UNIVERSIDADE DE LISBOA
FACULDADE DE CIÊNCIAS
DEPARTAMENTO DE BIOLOGIA ANIMAL

Hedgehogs in urban areas.
The case-study of *Erinaceus europaeus* in Almada

Inês Pezarat Correia Bom

Mestrado em Ecologia e Gestão Ambiental

Dissertação orientada por:
Professora Doutora Margarida Santos-Reis

2020

Agradecimentos

Porque todo o projeto humano é coletivo quero agradecer a todas as pessoas que o fizeram comigo:

À professora Margarida, que me lançou o desafio e que me auxiliou durante todo o processo sem nunca me cortar as asas e sendo solidária com todas as dificuldades do processo.

À Raquel, que se lembrou deste projeto e o construiu comigo;

À Câmara Municipal de Almada pela parceria que permitiu este trabalho avançar;

Ao Fernando, que na hora mais difícil veio em meu auxílio e por cá ficou;

À Ana, que me abriu a porta de casa, várias vezes, durante os meus desesperos e bloqueios;

À Maria, à Sara, à Nicole, à Rita, que me ajudaram no trabalho de campo às tantas da madrugada;

Ao Hugo e ao Gonçalo, pela preciosa ajuda com os terríveis modelos;

À Joana, cuja revisão e paciência no momento de loucura que é o final, foi imprescindível;

À Andreia, e restante equipa do GAPSI por todo o apoio e acompanhamento durante este processo;

À Mafalda, por nunca faltar à chamada quando isso é tudo o que preciso;

Ao Fabian, que tem um abraço apertado para todas as horas;

Ao Gonçalo e ao Luís, companhia constante mesmo que à distância;

À Isabel, que foi e é sempre casa quando mais preciso;

À Sara e à Mariana por serem pedra e cal e me aturarem tudo;

À Peraltinha por todos os dias me ter dito que ia ser capaz e nunca me ter largado a mão;

À Rita, companheira nesta e nas outras travessias que fizemos juntas.

À mãe, ao pai, ao avô, aos manos, aos primos, aos tios e a todos os familiares e amigos que de uma forma ou outra tornaram isto possível.

Resumo

A preservação da biodiversidade em áreas urbanas é uma preocupação da sociedade atual. O ouriço-cacheiro (*Erinaceus europaeus,* LINNAEUS 1758) é um dos valores naturais da cidade de Almada, a sul de Lisboa. No entanto, tem sido uma das espécies mais afetada pelos atropelamentos nesta área. Para compreendermos a presença desta espécie nesta área urbana definimos cinco objetivos: (1) analisar a distribuição da espécie e fatores promotores da mesma; (2) compreender a distribuição especial dos atropelamentos e fatores promotores dos mesmos; (3) compreender a distribuição temporal dos atropelamentos; (4) compreender a perceção dos cidadãos de Almada a este fenómeno; (5) propor medidas de gestão para esta espécie no concelho de Almada.

Os dados de distribuição e de perceção foram recolhidos através de um processo de ciência-cidadã numa plataforma online (maptionnaire). Desenvolveu-se um modelo de distribuição com os dados dos avistamentos da espécie e seis variáveis ambientais: tipo de uso de solo, impermeabilidade do solo, SAVI, densidade de cobertura de árvores, distância às linhas de água, diversidade de tipos de uso de solo. O modelo demonstrou que as variáveis: impermeabilidade do solo, tipo de uso de solo, SAVI e densidade de cobertura de árvores influenciam a distribuição desta espécie. Mostrou também que em Almada existe uma grande área com alta probabilidade de ocorrência de ouriços-cacheiros.

Para compreender a distribuição espacial e temporal dos atropelamentos de que esta espécie estava a ser vítima, utilizaram-se os dados recolhidos pelas monitorizações de atropelamentos de vertebrados feitos nas estradas do concelho desde 2013 e os dados das novas monitorizações feitas durante o ano de 2018. Estes dados permitiram concluir que existem hotspots de mortalidade onde devem ser aplicadas, com maior urgência, medidas de minimização deste impacto. Para se compreender quais as variáveis que influenciam espacialmente os atropelamentos realizou-se um GLM com três variáveis: probabilidade de ocorrência da espécie, tipo de estrada e distância à passagem para fauna mais próxima. As estradas terciárias e residenciais diminuem significativamente a probabilidade de atropelamentos desta espécie. O melhor modelo inclui ainda, apesar de não serem significativas, as estradas secundárias (a probabilidade de atropelamento aumenta) e a distância à passagem mais próxima (probabilidade de atropelamento diminui).

Por último, averiguámos a sensibilidade dos residentes de Almada quanto à presença dos ouriços nesta mesma área, recorrendo a perguntas no questionário online. As respostas indicaram que a espécie é bastante apreciada pela maioria da população e bem aceite nesta área urbana. No entanto, esta espécie não é completamente percecionada como selvagem, o que pode a atitudes menos adequadas por parte dos cidadãos para com estes animais. É por isso importante desenvolver iniciativas de esclarecimento da população sobre os melhores comportamentos a ter para com a espécie.

Palavras-chave: Ouriço-cacheiro, cidade, distribuição, atropelamentos, perceção social

Resume

The preservation of biodiversity in urban areas is a concern in our society. The hedgehog (Erinaceus europaeus, LINNAEUS 1758) is one of the natural values of the city of Almada, south of Lisbon. However, it has been one of the species most affected by road-kills in this area. To understand the presence of this species in this city were defined five objectives: (1) analyze the distribution of the species and its promoting factors; (2) analyze the spatial distribution of road-kills and factors that promote them; (3) analyze the time distribution of road-kills; (4) understand the perception of Almada citizens to this phenomenon; (5) to propose management measures for this species in the municipality of Almada.

To study the distribution of hedgehogs in this urban area we collected citizen-sights in an online survey. Then, we developed a species distribution model with the sights data and six variables: soil imperviousness, land-use, SAVI, Tree-cover-density, distance to water lines, and land-use diversity. The model showed that the variables: soil imperviousness, land-use, SAVI, and Tree-cover-density influence the species probability of occurrence. It also showed that Almada has a large area with a high probability of hedgehogs to occur.

To understand the spatial and temporal distribution of the road-kills was used the data collected by the roadkill monitoring carried out since 2013 and developed new monitoring during 2018. From these data was concluded that there are mortality hotspots. Then, we developed a GLM with the variables: species probability of occurrence (SDM), type of the road, and distance to the nearest wildlife passage to understand if these variables are influencing the hedgehog's road-kills. The model indicated that in tertiary and residential roads the probability of road-kills is significantly lower. It also showed that, although not significant, secondary roads have a higher probability of hedgehogs being road-killed and the distance to wildlife passages contributes to decreasing mortality.

Finally, was investigated the sensitivity of residents of Almada about the presence of hedgehogs in this area, using questions in the online questionnaire. The responses indicate that hedgehogs are highly appreciated by most of the population and well accepted in this urban area. However, people do not perceive them as wild animals, which can encourage less appropriate attitudes. It is, therefore, important to develop initiatives to inform the population about the best behaviors to preserve the species.

Keywords: Hedgehogs, city, distribution, roadkill, social perception

Índex

Figure index

Table index

1. INTRODUCTION

1.1. Biodiversity crisis and the preservation of urban biodiversity

It is of a broad consensus that biodiversity is deteriorating worldwide, what some scientists defend to be the six-mass extinction (Barnosky, 2011). Of the assessed animal and plant groups around, 25 percent are threatened, and the global rate of species extinction is already tens to hundreds of times higher than it has averaged over the past 10 million years (IPBES, 2018). The conscious that biodiversity loss is a major problem that must be stopped led to several international diplomatic efforts like the Aichi Biodiversity Targets, 2030 Agenda for Sustainable Development, the Paris Agreement, or the 2050 Vision for Biodiversity. However, future scenarios project negative trends in biodiversity and ecosystem functions which means that even the goals determined in these agreements will not be achieved (IPBES, 2018).

For most of the 20th century, the ecological perspective was that humans are an outside factor causing bad effects on nature or ecological conditions (Geddes, 2013). Thus, ecologists tried to exclude people of their ecological research (Geddes, 2013) and most conservation strategies were settled in the creation of protected areas that could isolate natural areas from human impacts (Mora, 2011). However, these ideas have changed as it becomes clear that protected areas alone could not solve the biodiversity crisis (Mora, 2011). Nowadays, it was recognized the importance of biodiversity conservation outside protected areas, particularly in managed ecosystems like cities (Reyes 2013).

Although they are usually recognized as unfavorable for wildlife, cities are heterogeneous, dynamic landscapes that have complex, adaptive, socioecological services linking society and ecosystems at multiple scales (Grimm, 2008). In the last decades has been a global tendency of wild birds and mammals to colonize cities taking advantage of higher abundance of food, alternative shelters, and the absence of natural predators, they were called urban adapters (Hubert, 2011).

1.2. The European hedgehog

Hedgehogs are small charismatic mammals due to the spines that covered their bodies. They belong to the *Erinaceidae* family and are present across Europe from Portugal to Czech Republic, Scandinavia, Ireland, and Great Britain (Pfaffle, 2010). They were also introduced in the late 19th century to New Zealand (Brockie, 1975) and in 1974 to the Scottish island of Uist (Jackson, 2004). These nocturnal and solitary animals spend the night foraging for food. Their main preys in natural conditions are earthworms (*Lumbricus Terrestris*) (Morris & Reeve, 2008). During the day they rest at the nets they construct gathering up dry leaves (Pfafle, 2010).

Hedgehogs belong to a group of animals that hibernate during the cold months (Morris & Reeve, 2008). In the Mediterranean region is though that hedgehog's activity starts to decrease in the first half of December. In January and February, the activity is very low and in March it increases again. The mating season starts after the hibernation so it is said to last from the middle of March to the end of October (Boitani, 1983). The reproductive period and the duration of the hibernation varies according to the latitude. Courtship and pregnancy (four to five weeks) can occur through the whole active season (Reeve 1981).

In most countries, there has been no recent census on this species, however, last studies shown some signs for concern. In The Netherlands, it is estimated that between 113 000 and 340 000 hedgehogs are killed each year on roads reducing the population by 3% to 22% (Huijser and Bergers 2000). However, roadkill reports point hedgehogs as one of the most affected species by this impact (Ambiente, 2012). Although hedgehogs can run fast, reaching average speeds of 30-40 meters per minute (Morris, 2006) they often choose to roll up in a ball, relying on their spines for protection. Thus, they are one of the most frequently killed animal on the Irish (Sleeman et al. 1985, Smiddy 2002, Haigh 2014), Dutch (Huijser et al. 1998), Belgian (Holsbeek et al. 1999), Slovakian (Hell et al. 2005) and Polish (Orlowski and Nowak 2004).

Due to their secretive behavior, this is a very difficult species to study. In Portugal, there is no recent study about the ecology, behavior, or population estimates of this species making it hard to know the real conservation status of this species. Most ecological studies come from the North of Europe showing their generalist's character in terms of habitat use. In the UK, Micol et. al (1994) reported that hedgehogs were abundant in pastures. In Denmark, Jensen (2004) found that 55% of nest sits occurred in forested areas with the similar result reported by Riber (2006). In Ireland, hedgehogs were found to spend a large amount of time in arable land (Haigh, 2011).

1.3. Hedgehogs in urban areas

Although hedgehogs were traditionally associated with farmland, they are increasingly present in human environments like cities and rural villages (Hubert et al. 2011, Young et al., 2006). High densities of this species have been found in parks and gardens of urban areas (Young et al., 2006).The approximation of hedgehogs to urban areas can be related to the agricultural intensification from the past 50 years that increased the use of pesticides and reduced the hedgerows, that these animals use to their nests (Asteraki et al. 2004). On the other hand, cities offer greater food abundance, including natural prey and anthropogenic sources, lower risk of predation, and high availability of nest sites like built-up areas and dense shrubbery (Morris, 2006, Doncaster *et al.* 2001). They also present a very heterogeneous landscape and warmer microclimates that are good for this species (Wania, Kühn, & Klotz, 2006).

However, terrestrial mammals living in fragmented landscapes, like cities, face the risk associated with moving through the environment without being killed (Dowding 2009). Analyses of real versus simulated movement patterns have suggested that hedgehogs tend to occupy the quieter suburbs where traffic volume is substantially low (Rondinini & Doncaster, 2002). Dowding (2010) registered a significant increase in hedgehogs' activity after midnight when there was a marked reduction in vehicle and foot traffic.

1.4. Citizen's perception of hedgehogs in urban areas

According to Kalterborn (2006) "Wildlife management often faces unanticipated public resistance or simply fails in attracting public support for goals and strategies, due to inadequate understanding of the public's attitudes and preferences". Thus, analyzing the presence of a wild species in an urban area implies, necessarily, to understand people's reaction to its presence.

A study was done in Trondheim, Norway, showed that urban residents were considerably interested in urban wildlife suggesting that they did not have a notion of the city as an exclusive domain of human beings (Bjerke, 2004). However, people's acceptance of these species in their residential area differs from species to species. A large majority of Norwegians endorse the existence of large predators in the wilderness, but very few accept the presence of these species close to human dwellings (Kleiven, 2004). Similarly, urban residents may highly appreciate the sight of a moose in the forest but dislike the presence of this species in their garden (Bjerke, 2004). Relatively to hedgehogs, there are no studies that have investigated the opinion of people about this species or their position about their presence in urban areas.

1.5. Study aim and hypothesis

In the city of Almada, in the south of Portugal, hedgehogs are one of the most affected species by road-kills (Ambiental, 2014). Since the Almada council defined has a strategic objective protecting its biodiversity, it became necessary to study this species in this urban area and the impact it was suffering. Thus, we studied the presence of this species in this city were defined five objectives: (1) analyze the distribution of the species and its promoting factors; (2) analyze the spatial distribution of road-kills and factors that promote them; (3) analyze the time distribution of road-kills; (4) understand the perception of Almada citizens to this phenomenon; (5) to propose management measures for this species in the municipality of Almada.

Thus, our first objective was to understand how hedgehogs are distributed in this city and the factors that influence it. The second objective was to understand the spatial and temporal patterns of hedgehog's road-kills in this area and. The final objective was to understand people's perceptions about the species and their willingness to conserve it in this urban context. Our hypotheses can be summarized: 1) Hedgehogs show an irregular distribution across the city; 2) Their distribution is related to environmental variables; 2) Road-kills are differently distributed across city roads; 3) Road-kills are differently distributed along the year; 4) Roadkill spatial distribution is related to environmental variables and the characteristics of the roads; 5) People like this species and support its preservation.

2. STUDY AREA

2.1. Sociological characterization

Almada has currently 174,030 inhabitants which means an average density of 479,6 inhabitants/km, 72,236 families, and 101,619 habitations (Censos INE 2011). 13,7% of Almada's citizens are under fourteen years, 11,1% between 14 and 24 years, 54,6% between 25 and 64 years, and 20,5% above 65 years (Censos INE, 2011). Also, the population is constituted by 47,4% of men and 52,6% of women (Censos INE, 2011). Regarding the education level, the people without schooling are 6.5%, with primary education 21%, with 6^{th} grade 9%, with 9^{th} grade 18%, with secondary education 17% and with superior education 15% (Censos INE, 2011).

2.2. Physical and climatic characterization and biodiversity

The Municipality of Almada (Figure 1) is in a climatic transition region, being influenced by the Mediterranean and the Atlantic. Almada can be characterized as having a temperate climate. highest temperatures are registered in summer months, normally in July and August, and the lowest in winter, November, December, and January. Precipitation is concentrated in the months between October and May with December being the rainiest month (Ambiental, 2014).

It is limited by the Tagus estuary in the north and the Atlantic Ocean in the west. Its constituted by a diverse land-use mosaic of constructed areas, agricultural fields, forest, brush, meadows, pasture, aquatic areas beach sands. The agriculture developed in the municipality is mostly familiar, non-intensive, and in small plots without large monocultures.

This landscape diversity makes this municipality very biodiverse in fauna and flora. The predominant vegetation in Almada forest is pine trees (*Pinus pinea*, *Pinus pinaster* and *Pinus halepensis*) in the arboreal strata. The shrub stratum is rich, standing out the beach sabine (*Juniperus turbinate*), the kermes oak (*Quercus coccifera*), the mastic (*Pistacia lentiscus*), the strawberry tree (*Arbutus unedo*), *Rhamnus lycioides subsp. Oleoids*) and the aromatic myrtle (*Myrtus communis*). In a lower stratum emerge the rosemary (*Lavandula luisieri*) and two barns - the Moorish (*Cistus salvifolius*) and the small rosemary (*Cistus crispus*). Several animal species can also be found. These include amphibians as the *Pelophylax perezi* and reptiles like *Malpolon monspessulanus, Podarcis hispanica, Psammodromus hispanicus, Psammodromus algirus, Acanthodactylus erythrurus* or *Tarentola mauritanica.* The number of terrestrial birds is considerable, exceeding 45 species. The red fox (*Vulpes Vulpes)*, beech marten (*Martes foina)*, European rabbit *(Oryctolagus cuniculus)*, and European hedgehog (*Erinaceus europaeus)* are among the mammal species present in this area. (Correia, 2015)

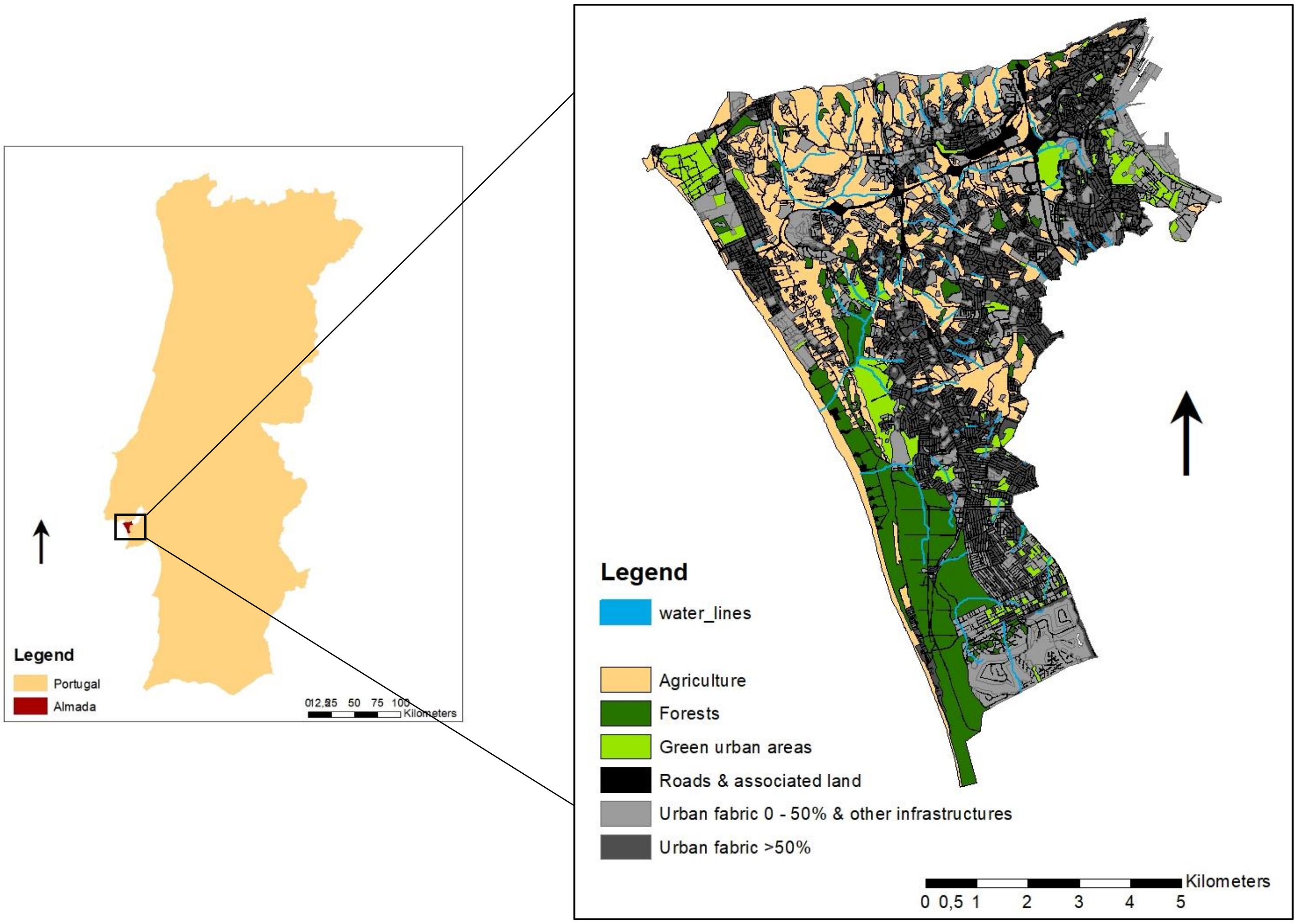


Figure 1- Study area: Municipality of Almada

3. METHODS

3.1. Sampling

3.1.1. Distribution data

The distribution data was collected through a citizen-science process in a Public Participatory Geographic Information System (PPGIS) online-based survey. The online software used was maptionnaire (https://maptionnaire.com/). Hedgehogs are difficult animals to study due to their small, nocturnal, and secretive behavior (Haigh, 2012). Thus, many techniques used in studies with other terrestrial mammals like traps, footprint tunnels, or even spotlighting are not effective with this species (Haigh, 2012; Poulton & Reeve, 2010). Questionnaires have become an important tool in ecological studies, especially for elusive species, since they allow them to gather extensive datasets in a relatively short period (White, 2005; Hof, 2011). Nevertheless, data obtained from the questionnaires must be regarded with some care since the targeted group is are not a specialist in the field. However, hedgehogs, are easily recognized and often observed by citizens of Almada what makes this reliable data. This data was complemented with some spotlighting sessions in the field.

Thus, the first part (see 3.1.3 for the second) of the survey was a map (georeferenced), for the citizens to locate the places where they had saw hedgehogs (dead or alive). This part of the survey was destined to everyone that have seen hedgehogs in Almada. The survey was done in collaboration with Câmara Municipal de Almada and it was available online from February to June 2019, after passing a pre-test phase with twenty people.

The sights collected in the maptionnaire were then transferred to ArcGis where they were converted into a shapefile. The sights marked outside the study area were eliminated. Were thus, considered valid 123 sightings of which 102 corresponded to alive hedgehogs and the remaining 21 to dead hedgehogs (Fig. 3).

3.1.2. Roadkill data

Since 2013, the Câmara Municipal de Almada has been monitoring the vertebrate road-kills. Thus, was the data from road-kill data from 2013 to 2017 and developed new surveys during 2018. The roads to be monitored had been chosen to identify the roads with more road-kills and so roads near green areas were preferred. Thus, our results need to be carefully analyzed given this road choice.

The roads were previously categorized by the municipality services according to their width and traffic. From the widest and most traffic to the narrowest and least traffic were sampled: primary, secondary, tertiary, residential, and unclassified roads. Highways (A2 and A33) as well as IC20, were excluded due to high traffic that could compromise security.

The campaigns had some differences in their duration, the sampled roads, and the frequency (some monitoring was weekly and other monthly). Thus, roads had different sampling efforts. Red roads were visited 135 times, yellow roads 117 times, and blue roads 92 times (fig.2).

Road-surveys were conducted in the following periods (summarized in table 1):

- From May of 2013 to April of 2014 – Weekly sampling of all roads (red, blue and yellow of fig.2);
- From June to September of 2015- Weekly sampling of red roads (fig.2);
- From February to December of 2017- monthly monitoring of all roads and from June to September was also done weekly monitoring of red and yellow roads;
- From January to December of 2018- monthly monitoring of all roads and from May to December, weekly monitoring of red and yellow roads.

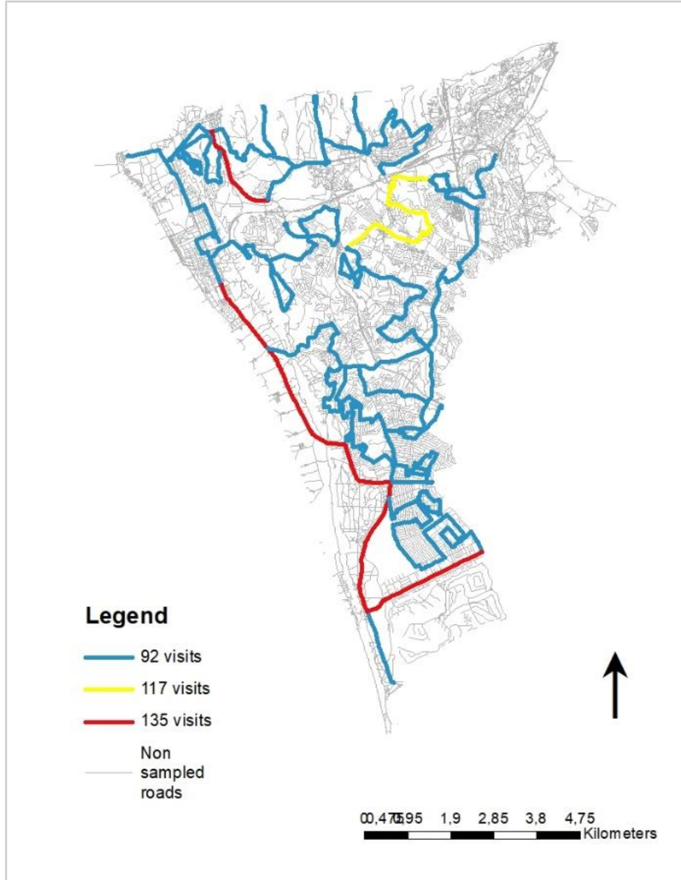


Figure 2- Roadkill surveyed roads

Table 1- Chronogram of road mortality surveys

<table>
<tr><th>Year/ Month</th><th>Jan</th><th>Feb</th><th>Mar</th><th>April</th><th>May</th><th>June</th><th>July</th><th>Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>2013</td><td></td><td></td><td></td><td></td><td colspan="8">Weekly monitoring of all roads (red, blue and yellow of fig.2)</td></tr>
<tr><td>2014</td><td colspan="4"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2015</td><td></td><td></td><td></td><td></td><td></td><td colspan="4">Weekly monitoring of red roads (fig.2)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">2017</td><td></td><td colspan="11">Monthly monitoring of all roads (blue, red and yellow from fig.2)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="4">Weekly sampling of red and yellow roads</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">2018</td><td colspan="12">Monthly monitoring of all roads (blue, red and yellow from fig.2)</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="8">Weekly monitoring of red and yellow roads (fig.2)</td></tr>
</table>

Every time an animal was found the car was stopped and the animal was removed off the road to avoid recounts. On a sheet of paper, it was pointed the number of the cadaver, the time and date, its localization was marked in a GPS device. The locations were then, transferred to ArcGis and converted into a shapefile. The dates were transferred to an excel table.

3.1.3. Public perception assessment

Public perception data were also collected using the online software maptionnaire (https://maptionnaire.com/). Questionnaires are particularly suitable tools for approaching public perceptions in ecological management, large-scale studies, studies of human impacts on wild species, and interdisciplinary studies that include ecological and non-ecological components (White, 2005).

The second part of the online survey was, thus, destined to understand the public perception of Almada citizens to the presence of hedgehogs in Almada and their willingness to preserve them. So, the responses were transferred to an Excel document and eliminated those that corresponded to people that do not live in Almada. For that, respondents wrote their postal code at the beginning of the survey.

3.2. Data analysis

3.2.1. Distribution data

To evaluate the drivers of the hedgehog distribution and to predict the areas with suitable conditions for this species we used a Species Distribution Model (SDM). SDMs are models that relate the species sights with the environmental and/or spatial characteristics of those sites (Franklin, 2009). From those relations the model produces a probabilistic map of the species distribution. Among the available tools for SDMs with presence-only data, the maximum entropy approach is one of the most widely used for predicting species distributions (Fitzpatrick, Gotelli & Ellison, 2013; Merow, Smith & Silander, 2013). This approach that belongs to the family of the machine learning methods, is currently available in the software MaxEnt (Phillips, Anderson & Schapire, 2006; https://www.cs.princeton.edu/~schapire/maxent/) and its predictive performance is consistently competitive with the highest performing methods (Elith et al., 2006).

So, we develop our SDM with the MaxEnt method and software, relating the data from alive sight hedgehogs with the following six spatial variables: soil imperviousness, type of land-use, distance to water, tree-cover-density, land-use diversity, and SAVI. We only use the alive hedgehog sights so than we could do the GLM relating the alive sights and roadkill data.

Soil characteristics are important for many animals; in the case of the hedgehog it has higher importance since this animal spends all night foraging for insects that live in the soil (Morris, 1969). Thus, we used the soil imperviousness to continue variable (0 - 100%). The layer was obtained from Copernicus (https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/status-maps/2012) and measures the percentage of soil sealing so that 0% is non-built up areas while built-up areas are characterized by IMD values 1-100%.

To have information about the type of habitat, a categorical variable, we used the land-use shapefile available from the urban atlas (European Environment Agency). The original shapefile was reclassified in the following six classes: (1) Urban fabric 0 – 50 %; (2) Agriculture; (3) Forest; (4) Urban fabric > 50%; (5) Roads and associated land; (6) Gardens.

Urban areas are very diverse and fragmented thus, we wanted to understand if in these areas' hedgehogs search for more continuous patches or not. For that we create a land-use diversity raster file from the urban atlas shapefile. For each cell, we calculated the amount of land-use types of the adjacent cells. This raster file was created with a resolution of 20 x 20m.

Hedgehogs' distribution is related to the vegetation present in each area. We used two variables to characterize vegetation: a vegetation index (SAVI) and the Tree-Cover-Density. SAVI is a raster layer created from satellite images that capture the reflectance in each place that is related to the vegetation cover. The tree-cover-density variable shows the level of tree cover density in each pixel in a range from 0-100%.

We also wanted to investigate the influence of water in hedgehogs' distribution not only because, like all animals, hedgehogs depend on these resources but also because next to watercourses there is a lot of riverside vegetation where animals can find more food and shelter. Thus, we create a raster file of water line distance from the water lines shapefile of the district provided by Câmara Municipal de Almada. To calculate the distance to water a raster file was created in which each pixel contains the distance information to the nearest water line.

In the Maxent model specifications, we selected the linear, quadratic, product, and hinge features and the Clog log output. To adjust the regularization multiplier parameter, we used ENMtools program. This model produces a continuous probability of the species occurrence for each pixel. However, to identify areas to conserve the species is necessary to convert this continuous response to a binary one. Thus, in ArcGIS, we reclassified the SDM in two classes (important and non-important areas for conservation) based on the maximum training sensitivity plus specificity threshold.

3.2.2. Road-kill assessment

In the ArcGis was applied a kernel density analysis to the roadkill data shapefile. The kernel density analyses estimate the number of hedgehogs that were killed, per cell (100 x 100) presenting this information in a map with different colors for each interval of numbers.

Then, to evaluate the factors that are influencing the presence or absence of roadkill we used a Binomial Generalized Linear Model (GLM). Because we only had presence data, the absences were generated randomly by the program: the same number of random points (absences) than presences but at 200m from the presence points. Then the model compared the presence and absence data with the following variables: the probability of occurrence, wildlife passages, and road type. The Species Distribution Model was used as a proxy of the probability of occurrence, wildlife passages were used as a proxy of permeability and the type of road was used as a proxy of road width, vehicle speed, and traffic. In the binomial GLM the response variable is a presence (1) / absence (0). The road type shapefile was available from Câmara Municipal de Almada and the wildlife passages were obtained from a survey conducted in the scope of a previous study in the municipality (Mendes et al, 2014). Data analyses were done using RStudio to develop the GLM. Spatial analyses were done in ArcGIS (10.5.1). The best model was chosen by AIC in a Stepwise Algorithm.

To understand the temporal distribution of the road-kills, the excel table was used the data of the following monitoring: May of 2013 to April of 2014, February to December of 2017, January to November of 2018 because these were the monitoring to all the roads. This data was converted into a graphic.

4. RESULTS

4.1. Species distribution

The sights are widely spread across de study area (fig.3). However, the distribution of these sightings seems to be uneven, with areas with a higher concentration of sightings.

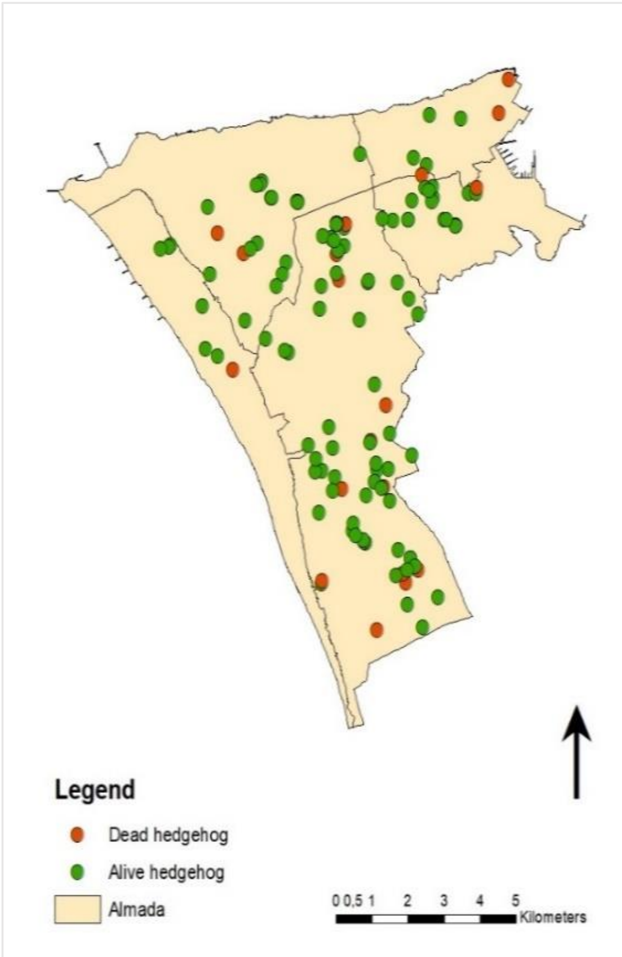


Figure 3- Hedgehog citizen sights

4.1.1. Species Distribution Model (SDM)

With the sightings of alive hedgehogs, we modeled the species distribution. The six spatially explicit variables were first tested for correlations between them. Since no value was higher than 0.7 or lower than -0.7 (Annex 3) all variables were used in the modeling procedure. For model validation we used the cross-validation with 10 replicates. Figure 4 shows the probability of the occurrence of hedgehogs in Almada. Red areas represent a higher probability of occurrence of the species while blue zones represent a lower probability of species occurrence. In the resulting map areas closer to the sea and the river have less probability of the species occurrence than inland areas, except for zone A. In zone A, B, and C, although no hedgehogs were spotted, the model suggests that these areas have good conditions for its occurrence. The Species Distribution Model has an AUC of 0.66, and the standard deviation is ±0.04.

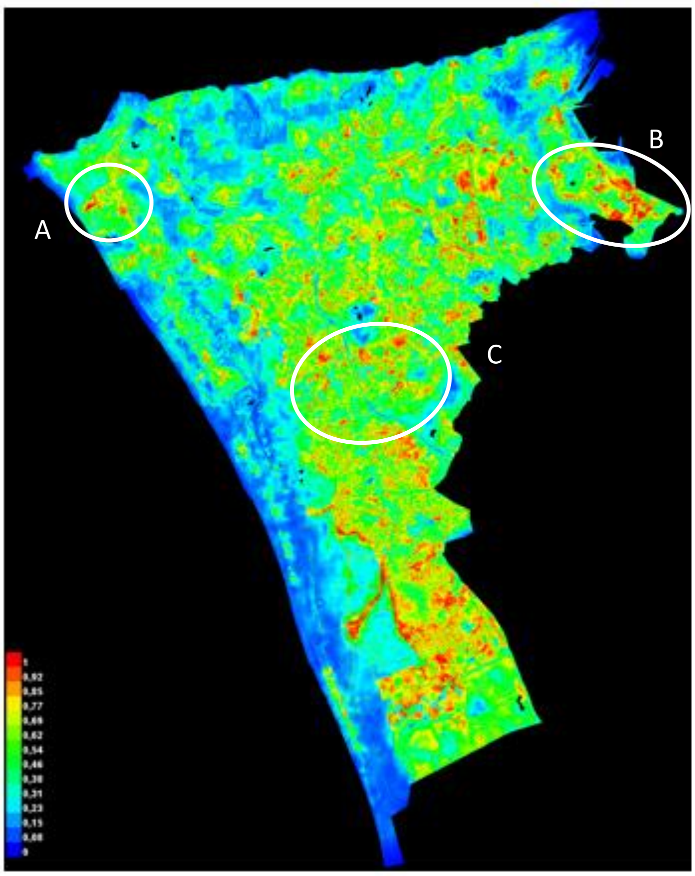


Figure 4- Species Distribution Model of hedgehogs in Almada

This SDM showed that soil imperviousness and land-use are the most influencing variables driving hedgehog's distribution in Almada municipality, although tree-cover-density and SAVI also revealed to be important to this species distribution. Distance to water lines has reduced importance and the land-use diversity showed no influence (Table 3).

Table 2- Contribution of each variable to the SDM

Variable	***Percent contribution (%)***
Soil imperviousness	33.3
Land-use	30.3
Tree-Cover-Density	19.6
SAVI	13.2
Distance to water lines	3.1
Land-use diversity	0.6

The type of land-use that showed the highest probability of occurrence for hedgehogs was urban fabric > 50% followed by green areas and the one where the species is less likely to occur is agricultural lands (Fig.5.e). The probability of occurrence increases with the increase of soil imperviousness (Fig. 5.a), soil vegetation and tree-cover-density (Fig.5.d). However, there is a limit beyond which the increase of vegetation or tree cover density no longer increases the probability of the species occurring. Should only be considered the positive values of the graphs, values below zero are a model error.

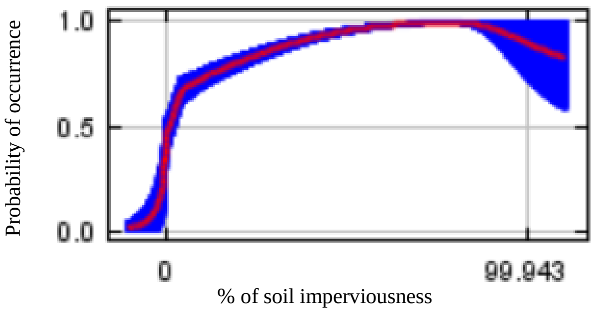


Figure 5.a) Soil imperviousness variable

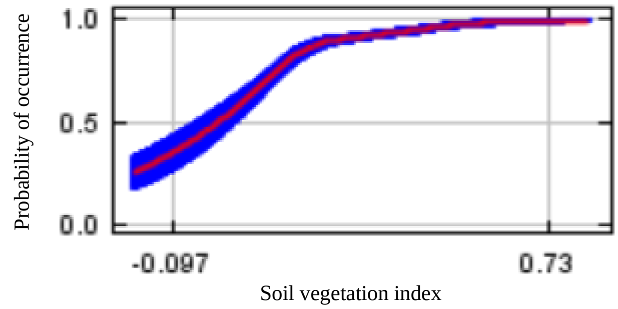


Figure 6.b) SAVI

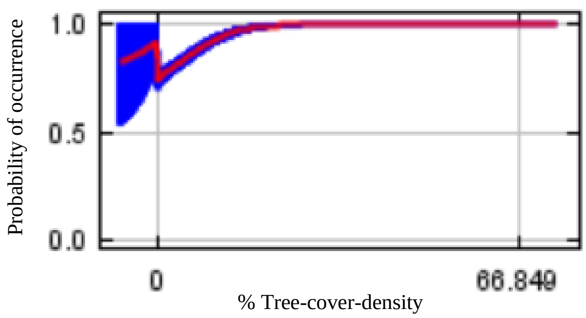
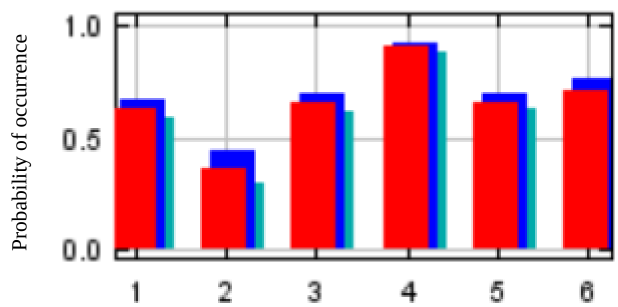


Figure 7.c) Tree-cover-density



1-Urban fabric 0 –50 %; 2-Agriculture; 3-Forest;4-Urban fabric > 50%; 5-Roads and associated land; 6-Gardens.

Figure 8.d) Type of land-use

Figure 5- Individual environmental variable curves. These curves show how each environmental variable affects the Maxent prediction. The curves show the mean response of the 10 replicate Maxent runs (red) and the mean +/- one standard deviation (blue, two shades for categorical variables).

4.2. Roadkill distribution

4.2.1. Roadkill distribution in space

During road surveys 109 hedgehogs were spotted dead, distributed across all the sampled roads during the different sampling periods (Fig.7).

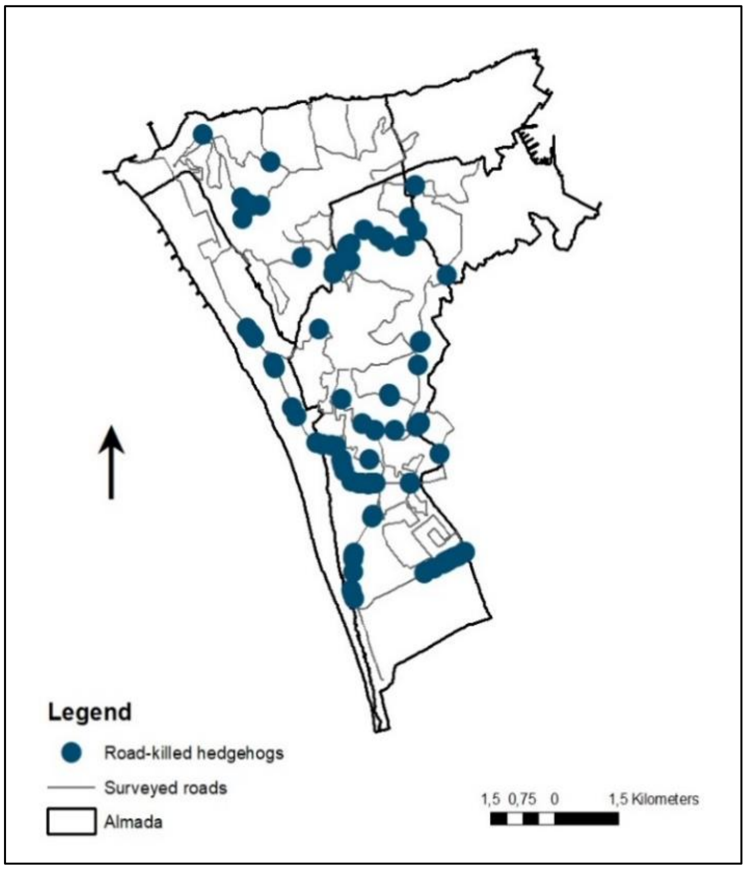


Figure 9- Road-killed hedgehogs

The kernel density analyses estimated the number of hedgehogs that were killed, per cell (100m x 100m) presenting this information in a map with different colors for each interval of numbers. The results show that the road-kills were not randomly distributed across de sampled roads (Fig. 8). We created five classes to classify the roads according to the density of road-killed hedgehogs (Ambiente, G. De., 2012). Thus, there are roads with a higher concentration of road-kills (red and orange) which are the ones that represent a higher risk for hedgehogs.

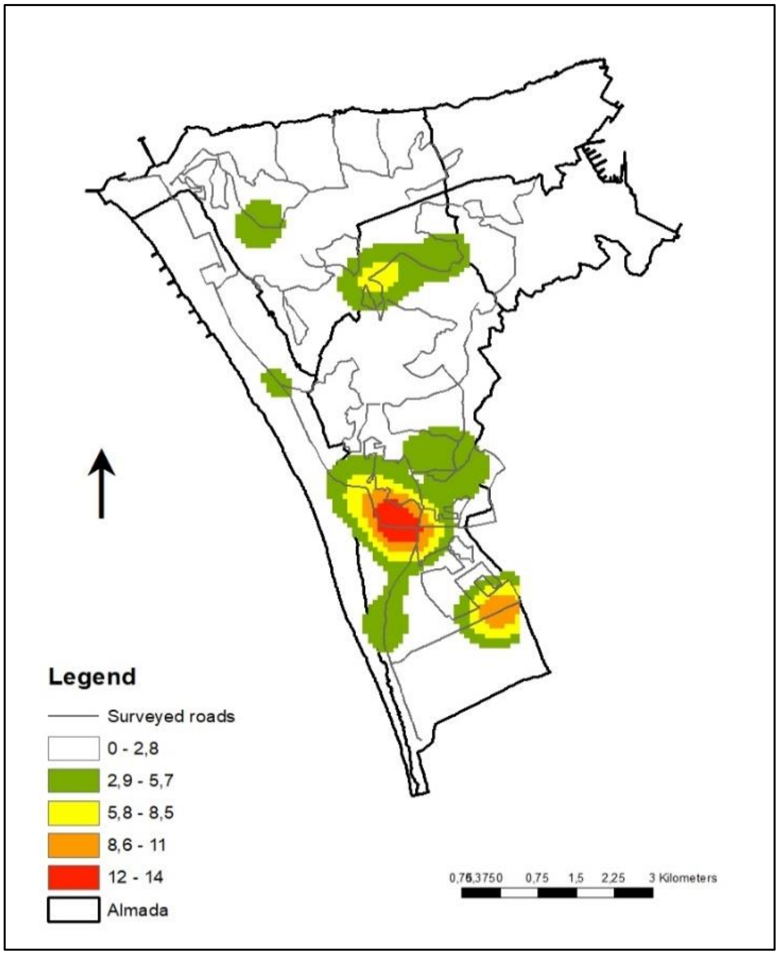


Figure 10- Kernel density of road-killed hedgehogs

4.2.2. Roadkill distribution over time

First, we compared monthly road-kills by year and represented the values in Figure 9. Since in 2013/2014 the monitoring was weekly-based and in 2017 and 2018 was monthly-based, for comparative purposes we did the weekly average of road kills per year.

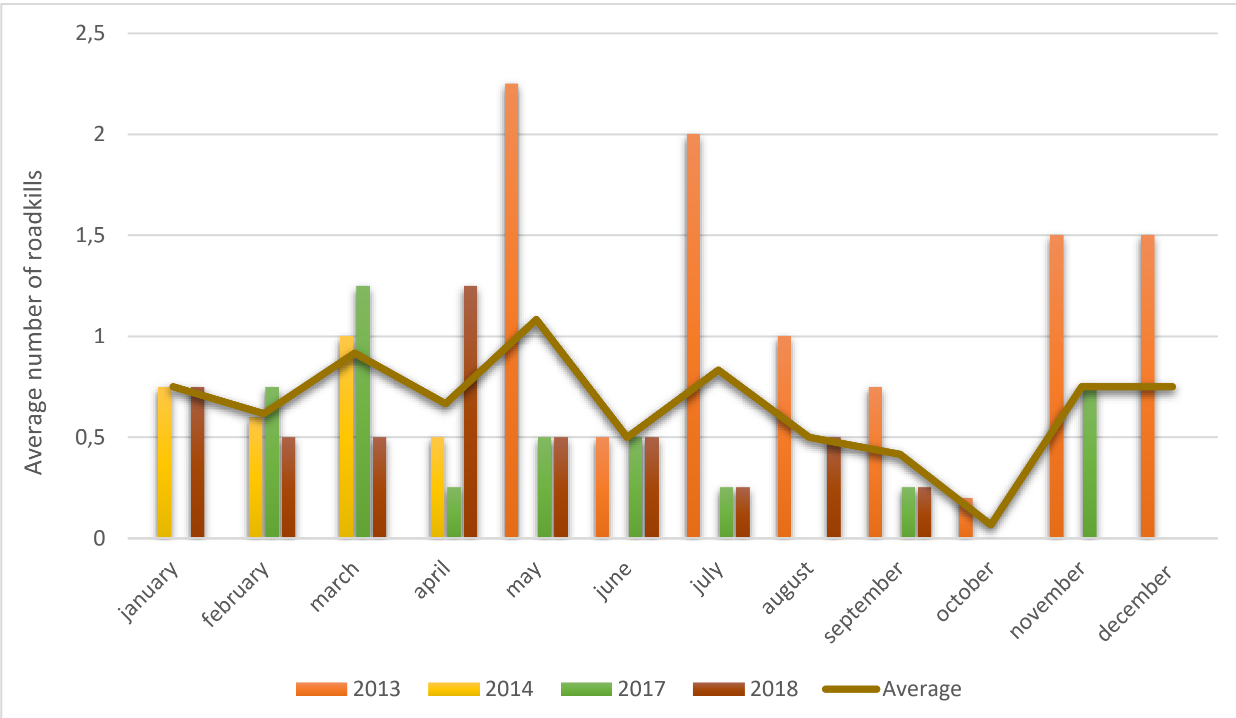


Figure 11- Average road-kill values per month

The months of January, February, and October have convergent values in the three years. In 2013/2014, the largest number of road-kills occurred in May while the lowest occur in October of 2013. The average number of road-kills per week in 2013/2014 was 1,925. In 2017 the peak of road-kills happened in March and the month with fewer road-kills was August, October, and December with no road-kills. The average number of hits per week this year was 0,409. In 2018 the month with more road-kills was April and the one with less was October and November. The average number of road-kills per week in 2018 was 0,455.

In all three years the peak of deaths occurred in spring months (March, April, and May) and the lowest numbers occurred in the Autumn (October). Looking at the average line of the three years, the month with the highest number of mortalities is May and the one with the lowest number of roadkill is October.

4.2.3. *Factors influencing road-kills distribution in space*

The GLM shows that residential and tertiary roads are significantly (***) and negatively related to the road-kills which means that in this type of road the probability of roadkills is lower for hedgehogs. The best model according to the AIC in a Stepwise Algorithm also includes, although not significantly, the wildlife passages and secondary roads. These two variables are positively related to the roadkills so, the distance to the wildlife passage and secondary roads seem to increase the probability of these animals being killed.

Table 3- GLM results

Explanatory variables	Estimate Std,	Error	z value	Pr(>|z|)
Road type: residential	-2,5031	0,5591	-4,477	7,56e-06 ***
Road type: secondary	0,6057	0,4361	1,389	0,164871
Road type: tertiary	-1,7633	0,4722	-3,734	0,000188 ***
log (dist. pass + 1)	0,2716	0,1713	1,585	0,112917

4.3. Citizen's perception of hedgehogs

Were collected 348 citizens' answers through the on-line questionnaire. Yet, this study was only considered those from people living in Almada, resulting in a subset of 150 responses. The average age of respondents was 39 years being the youngest 8 years old, the oldest 68, and the median 40 years. 67% of the respondents were women, 33% of men and 1 did not identify the gender. The academic qualifications of respondents are represented in table 5.

Table 4- Academic qualifications of the respondents

6th grade	9th grade	12th grade	Graduation	Master degree	PhD	Do not answer	Blank
1%	3%	23%	39%	23%	9%	1%	1%

a. <u>Do you consider this species domestic or wild?</u>

Most people (100) responded that this is a wild species (Fig.11). However, 45 people responded "do not know" (9) or did not answer (blank-36).

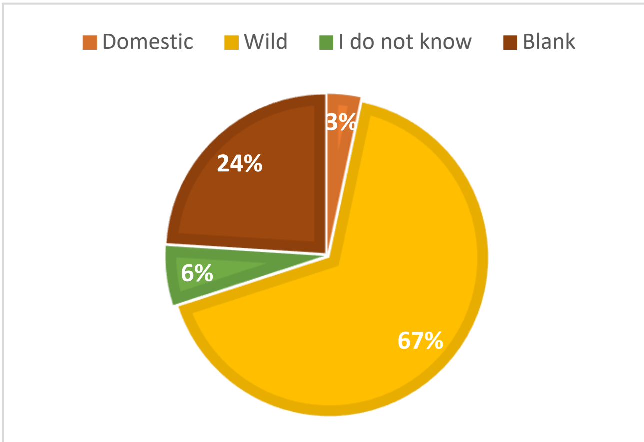


Figure 12- Answers to question A of the survey: "Do you consider this species domestic or wild?"

b. <u>Do you think this species is endangered in Portugal?</u>

Most people (94) did not answer (blank-35) or answer "I do not know" (59). 39 people responded that the species is endangered in Portugal and only 17 responded that the species is not endangered (Fig.12).

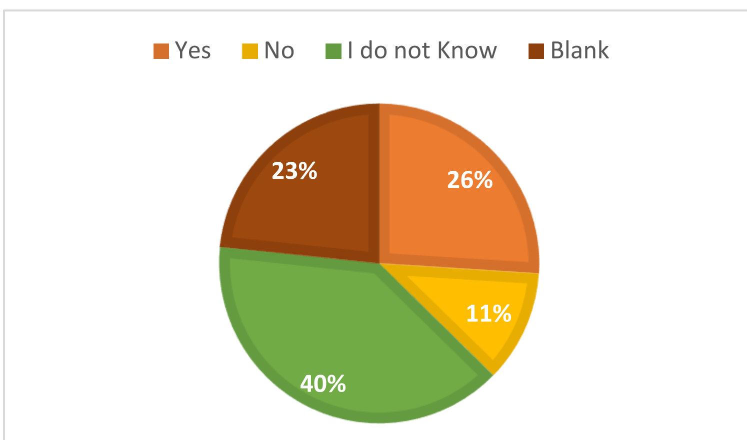


Figure 13- Answers to question B of the survey: "Do you think this species is endangered in Portugal?"

c. *<u>How do you think the hedgehog population has been evolving: in Portugal and Almada</u>?*

Only one person responded that the hedgehog population is increasing, in Portugal, 43 respondents said that is decreasing and 9 that has been constant, 53 people did not know and 44 did not respond. Regarding Almada, only one person defended that the species has been increasing, 9 people said that it has been constant 43 that the hedgehog population has been decreasing, 53 people responded, "I do not know" and 44 did not respond (blank) (Fig.13).

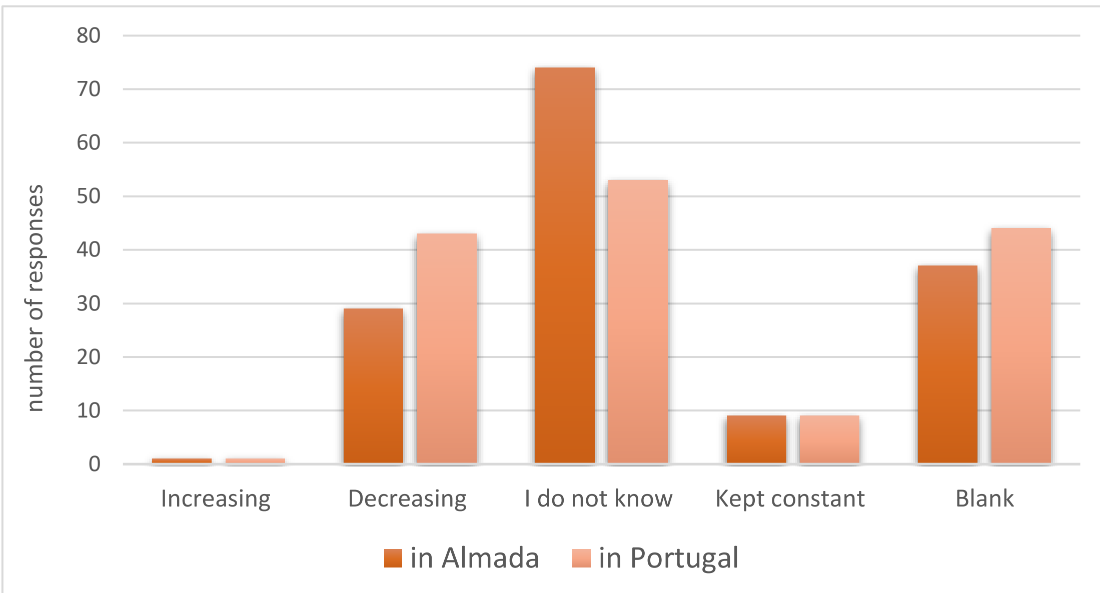


Figure 14- Answers to question c of the survey: "How do you think the hedgehog population has been evolving: in Portugal and Almada?

d. *<u>Do you think it is important to take measures to protect this species: in Almada, outside Almada, in protected areas?</u>*

Most people considered that it is important to protect this species in all the three areas (Almada-98; outside Almada- 97 and in protected areas-100). The number of people that responded "I do not know" was low but the number of people that did not respond remained high (Fig.14).

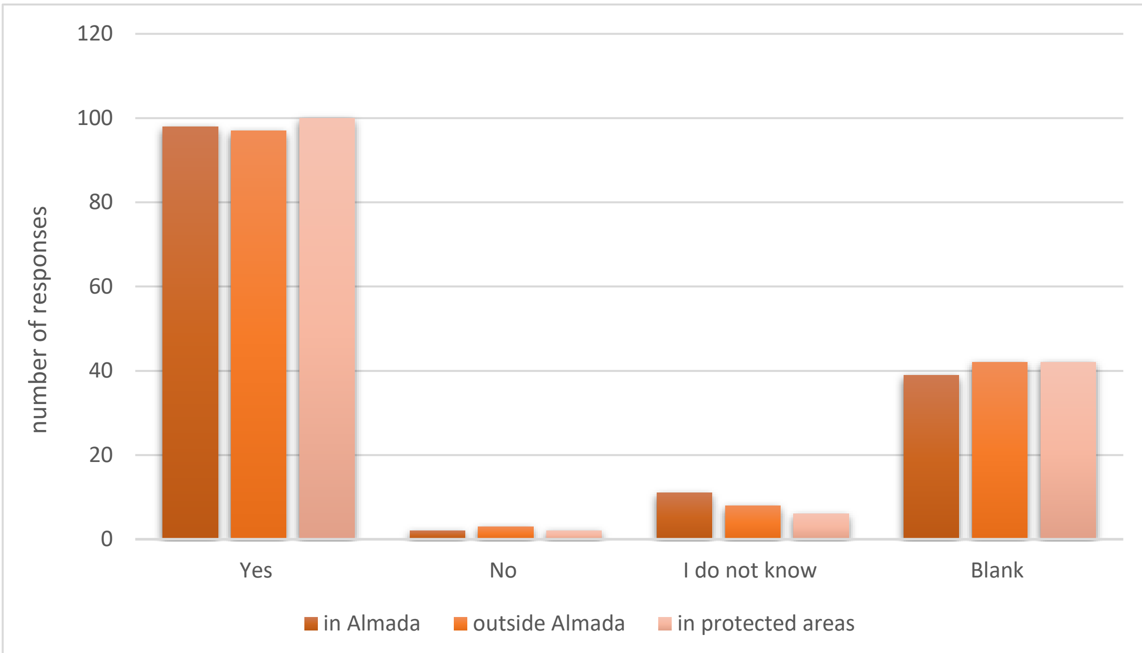


Figure 15- Answers to question c of the survey: "How do you think the hedgehog population has been evolving: in Portugal and Almada?

e. *Do you think it is important for the presence of wild species in cities, outside cities, and in protected areas?*

Most people considered it important to preserve wild species in protected areas and outside cities. However, fewer people considered it important to preserve wild species in cities (Fig.15).

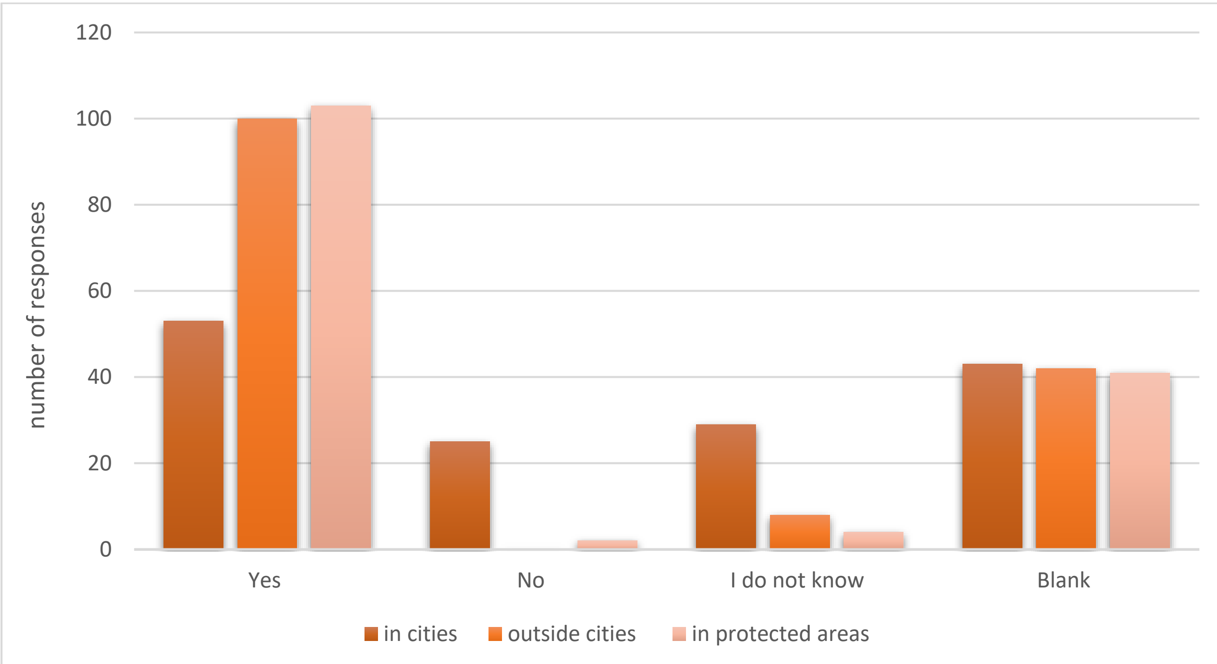


Figure 16- *Do you think it is important for the presence of wild species in cities, outside cities, and in protected areas?*

f. *Do you think hedgehogs are important: for humans and ecosystems?*

Only one person said that hedgehogs are not important for ecosystems and seven responded "I do not know". All other responses were that hedgehogs are important for the ecosystems. When asked about the importance of hedgehogs for people the positive responses decreased and the negative and "I do not know" responses increased (Fig.16).

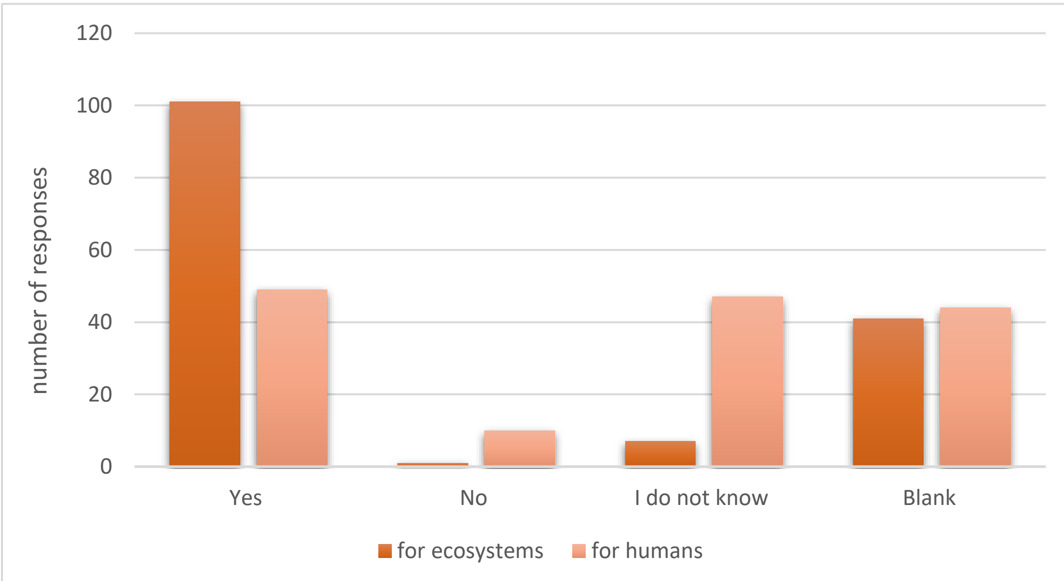


Figure 17- *Do you think hedgehogs are important: for humans and ecosystems?*

g. *How much do you like hedgehogs?*

From 0 (zero) to 10 (ten) the average value of responses was 8,659 and the median was 9 which means that most people like this species a lot.

h. <u>Describe hedgehogs in one word</u>

We divided the words into three groups: biological concepts, feelings and sensations, physical attributes, and others (Fig. 17). 10% of people used ecological concepts to define the species, 41% of people used feelings and sensations, 44% used physical attributes (Table 6).

Table 5- Words used to describe hedgehogs

Feelings and sensations	**Number**	**Physical attributes**	**Number**	**Ecological concepts**	**Number**	**Others**	**Number**
Curious	1	Spiky	1	Rare	1	Chestnuts	1
Tenderness	1	Little ball	1	Species	1	Home	1
Wonderful	1	Spines	18	Biodiversity	1	Sonic	2
Friendly	1	Spikes	19	Forest	1		
Beautiful	1			Running-over	1		
Shy	1			Animal	1		
Harmless	2			Threatened	1		
Loving	2			Field	2		
Cutes	2						
Fear	2						
Sting	2						
Amusing	3						
Pretty	3						
Likeable	3						
Cuddly	11						
Total	***= 36***	***Total***	***= 29***	***Total***	***= 9***	***Total***	*= 4*

5. DISCUSSION

5.1. How are hedgehogs distributed in the urban space?

The SDM showed a large area with a high probability of the species to occur. However, the concentration of sights was not the same across de study area. In Almada, this species is present in very humanized areas like built-up areas and roads. However, they are also present in green areas like parks, gardens, and forests. The high densities of this species in parks and urban gardens have already been reported (Huijser, 2000; Young et al., 2006). The presence in forests of urban areas is somehow new information. Probably, as happens in rural areas, in urban areas hedgehogs use these areas to make their nests (Jensen, 2004; Riber, 2006). Forest and gardens in Almada have a rich shrub stratum and a dense substrate composed of dry leaves, present in all seasons what is good for hedgehogs to construct their nets. The places with less probability of occurrence, according to the SDM, were coastal beaches. However, these animals were spotted in the beach dunes during fieldwork. Heterogeneity and distance to water lines had no significant contribution to the model probably due to the study area being highly heterogeneous and with many water lines.

Thus, in this urban area, hedgehogs seem to maintain their generalist character, using various types of habitat, probably for their different activities (eating, nesting, etc). Dowding, 2010 defended that in urban areas hedgehogs actively avoided exposure to humans. Our study seems to conclude differently probably because Almada has a very fragmented and diverse landscape. Even the most urbanized areas have are fragmented and have green areas near them. This behavior and habitat use can be different in other cities with different characteristics like more dense urbanized areas. It is important to develop studies with this species in other cities.

The fact that the hedgehogs use various types of habitats in the study area, the area with a high probability of occurrence is large, means that management measures for this species in this area should focus on ensuring the habitat diversity and connectivity for the species to circulate among the different habitats like Hof (2009) has already suggested.

These results can be biased toward people's density. However, the high probability of the species to occur in roads and forests opposes this tendency and gave us some confidence in our results. Our AUC values can be considered low since, according to Hosmer and Lemeshou (2000) models are only considered acceptable with AUC values higher than 0.7. However, since we are studying a generalist species high AUC values are not expected. The species appears in all environments which makes it difficult for the model to find connections between this species presence and the environmental variables. Also, some authors have begun to criticize the use of AUC as the standard measurement of accuracy in distribution models (Austin, 2007). Austin (2007) warns that "reliance on AUC as a sufficient test of model success needs to be re-examined."

A limitation of our study is that we have only used presence data since models constructed with presences and absences have more robust results. However, all presence/absence data have the problem of false absences. Some authors even suggest that presence-only data, in some sense, release us from the problems of unreliable absence records (Lobo et al., 2008). Also, MaxEnt's predictive performance has been consistently competitive with the highest performing methods (Elith et al., 2006) which gave us some confidence in our results. However, it would be interesting to develop another study with another sampling method like spotlights that could detect absences and avoid density population bias

5.2. What is influencing road-kills?

Road mortality assessments are important to identify species in need of detailed population studies, to identify road network sections in need of mitigation measures but also to determine the effectiveness of mitigation measures like evaluating the effectiveness of wildlife passages (Lesbarreres and Fahrig, 2012).

Our road monitoring results show that road mortality is a problem that also affects the hedgehog population's in urban areas. Roadkills are distributed in clusters in Almada city roads. The kernel density analysis allowed us to distinguish mortality risk levels, key information for management purposes.

The best model according to the AIC in a Stepwise Algorithm includes the residential and tertiary roads (significant variables***) and also, although not significant, secondary roads and the distance to the wildlife passages. The GLM shows that it is less probable for the hedgehogs to be killed in tertiary and residential roads. On the other hand, the distance to the wildlife passage and residential roads seems to increase the probability of these animals to be killed.

These results suggest that hedgehogs use wildlife passages of the council as an alternative to cross the roads. A report in Alentejo, Portugal, has already defended that this species uses wildlife passages if they are large and open (Ascensão, 2006) since hedgehog avoids small spaces (Haigh, 2012). Most wildlife passages in Almada are large and open, being suitable for these animals. Thus, the construction of new passages seems a good option to reduce hedgehog's road mortality. However, further study on the use of these structures by the county's animals was important.

The type of road also influences hedgehog road mortality, secondary roads having higher mortality than tertiary and residential ones. In our study area, secondary roads are larger and have more traffic than tertiary and residential ones. Rondinini & Doncaster (2002) defended major roads carrying large volumes of traffic are a major obstacle to the movements of urban hedgehogs. That is also the explanation presented to explain why hedgehogs are significantly more active after midnight because there is a marked reduction in vehicle and foot traffic (Dowding, 2009). Although these animals avoid larger roads when they cross them the probability of being roadkills is higher than in smaller roads. Thus, measures to minimize the impact of roadkill in the hedgehog population, like the implementation of wildlife passages should be planned, first, for secondary roads.

The GLM showed no relation between the probability of the species to occur and the risk of roadkill. So, hedgehogs can be more road-killed when they are dispersing and not in the places they use more often. However, this result can also be due to sampling limitations. To study roadkill patterns is important to have good estimates of species abundance because road kills are very susceptible to variations in population numbers. Thus, for future research in road kills assessment we propose to estimate the density values of the species in the study area.

5.3. How are roadkill's distributed over time?

Seasonality seems to be one of the factors that influence most the road-kills (Smith-Patten & Patten 2008, Rosa & Bager 2012). Our data show that casualties happened all over the year with a variation in the roadkill numbers throughout the year. In Winter and Spring, the values were similarly high. In Summer months the values decreased, and Autumn was the season with fewer deaths. These variations are probably related to the hedgehog's annual cycle.

High roadkill values in Spring, with a peak in March, can be related to the hedgehog sexual activity (Boitani,1984). High values of winter months are more difficult to explain since hedgehogs are hibernating species (Morris, 1969) being, thus, expected that in these months the number of road-kills was lower. However, in our study area temperatures in coldest months never reach very low values. So, probably in Almada, and in most of the country, hedgehogs do not enter in full hibernation, continuing to be active in the Winter. However, this only explains why road-kills do not cease in the winter and not why values are so high in these months, being necessary more studies to understand this point. For management purposes it is important to know that minimization measures need to be implemented and applied during the entire year with special attention in the Winter and Spring months.

In road mortality assessments it is necessary to consider the carcasses' persistence time in the roads and their detectability by the observers. Carcass persistence time on roads can be influenced by weather, scavenger's activity, and traffic flow (Santos, 2016). In our study, rain may have influenced the persistence of the carcasses on the road and therefore reduced the number of sightings in Winter and Autumn, the rainier seasons. However, because the number of sights is high in the winter, probably the weather did not have much influence. The traffic flow could have influenced the fewer sights on larger roads. Ascensão & Mira (2007), suggested that for hedgehogs the persistency in Portuguese roads is between 3 to 6 days. In our study, we could not always have weekly monitoring but for future research we suggest this monitoring periodicity.

Detectability can be affected by carcass size, amount of roadside vegetation, survey method, and researcher's abilities (Slater, 2002; Hobday, 2008). Hedgehog carcasses are likely to be detected with a greater probability because of their distinctive appearance and the monitorization was done with two investigators, one of them with a lot of experience in detecting carcasses that gave us some confidence in our results. The only way to understand if our data were very affected by detectability is to do a species occupancy model for hedgehog's mortality on Almada's roads.

Although we considered the sampling effort in these analyses, the fact that we surveyed in 2015 and 2017/2018 the five areas with higher mortality in 2013/2014 may have skewed the data. Thus, it is recommended that the monitoring be maintained weekly and extending the sampled roads if possible.

5.4. How are hedgehogs perceived by the citizens?

The responses of our online survey show that many people consider that the hedgehog population in Portugal is at risk of extinction and that the hedgehog population is declining. These responses are surprising since in Portugal the conservation status of the *E. europaeus* is least concerned and there is no recent study indicating that the species is in danger. These answers can be related to the fact that the environment is now more on the social and political agenda leading to an increase of peoples' awareness of the biodiversity crisis, global warming, and other environmental problems.

Respondents say to approve the conservation of hedgehogs "in cities", "outside cities" and in "protected areas". About wild species, they also consider important their conservation "outside cities" and "in protected areas" but fewer people consider it important in "urban areas". First, it is worrying that people consider less important the preservation of wild species in urban areas. On the other hand, the analysis of these questions shows that hedgehogs are not perceived exactly as a wild species, even though people say so when directly asked. This denotes a miss understanding of the concept of wildlife. People probably link the idea of wildlife to dangerous animals that would represent danger in cities. Because hedgehogs are perceived as inoffensive, they are tolerated in cities. Thus, it is important to clarify the citizens about hedgehogs, biodiversity, and wildlife through public sessions, brochures, online materials, and resources.

When asked to describe hedgehogs in one word, 41% of people resorted to feelings and sensations that are more suitable for pets than wild animals like cuddly, pretty, or cute. Showing, again, that hedgehogs are not exactly perceived as a wild species but more like pets. These wrong ideas can lead to inadequate behaviors towards these animals, like feed them constantly, approach and touch them putting them in danger. Thus, it is important to clarify people about best practices for this species. At last, respondents considered this species important for ecosystems but not so much for humans. This means that people do not recognize humans as part of ecosystems and as being directly affected by them.

Most people seem to appreciate hedgehogs since the average values were nine on a scale from zero to ten. In other countries, the hedgehog is also a very cherished species. In the UK is widely recognized as the most popular wild animal (Hoare, 2013). Collèony (2016) defended that the willingness to conserve some species is "mostly driven by affect-related motivations and arbitrary influences, rather than by more ecological considerations such as the endangered status of a species".

Since affective factors are important to explain people's predisposition for the conservation of a specific species (Martín-Lopes, 2007) the fact that people like this species and say they support their presence in an urban area is positive because they probably are available to support conservation measures for hedgehogs in this area.

The questionnaire was unable to reach people with no education and primary education probably because it was a written online questionnaire. On the other hand, is a computer-based questionnaire that needs internet access, it has eliminated people who do not have a computer or internet or who are unable to work with computer platforms. To solve this limitation, we propose that future studies collect door-to-door oral response surveys. Also, the number of people who participated in the questionnaire who attended higher education is larger than the reality of the municipality of Almada. This probably happened because the questionnaire was originated in the university so in the future this questionnaire should be more disseminated in the community.

Annexes

Annex 1- Roadkill report of Câmara Municipal de Almada

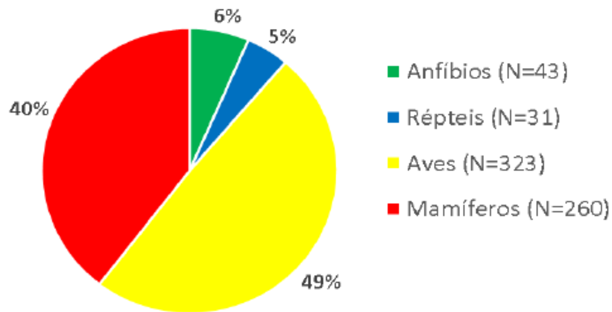


Figura 6 – Percentagem de atropelamentos de vertebrados por classe, na rede de estradas do Concelho de Almada, entre Maio de 2013 e Abril de 2014. Na legenda indica-se, entre parênteses, o número respectivo de animais em cada uma das classes.

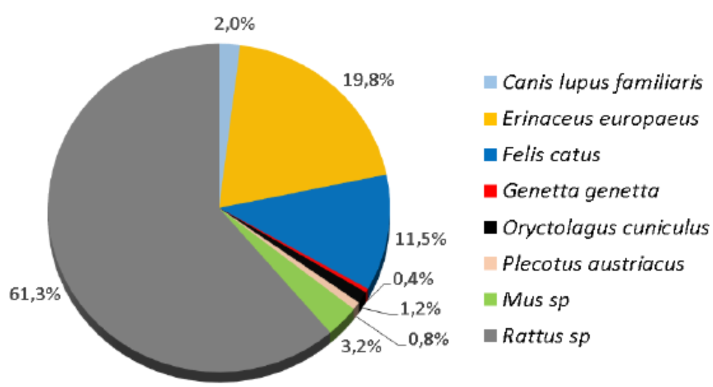


Figura 10 – Distribuição relativa por espécie dos mamíferos encontrados atropelados, de Maio de 2013 a Abril de 2014, na rede viária do Concelho de Almada.

Annex 2- Roadkill monitoring report of Estradas de Portugal

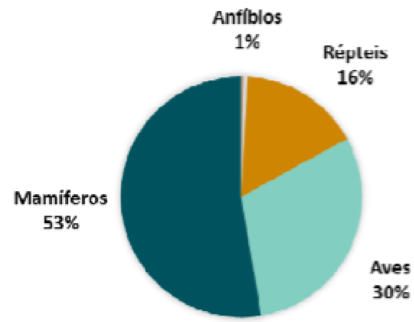


Fig. 6 – Percentagem de registos de atropelamentos, por grupo faunístico, em 2015.

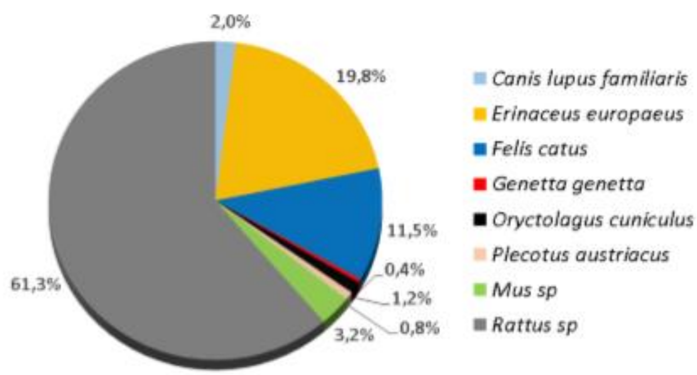


Figura 10 – Distribuição relativa por espécie dos mamíferos encontrados atropelados, de Maio de 2013 a Abril de 2014, na rede viária do Concelho de Almada.

Annex 3- Correlation matrix of variables used in SDM

CORRELATION MATRIX

Layer	1	2	3	4	5	6
1	1,00000	-0,01782	0,37717	-0,32553	-0,19107	0,20580
2	-0,01782	1,00000	-0,23649	0,04825	-0,06768	-0,01104
3	0,37717	-0,23649	1,00000	-0,58112	-0,49352	0,48519
4	-0,32553	0,04825	-0,58112	1,00000	0,44470	-0,29672
5	-0,19107	-0,06768	-0,49352	0,44470	1,00000	-0,20759
6	0,20580	-0,01104	0,48519	-0,29672	-0,20759	1,00000

REFERENCES

Ambiental, B. (2014). *Estudos De Fragmentação Territorial E Impactes Sobre a Biodiversidade E Continuidades Ecológicas*.

Ambiente, G. De. (2012). *Monitorização da Mortalidade de Fauna nas Estradas da EP. RELATÓRIO SÍNTESE, 2012 Monitorização da Mortalidade de Fauna*.

Ascensão, F., & Mira, A. (2006). Impactes das vias rodoviárias na fauna silvestre. *Avaliar o Impacto Da Mortalidade Em Populações de Vertebrados Em Estradas Do Alto Alentejo, e Sua Relação Com o Uso de Passagens Hidráulicas*, 63.

Asteraki, E. J., Hart, B. J., Ings, T. C. & Manley, W. J. (2004). Factors influencing the plant and invertebrate diversity of arable field margins. *Agriculture, Ecosystems & Environment*, 102**,** 219-231.

Austin, P. C. (2007). The performance of different propensity score methods for estimating marginal odds ratios. Statistics in Medicine, 26(16), 3078–3094.

Blair, R. B. (1996). Land use and avian species diversity along an urban gradient. *Ecological Applications*, 6(2), 506–519.

Bjerke, T., & Østdahl, T. (2004). Animal-related attitudes and activities in an urban population. *Anthrozoos*, *17*(2), 109–129.

BOTTANI, L., & REGGIANI, G. (1984). Movements and activity patterns of hedgehogs (Erinaceus europaeus) in Mediterranean coastal habitats. *Zeitschrift Für Säugetierkunde*, *49*(4), 193–206.

Brockie, R.E. (1975) Distribution and abundance of the hedgehog (*Erinaceus europaeus*) L. in New Zealand, 1869–1973, New Zealand Journal of Zoology, 2:4, 445-462.

Colléony, A., Clayton, S., Couvet, D., Saint Jalme, M., & Prévot, A. C. (2017). Human preferences for species conservation: Animal charisma trumps endangered status. *Biological Conservation*, 206, 263–269.

Correia, O., Santos-Reis, M., Branquinho, C., Rebelo, R., Pinho, P., Munzi, S., … Novais, B. (2011). *ANEXO AO PROTOCOLO ENTRE O MUNÍCIPIO DE ALMADA (CMA) E O CENTRO DE BIOLOGIA AMBIENTAL (CBA) DA FACULDADE DE CIÊNCIAS DA UNIVERSIDADE DE LISBOA PARA A CARACTERIZAÇÃO DA FLORA E VEGETAÇÃO DO CONCELHO DE ALMADA RELATÓRIO FINAL Avaliação de impactes na biodiv*.

Davidson, J., Huck, M., Delahay, R. J., & Roper, T. J. (2008). Urban badger setts: Characteristics, patterns of use and management implications. Journal of Zoology, 275, 190–200.

Delahay, R. J., Davidson, J., Poole, D. W., Matthews, C. J., Heydon, M. J., & Roper, T. J. (2009). Managing conflicts between humans and wildlife: Trends in licensed operations to resolve problems with badgers *Meles meles* in England. Mammal Review, 39, 53–66.

Doncaster, C. P. (1994). Factors Regulating Local Variations in Abundance: Field Tests on Hedgehogs, Erinaceus europaeus. *Oikos*, *69*(2), 182.

Doncaster, C. P., & Rondininit, C. (2001). Field Test for Environmental Correlates of Dispersal in Hedgehogs Erinaceus europaeus Author (s): C. Patrick Doncaster, Carlo Rondinini, Paul C. D. Johnson Published by: British Ecological Society Stable.

Dowding, C. V., Harris, S., Poulton, S., & Baker, P. J. (2010). Nocturnal ranging behaviour of urban hedgehogs, Erinaceus europaeus, in relation to risk and reward. *Animal Behaviour, 80*(1), 13–21.

Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E., & Yates, C. J. (2011). A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, *17*(1), 43–57.

Fitzpatrick MC, Gotelli NJ, Ellison AM. (2013). MaxEnt versus MaxLike: empirical comparisons with ant species distributions. Ecosphere 4(5):1_15.

Franklin J. (2009). Mapping Species Distributions: Spatial Inference and Prediction. Cambridge: Cambridge University Press.

Haigh, A. J. (2011). The Ecology of the European hedgehog (Erinaceus europaeus) in rural Ireland. *PhD Thesis, University College Cork*, (March).

Haigh, A., Butler, F., & O'Riordan, R. (2012). An investigation into the techniques for detecting hedgehogs in a rural landscape. *Journal of Negative Results*, *9*(1).

Haigh, A., O'Riordan, R. M., & Butler, F. (2014). Hedgehog Erinaceus europaeus mortality on Irish roads. *Wildlife Biology*, *20*(3), 155–160.

Harris, S., & Baker, P. (2001). Urban foxes. Stowmarket: Whittet Books.

Hell, P. et al. 2005. Losses of mammals (Mammalia) and birds (Aves) on roads in the Slovak part of the Danube Basin. – Eur. J. Wildlife Res. 51: 35–40.

Hoare, B. (2013) Britain's national species revealed. Available from: http://www.discoverwildlife.com/british-wildlife/britains-national-species-revealed [Accessed 8th October 2015].

Hobday, A. J., & Minstrell, M. L. (2008). Distribution and abundance of roadkill on Tasmanian highways: Human management options. *Wildlife Research, 35*(7), 712–726.

Holsbeek, L. et al. 1999. Hedgehog and other animal traffic victims in Belgium: results of a countryside survey. – Lutra 42:111–119.

Hosmer, D. W., & Lemeshow, S. (2000). *Applied Logistic Regression.pdf* (pp. 161–164). pp. 161–164.

Hubert, P., Julliard, R., Biagianti, S., & Poulle, M. L. (2011). Ecological factors driving the higher hedgehog (*Erinaceus europeaus*) density in an urban area compared to the adjacent rural area. *Landscape and Urban Planning*, *103*(1), 34–43.

Huijser, M. P., & Bergers, P. J. M. (2000). The effect of roads and traffic on hedgehog (Erinaceus europaeus) populations. *Biological Conservation*, *95*(1), 111–116.

Huijser, M. et al. 1998. Hedgehog traffic victims: how to quantify effects on the population level and the prospects for mitigation. – Proc. Int. Conf. Wildlife Ecol. Transportation, pp. 171–180.

Instituto Nacional de Estatística. <Lissabon>. (2012). Resultados definitivos : Portugal.

Jackson, D. B., Fuller, R. J., & Campbell, S. T. (2004). Long-term population changes among breeding shorebirds in the Outer Hebrides, Scotland, in relation to introduced hedgehogs (Erinaceus europaeus). *Biological Conservation*, *117*(2), 151–166.

Jensen, A. B. (2004). Overwintering of European hedgehogs Erinaceus europaeus in a Danish rural area. *Acta Theriologica*, *49*(2), 145–155.

Kaltenborn, B. P., Bjerke, T., Nyahongo, J. W., & Williams, D. R. (2006). Animal preferences and acceptability of wildlife management actions around Serengeti National Park, Tanzania. *Biodiversity and Conservation*, *15*(14), 4633–4649.

Kleiven, J., Bjerke, T., & Kaltenborn, B. P. (2004). Factors influencing the social acceptability of large carnivore behaviours. *Biodiversity and Conservation*, *13*(9), 1647–1658.

Kristiansson H. (1984), Ecology of a hedgehog population in southern Sweden, *Journal of Zoology* **220**: 391-404.

Lesbarrères, D., & Fahrig, L. (2012). Measures to reduce population fragmentation by roads: What has worked and how do we know? *Trends in Ecology and Evolution*, *27*(7), 374–380.

Lobo, J. M., Jiménez-valverde, A., & Real, R. (2008). AUC: A misleading measure of the performance of predictive distribution models. *Global Ecology and Biogeography*, *17*(2), 145–151.

Merow, C., Smith, M. J., & Silander, J. A. (2013). A practical guide to MaxEnt for modeling species' distributions: What it does, and why inputs and settings matter. *Ecography*, *36*(10), 1058–1069.

Micol, T., Doncaster, C.P., Mackinlay, L. A. (1994). Correlates of Local Variation in the Abundance of Hedgehogs Erinaceus europaeus Author (s): T . Micol , C . P . Doncaster and L . A . Mackinlay Published by : British Ecological Society Stable URL : http://www.jstor.org/stable/5262 REFERENCES Linked ref. *Journal of Animal Ecology*, *63*(4), 851–860.

Mora, C., & Sale, P. F. (2011). Ongoing global biodiversity loss and the need to move beyond protected areas: A review of the technical and practical shortcomings of protected areas on land and sea. *Marine Ecology Progress Series*, *434*(July), 251–266.

Morris, P. A. (1988). A study of home range and movements in the hedgehog (Erinaceus europaeus). *Journal of Zoology*, *214*(3), 433–449.

Morris, P. (2006) The New Hedgehog Book. Whittet Books, Stansted.

Morris, P. A. & Reeve, N. J. (2008). Hedgehog Erinaceus europaeus. In: Mammals of the British Isles: Handbook (Ed. by S. Harris & D. W. Yalden), pp. 241e248, 4th edn. Southampton: The Mammal Society.

Pagh, S. (2008). The history of urban foxes in Aarhus and Copenhagen, Denmark. Lutra, 51(1), 51–55.

Pfäffle, M. (2010). *Influence of parasites on fitness parameters of the European hedgehog (Erinaceus europaeus)*. (APRIL), 255.

Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190(3_4):231_259.

Reeve N. J. (1981), A field study of the hedgehog (Erinaceus europaeus) with particular reference to movements and behaviour, Ph.D. Thesis, University of London, London, UK.

Reeve N. (1994), *Hedgehogs*, T & AD Poyser (Natural History), London, UK.

Riber, A. B. (2006). Habitat use and behaviour of European hedgehog Erinaceus europaeus in a Danish rural area. *Acta Theriologica*, *51*(4), 363–371.

Robardet, E., Giraudoux, P., Caillot, C., Boue, F., Cliquet, F., Augot, D., et al. (2008). Infection of foxes by Echinococcus multilocularis in urban and suburban areas of Nancy. France: Influence of feeding habits and environment. Parasite, 15, 77–85.

Rondinini, C., & Doncaster, C. P. (2002). *Rondininini a Doncaster 2002_Hedgehogs.Pdf*. 504–509.

Roos, S., Johnston, A., & Noble, D. (2012). UK Hedgehog datasets and their potential for long-term monitoring. *British Trust for Ornothology Research Report*, (598), 9–59.

Rosa, C.A., Bager, A. (2012). Seasonality and habitat types affect roadkill of neotropical birds. *Journal of Environmental Management*, **97**, 1-5.

Santos, R. A. L., Santos, S. M., Santos-Reis, M., De Figueiredo, A. P., Bager, A., Aguiar, L. M. S., & Ascensão, F. (2016). Carcass Persistence and Detectability: Reducing the Uncertainty Surrounding Wildlife-Vehicle Collision Surveys. *PLoS ONE*, *11*(11), 1–15.

Santos, R. A. L., Mota-Ferreira, M., Aguiar, L. M. S., & Ascensão, F. (2018). Predicting wildlife road-crossing probability from roadkill data using occupancy-detection models. *Science of the Total Environment*, *642*, 629–637.

Santos, S. M., Carvalho, F., & Mira, A. (2011). How long do the dead survive on the road? Carcass persistence probability and implications for road-kill monitoring surveys. *PLoS ONE*, *6*(9).

Slater, F. M. (2002). An assessment of wildlife road casualties - The potential discrepancy between numbers counted and numbers killed. *Web Ecology*, *3*, 33–42.

Sleeman, D. P. et al. (1985). Irish Mammal road casualties. – Irish Nat. J. 21 (12).

Smiddy, P. (2002). Bird and mammal mortality on roads in counties Cork and Waterford, Ireland. – Bull. Irish Biogeogr. Soc. 26: 29–38.

Smith-Patten, B.D., Patten, M.A. (2008). Diversity, Seasonality, and Context of Mammalian Roadkills in the Southern Great Plains. *Environmental Management*, **41**, 844-852.

Wania, A., Kühn, I., & Klotz, S. (2006). Plant richness patterns in agricultural and urban landscapes in Central Germany-spatial gradient of species richness. Landscape and Urban Planning, 75, 97–100.

White, P. C. L., Jennings, N. V., Renwick, A. R., & Barker, N. H. L. (2005). Questionnaires in ecology: A review of past use and recommendations for best practice. *Journal of Applied Ecology*, *42*(3), 421–430.

Young, R. P., Davison, J., Trewby, I. D., Wilson, G. J., Delahay, R. J., & Doncaster, C. P. (2006). Abundance of hedgehogs (Erinaceus europaeus) in relation to the density and distribution of badgers (Meles meles). *Journal of Zoology*, *269*(3), 349–356.