias de regadio associadas a pomar	Irrigated
2.4.1.02.3 Culturas temporárias de regadio associadas a olival	Irrigated
2.4.1.03.2 Pastagens associadas a pomar	Pastures
2.4.2.01.1 Sistemas culturais e parcelares complexos	Orchards
2.4.3.01.1 Agricultura com espaços naturais e seminaturais	Pastures
2.4.4.01.5 SAF de outras espécies com culturas temporárias de sequeiro	Dry
3.1.1.01.3 Florestas de outros carvalhos	Broadleaved
3.1.1.01.4 Florestas de castanheiro	Broadleaved
3.1.1.01.5 Florestas de eucalipto	Eucalyptus
3.1.1.01.6 Florestas de espécies invasoras	Invasive
3.1.1.01.7 Florestas de outras folhosas	Broadleaved
3.1.1.02.3 Florestas de outros carvalhos com folhosas	Broadleaved
3.1.1.02.5 Florestas de eucalipto com folhosas	Broadleaved
3.1.1.02.6 Florestas de espécies invasoras com folhosas	Broadleaved
3.1.1.02.7 Florestas de outra folhosa com folhosas	Broadleaved
3.1.2.01.1 Florestas de pinheiro bravo	Coniferous
3.1.2.01.2 Florestas de pinheiro manso	Coniferous
3.1.2.01.3 Florestas de outras resinosas	Coniferous
3.1.2.02.1 Florestas de pinheiro bravo com resinosas	Coniferous
3.1.2.02.2 Florestas de pinheiro manso com resinosas	Coniferous
3.1.2.02.3 Florestas de outra resinosa com resinosas	Coniferous
3.1.3.01.3 Florestas de outros carvalhos com resinosas	Mixed
3.1.3.01.5 Florestas de eucalipto com resinosas	Mixed
3.1.3.01.6 Florestas de espécies invasoras com resinosas	Mixed
3.1.3.01.7 Florestas de outra folhosa com resinosas	Mixed
3.1.3.01.8 Florestas de misturas de folhosas com resinosas	Mixed
3.1.3.02.1 Florestas de pinheiro bravo com folhosas	Mixed
3.1.3.02.3 Florestas de outra resinosa com folhosas	Mixed
3.1.3.02.4 Florestas de misturas de resinosas com folhosas	Mixed
3.2.1.01.1 Vegetação herbácea natural	Pastures
3.2.2.01.1 Matos densos	Shrub
3.2.2.02.1 Matos pouco densos	Shrub
3.2.3.01.1 Vegetação esclerofila densa	Shrub
3.2.4.01.3 Florestas abertas de outros carvalhos	Broadleaved
3.2.4.01.5 Florestas abertas de eucalipto	Eucalyptus
3.2.4.01.6 Florestas abertas de espécies invasoras	Invasive
3.2.4.01.7 Florestas abertas de outras folhosas	Broadleaved

3.2.4.02.3 Florestas abertas de outros carvalhos com folhosas	Broadleaved
3.2.4.02.5 Florestas abertas de eucalipto com folhosas	Mixed
3.2.4.02.6 Florestas abertas de espécies invasoras com folhosas	Mixed
3.2.4.02.7 Florestas abertas de outra folhosa com folhosas	Broadleaved
3.2.4.03.1 Florestas abertas de pinheiro bravo	Coniferous
3.2.4.03.3 Florestas abertas de outras resinosas	Coniferous
3.2.4.05.5 Florestas abertas de eucalipto com resinosas	Mixed
3.2.4.05.6 Florestas abertas de espécies invasoras com resinosas	Mixed
3.2.4.05.7 Florestas abertas de outra folhosa com resinosas	Mixed
3.2.4.05.8 Florestas abertas de misturas de folhosas com resinosas	Mixed
3.2.4.06.1 Florestas abertas de pinheiro bravo com folhosas	Mixed
3.2.4.06.2 Florestas abertas de pinheiro manso com folhosas	Mixed
3.2.4.06.4 Florestas abertas de misturas de resinosas com folhosas	Mixed
3.2.4.08.3 Cortes rasos de florestas de outros carvalhos	Clearcuts
3.2.4.08.5 Cortes rasos de florestas de eucalipto	Clearcuts
3.2.4.08.6 Cortes rasos de florestas de espécies invasoras	Clearcuts
3.2.4.08.7 Cortes rasos de florestas de outras folhosas	Clearcuts
3.2.4.09.1 Cortes rasos de florestas de pinheiro bravo	Clearcuts
3.2.4.09.3 Cortes rasos de florestas de outras resinosas	Clearcuts
3.2.4.10.5 Novas plantações de florestas de eucalipto	Eucalyptus
3.2.4.10.6 Novas plantações de florestas de espécies invasoras	Invasive
3.2.4.10.7 Novas plantações de florestas de outras folhosas	Broadleaved
3.2.4.11.1 Novas plantações de florestas de pinheiro bravo	Coniferous
3.2.4.11.2 Novas plantações de florestas de pinheiro manso	Coniferous
3.2.4.11.3 Novas plantações de florestas de outras resinosas	Coniferous
3.2.4.13.1 Aceiros e/ou corta-fogos	Clearcuts
3.3.1.01.1 Praias, dunas e areais interiores	Sand
3.3.1.02.1 Praias, dunas e areais costeiros	Sand
3.3.3.01.1 Vegetação esparsa	Pastures
3.3.4.01.1 Áreas ardidas não florestais	Burnt
3.3.4.02.5 Áreas ardidas em florestas de eucalipto	Burnt
3.3.4.02.7 Áreas ardidas em florestas de outras folhosas	Burnt
3.3.4.03.1 Áreas ardidas em florestas de pinheiro bravo	Burnt
4.1.1.01.1 Pauis	Swamp
4.2.1.01.1 Sapais	Swamp
4.2.2.01.1 Salinas	Swamp
4.2.2.02.1 Aquicultura litoral	Water
4.2.3.01.1 Zonas entre-marés	Swamp
5.1.1.01.1 Cursos de água naturais	Water
5.1.1.02.1 Canais artificiais	Water
5.1.2.01.1 Lagos e lagoas interiores artificiais	Water
5.1.2.01.2 Lagos e lagoas interiores naturais	Water
5.1.2.02.1 Reservatórios de barragens	Water
5.1.2.03.2 Charcas	Water
5.1.2.03.3 Aquicultura interior	Water
5.2.1.01.1 Lagoas costeiras	Water

Table 8 Overdispersion of the best models built with Poisson distribution. Significant values are underlined.

Scale	Model	z-value	p-value
500	**H1:**		
	Bleaved + Pasture	1.344	0.090
	Bleaved + Eucalypt + Pasture	1.284	0.100
	H2:		
	Null model	<u>1.846</u>	<u>0.032</u>
	DistUrban	<u>1.780</u>	<u>0.038</u>
	DistHWay	<u>1.844</u>	<u>0.033</u>
	H3:		
	DistWater + Water	1.573	0.058
	Water	<u>1.647</u>	<u>0.050</u>
	DistWater	<u>1.827</u>	<u>0.034</u>
	Null model	<u>1.846</u>	<u>0.032</u>
2000	**H1:**		
	Bleaved2	<u>1.853</u>	<u>0.032</u>
	Null model	<u>1.846</u>	<u>0.032</u>
	H2:		
	Null model	<u>1.846</u>	<u>0.032</u>
	DistUrban2	<u>1.780</u>	<u>0.038</u>
	DistHWay2	<u>1.844</u>	<u>0.033</u>
	H3:		
	DistWater2 + Water2	1.573	0.058
	Water2	<u>1.647</u>	<u>0.050</u>
	DistWater2	<u>1.827</u>	<u>0.034</u>
	Null model	<u>1.846</u>	<u>0.032</u>