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NOVA IMS Information Management School

Geospatial Data Science

Subject: Spatial Database

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Development of a Spatial Database for Camera Trapping

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Summary

Camera trapping, used by Palombar in the Northeast region of Trás-os-Montes in Portugal, is the basis of this study, which aims to improve the management and analysis of local biodiversity. Through the integration of tools such as QGIS, PostgreSQL and PostGIS, a spatial database was developed. The main focus is on the identification of areas of high biological richness, the geographical distribution of diverse species and their habitat preferences. This method provides a detailed and valuable view for wildlife conservation, optimizing the use of data in environmental projects.

Keywords: Camera Trapping, Database, QGIS, PostgreSQL, PostGIS

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1. Introduction

Camera trapping (PA) is a biodiversity monitoring technique that consists of capturing photographs or videos through cameras installed in the field (Forrester et al., 2016). The motion sensors of cameras make it possible to detect the infrared radiation emitted by the body heat of animals and thus capture records of wildlife passively (Wearn & Glover-Kapfer, 2017).

The use of this method has been increasing, and consequently the volume of information produced and that needs to be stored, managed and analyzed (Forrester et al., 2016). In Portugal, it serves purposes as diverse as detecting the presence of species, monitoring their health status, or studying their behavior.

Palombar – Conservation of Nature and Rural Heritage has as its mission to conserve biodiversity, wild, forest and agricultural ecosystems and preserve the rural built heritage, as well as traditional construction techniques (Palombar, n.d.) and within the scope of its activity it has been promoting several projects where it uses the PA technique.

Through this work, we intend to develop and implement a spatial database to manage the records obtained during the PA campaigns carried out by this association. In order to reduce the time used in data pre-processing, records from two projects were used:

- ENET WILD, an international project that aims to monitor the population and health situation of wildlife in Europe (Palombar, 2021);
- UP4Rehab, which aims at the ecological restoration of a eucalyptus area in the municipality of Vimioso (Palombar, 2022).

As mentioned earlier, one of the challenges that AF currently faces is related to its ability to produce a lot of data and files, which makes its management a real challenge for the technicians who review the cameras, and for those who analyze the data. Currently, all these records are maintained and stored in excel spreadsheets. With the development of this work, it is intended to contribute to the storage and management system of data collected through Palombar's FA.

The specific objectives of this work are:

1. Identify the areas with the greatest specific richness

Based on the geographical records of the species, and using a GIS software, it is intended to carry out a geospatial analysis to identify and map the areas that present greater biodiversity. This analysis, focused on the distribution and number of species observed, facilitates the identification of areas of high biological richness, helping to guide conservation efforts.

2. Know the geographical distribution of species

A basic parameter in the study of fauna is the knowledge of its distribution area. With the database in place, it will be possible to develop maps that illustrate the presence and absence of species in a distribution grid.

3. Perform a Habitat Preference analysis

Within the scope of this work it will be possible to measure the frequency of observations of the species for each class of land use, overlaying the database records with a land use map. This analysis will tell us the preferences, or lack of preference, of the species for each type of habitat. This type of analysis is particularly useful for understanding the conservation requirements of endangered species.

2. Field of study

Palombar's area of intervention is focused on the Northeast region of Trás-os-Montes, however, the organization has been expanding its territory of operation (Palombar, n.d.).

The ENET WILD project arose from a collaboration between Palombar and the Institute for Research in Hunting Resources of the University of Castilla-La Mancha (IREC), in Spain, in September 2021, with the aim of improving the tools for monitoring the populations of wildlife species, taking into account their distribution and abundance, through the development of standardized protocols for data collection and validation and the creation of a European database. The main and initial focus of the project was on wild boar (*Sus scrofa*) populations (Palombar, 2021).

The intervention area of this project focused on the Associative Hunting Zone (ZCA) of Santulhão, in the municipality of Vimioso, district of Bragança, in the Northeast of Trás-os-Montes (**Figure 1**). Area where you want to "*collect data on comparable wildlife species at European level, with the main objective of assessing the risks of shared wildlife diseases more effectively and rapidly*". (Palombar, 2021).

The project UP4REHAB - Landscape Unit for the Restoration of Habitats of Algoso da Palombar - Conservation of Nature and Rural Heritage, approved in 2022, arose in response to the COVID-19 pandemic, in the component of Support for climate transition - resilience of territories in the face of erosion risk. The study area of this project is located in the Northeast of Trás-os-Montes, more specifically in the former parish of Algoso, municipality of Vimioso, district of Bragança and is part of the Transboundary Biosphere Reserve of the Iberian Meseta and Special Area of Conservation and Special Protection Area Sabor and Maçãs Rivers of the Natura 2000 Network (Palombar, 2021).

According to the information provided by the ICNF, it is possible to identify the delimitation of the Biosphere Reserve (ICNF, 2022) and the Special Protection Area (SPA) that the project's study area integrates (ICNF, 2023) (**Figure 1**).

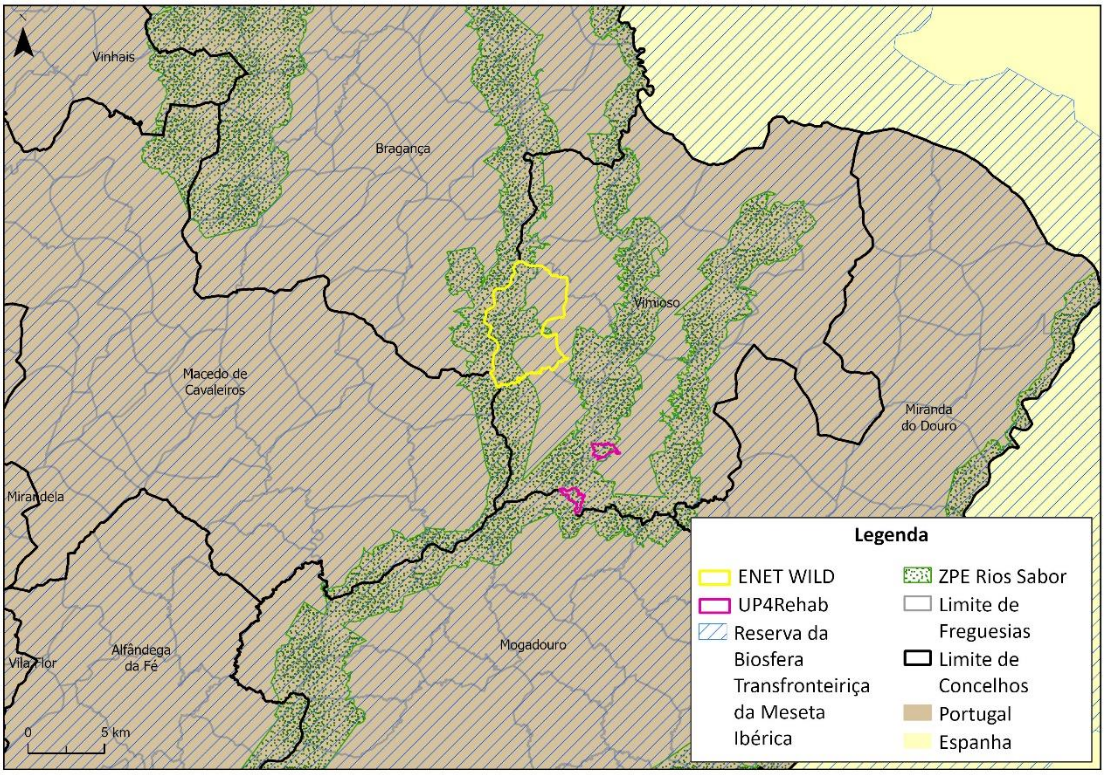


Figure 1 - Geographical framework of the study areas.

3. Data and methodology

Ideally, the creation and implementation of a spatial database should be initiated by Pre-Analysis. In this phase of research, the "business rules" are captured, which will guide us to the design of the database and the data collection process. It was not possible to follow this initial approach because for this work we started from previously collected data. The geographic coordinate system of the available data was WGS 1984.

In addition to these data, the Land Use and Occupation Chart (COS) for 2018, from the Directorate-General for the Territory, (DGT, 2019), was also used to respond to the third objective of the work.

Thus, the first step in the creation of the relational database consisted of the analysis of the spreadsheet provided by Palombar, and the remaining phases followed the workflow taught.**Figure 2**).

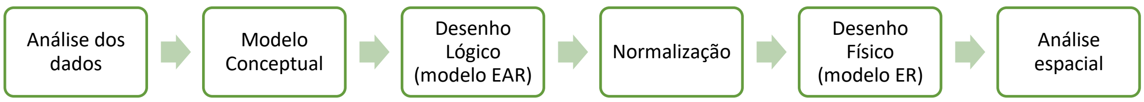


Figure 2 - Workflow of creating a spatial relational database.

For the development of this work, an integrated approach was adopted with the use of PostgreSQL, [1]with the PostGIS extension[2], combined with the spatial analysis capabilities of QGIS.

PostgreSQL is an open-source object-oriented relational database management system (ORDBMS) that allows for the definition of custom data types, functions, and operators, which is particularly useful for complex data handling and domain-specific operations, such as those found in Geographic Information Systems. However, for PostgreSQL to support geographic data, it is necessary to use the PostGIS extension, which allows you to store locations, maps, and other geospatial information (Obe & Hsu, 2021).

PostgreSQL was used as a Relational Database Management System, where, after pre-processing the data, the data was stored according to the EAR model. Through the integration of PostGIS it was possible to work on new features for PostgreSQL geospatial data. QGIS, as a Geographic

[1] https://www.postgresql.org/
[2] https://postgis.net/

Information Systems tool and with capabilities for accessing, querying and manipulating database data, allowed the analysis of these data and the development of detailed thematic maps with the information.

3.1. Relational Database

3.1.1. Conceptual Model

The conceptual model is the first model to be designed, where one tries to capture the "rules of the business", describing in an abstract and high-level way, how the data relates to each other. The PA database is based on teams that develop conservation and research projects. Each project and each team executes AF campaigns, which consist of installing AF cameras in various locations for varying periods. On the other hand, the places where the AF equipment was installed are superimposed on different types of land use. Each campaign produces media, which in turn contain observations.**Figure 3**).

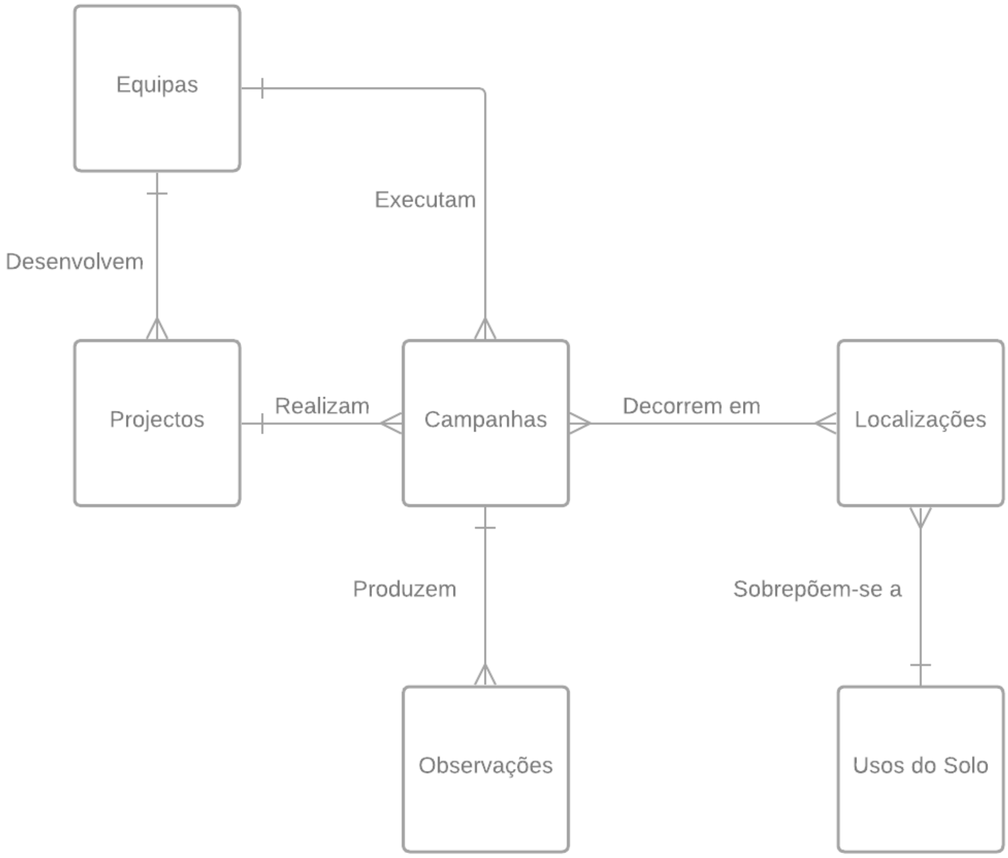


Figure 3 - Conceptual model of the AF database.

3.1.2 Logical Design – Entity Modeling – Attribute – Relationship

The transformation from the conceptual model to the logical model is done through Entity-Attribute-Relationship (EAR) modeling, which consists of the following process:

- Identification of the entities - the entities had been previously defined in the conceptual model, so the first step was completed;
- Identification of the relationship between entities - it was found that the entities maintain a relationship of 1:M among themselves, except for the relationship between **LOCATIONS** and **CAMPAIGNS**, which is M:N;
- Identification of the attributes of the entities – the attributes for each entity have been established, as well as the primary keys (PK) and foreign keys;
- Derive tables - it doesn't always have to be fulfilled, as it's only necessary when there are M:N relationships, which can't be modeled through the EAR process. In the case of the present work it is necessary to derive a table, since each PA campaign takes place in many locations, but the same location can be occupied by several campaigns over time. To solve this problem, an intermediate table was introduced that allows 1:M relationships between the two entities. In this sense, a new table has been added called **CAMPAIGN LOCATION.**

The next stage is standardization. The first normal step is to ensure that the primary keys consist of non-null and unique atomic (i.e., indivisible) values, and to eliminate repeated groups, which manifest themselves in the form of redundant data. Although the primary keys of the project are all made up of unique atomic alphanumeric sequences, it was found that there were repeated groups in the following entities:

- **Teams** - contained repeated names of coaches and coordinators. To solve this problem, two tables were derived, one containing data from the technicians, and the other containing data from the coordinators.
- **Observations** – contained repeated scientific names as well as the type of observation. The problem was solved by creating two tables – Species and Type of Observation, where for each scientific name and for each type of observation an alphanumeric code was assigned.

The second normal form requires that if there are composite primary keys, all attributes depend on both. In this work, there were no composite primary keys, so the second normal way was guaranteed. The third normal form insists that attributes can only depend on the primary key and cannot depend on other attributes. As the data respected this condition, the third normal form was also guaranteed. The logical design after normalization consisted of 11 entities with cardinalities of 1:1 and 1:M (**Figure 4**).

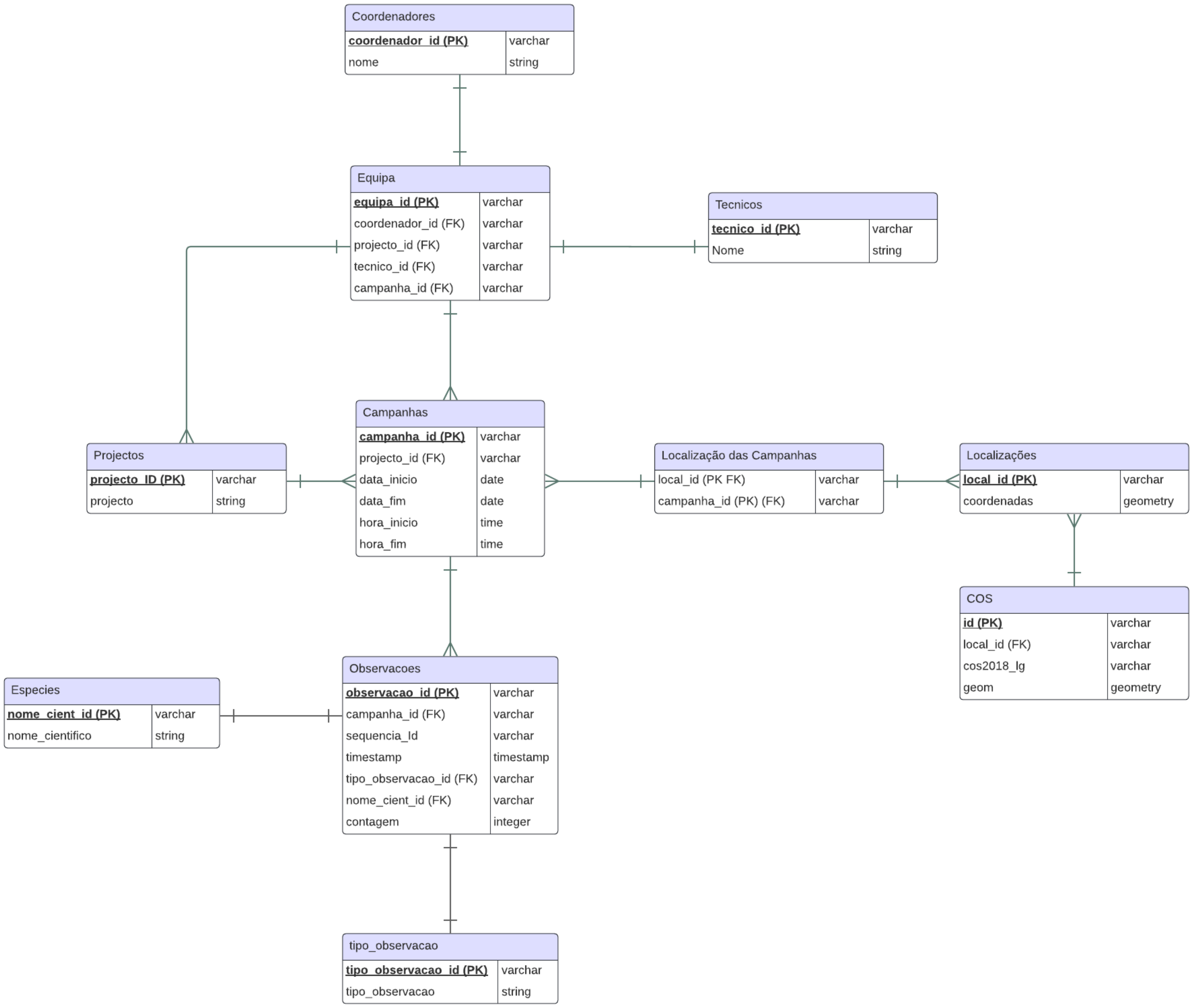


Figure 4 - Logical design for the construction of the AF database, based on EAR modeling.

3.1.3 Physical Drawing

For the implementation of the spatial database of this project, the tutorial of Learning Unit 8 – Open Source Spatial Databases was used.

Initially, the data were processed and organized through Microsoft Excel, which ensured their quality when they were imported into the database. In this sense, 9 *.csv*, corresponding to each of the non-spatial entities defined in Figure 4.

After organizing the data, the PostgreSQL database was created in the PgAdmin 4 program. The entities have been entered, as well as their attributes and primary keys.

The data was imported from the *.csv*, which was followed by the definition of foreign keys, thus establishing the relationships between the various tables (**Figure 5**).

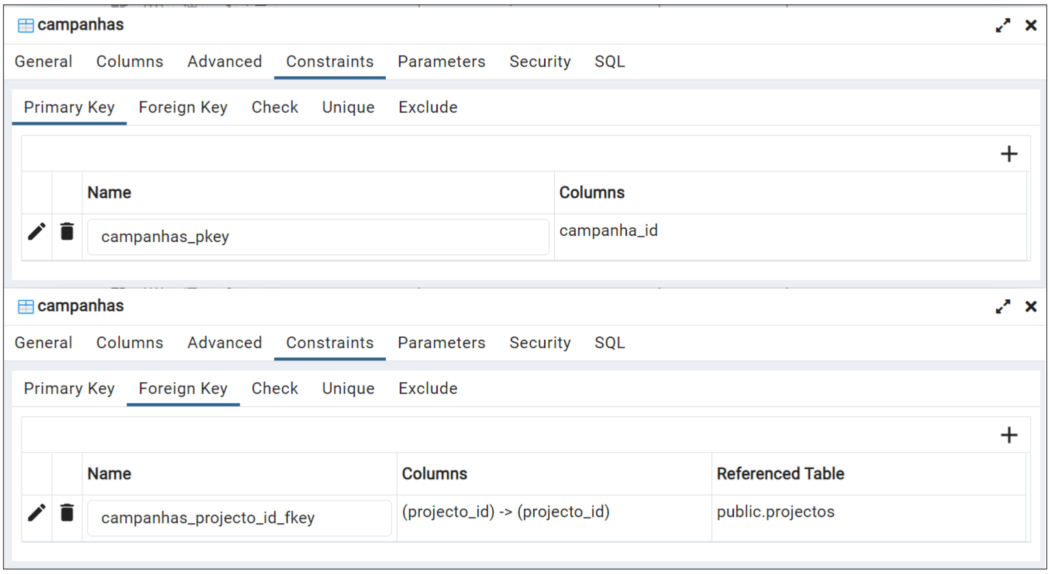


Figure 5 - Definition of the primary key and foreign key of the "Campaigns" entity.

Given the spatial nature of the table data **LOCATIONS**, a slightly different procedure was adopted, using the PostGIS extension through a simple command in the *Query Tool* from PgAdmin 4 (**Figure 6**).

Figure 6 - Activation command of the PostGIS extension, which allows you to work with spatial data in PostgreSQL.

Once the PostGIS extension was activated, the *shapefile* **LOCATIONS** for PgAdmin4, using the PostGIS Shapefile Import/Export Manager application (**Figure *7***).

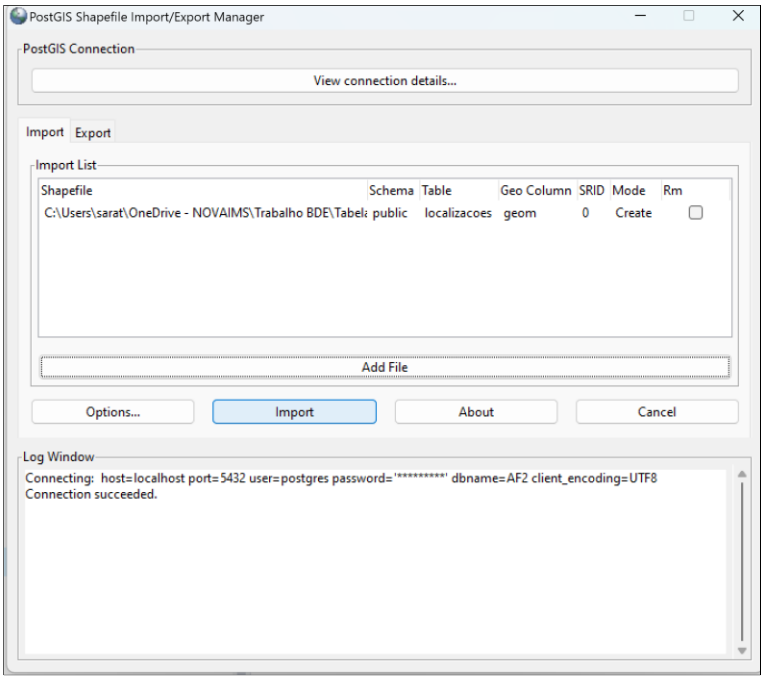


Figure 7 - PostGIS extension for PostgreSQL, used to import *shapefiles*.

To respond to the third objective of the work, it was also necessary to import the land use classes to the COS table database. To carry out this operation, it was necessary to pre-process in QGIS, namely:

- Cut the extension of the COS by the study area of the ENET WILD project[3];
- Use the "Merge attributes by location" tool, thus linking the land use classes of the study area to each of the AF station locations.

The result consisted of a table that includes each local_id and relates it to the land use classes. The import process for the resulting *shapefile* - **COS** - was the same as for the **LOCATIONS table**.

After the implementation of the database, queries and data analysis were carried out, which are described in the "Results" chapter. To conduct the analysis, the QGIS DB Manager was used.

[3] Given the high number of species, it was decided to present only the results of the ENET WILD project, and to select some demonstrative taxa since the repetition of the analysis for each taxonomic group would be a repetitive work, and that does not add value to the objective of the discipline.

3.2. Data Dictionary

For the elaboration of this project, a comprehensive data dictionary was developed, which serves as a detailed repository of the information collected (**Table 1**).

Table 1 - Dictionary of the data used in the field of work.

Entity	Attribute	Definition	Kind
Projects	**Projecto_ID**	Project identification code	varchar
	project	Name of the projects	string
Campaigns	**Campanha_ID**	Identification of the PA campaign. Each campaign consists of the installation of a number of AF cameras in the field, which are active for a variable period of time.	varchar
	Data_Início	Campaign start date	date
	Data_Fim	Campaign end date	date
	Hora_Início	Campaign start time	time
	Hora_Fim	Campaign end time	time
Coordinators	**Coordenador_ID**	Identification code of the coordinators of each project	varchar
	Name	Name of the coordinators of each project	string
Technical	**Técnico_ID**	Identification code of the technicians responsible for the installation of the cameras in the field	varchar
	Name	Name of technicians for each project	string
Locations	**local_ID**	Individual identification of the places where the PA campaigns took place	varchar
	Coordinates	Latitude and Longitude (WGS84) of each point	Point
COS	**ID**	Identification code for each land use class at each PA location	Integer
	Cos2018_lg	Land use classes	varchar
	Geom	Spatial information of the polygons of each land use class	Geom
Observation	**Observação_ID**	Identification code of the comments made. Each observation corresponds to a photo or video.	varchar
	Timestamp	Notice timestamp	timestamp
	Sequência_ID	Identification of the sequence in which each photograph or video was taken	varchar
	Count	Number of individuals present at each observation	Integer
Tipo_Observação	**Tipo_Observação_ID**	Identification code for each type of observation	varchar
	Tipo_observação	Type of observation: blank data (sometimes the machine shoots with the wind or the intensity of the light), animal, human, unknown, unclassified, vehicle	string
Species	**Nome_cient_id**	Identification code of the species recorded for each observation	varchar
	Nome_Científico	Scientific name of the species recorded in each observation	string

4. Findings

After the implementation of the database, it was possible to explore the results obtained in the PA campaigns. Through the DB Manager in QGIS, several relevant queries were carried out to respond to the objectives of this work.

4.1. Identification of areas with greater specific richness

In order to respond to the first objective of the work, identifying the places with the greatest biodiversity, two consultations were carried out to know:

- the total number of observations;
- the number of observations for each AF location;
- number of species recorded in each AF station.

4.1.1. Total number of observations

In order to know the total number of wild animal observations, it was necessary to carry out a query that excluded all types of observations[4] with the exception of animals (AA), and to exclude domestic animals (*Eqqus asinus, Capra hircus, Bos taurus, Canis lupus familiaris, Ovis aries* and all ambiguous classes (Mammalia), which may include observations of humans or domestic animals. The result of the consultation indicated that a total of 2742 comments were recorded in the period from 18-07-2022 to 15-05-2023 (**Figure 8**).

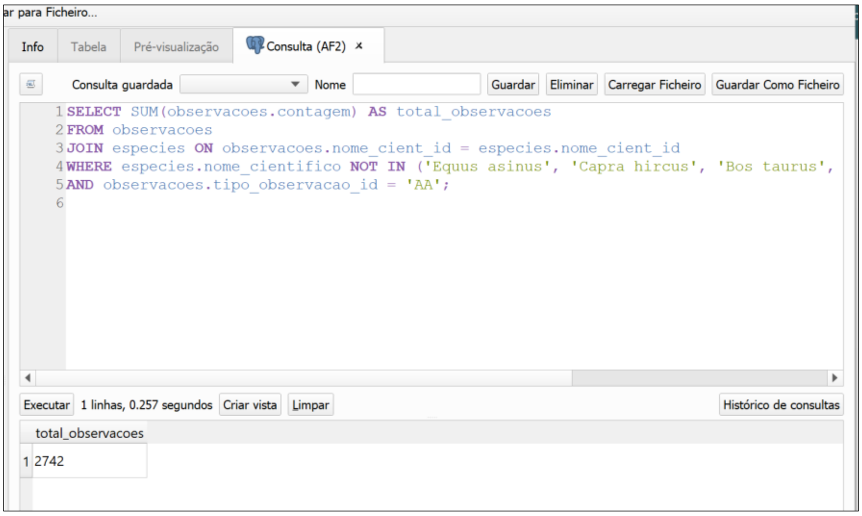


Figure 8 - Consultation of the database to know the total number of wild animals, excluding people, domestic animals and Mammalia.

[4] This table includes 6 types of observation: animal, human, blank data, unknown, unclassified, and vehicle

It should be noted that observation data may include multiple records of the same individual, taken at different times. Considering that with the available data it is not possible to identify the animals individually, it is only possible to conclude that 2742 observations of wild animals were recorded.

4.1.2. Number of distinct species

To obtain the total number of species recorded, a query was performed with the same exclusions, but this time, instead of adding the records in the counts column (of the table **OBSERVATIONS**), the number of distinct species was inquired about, where COUNT(DISTINCT observacoes.nome_cient_id) counts the total number of distinct species in all observations (**Figure 9**). The result indicated that 59 different species were recorded in the scope of this work.

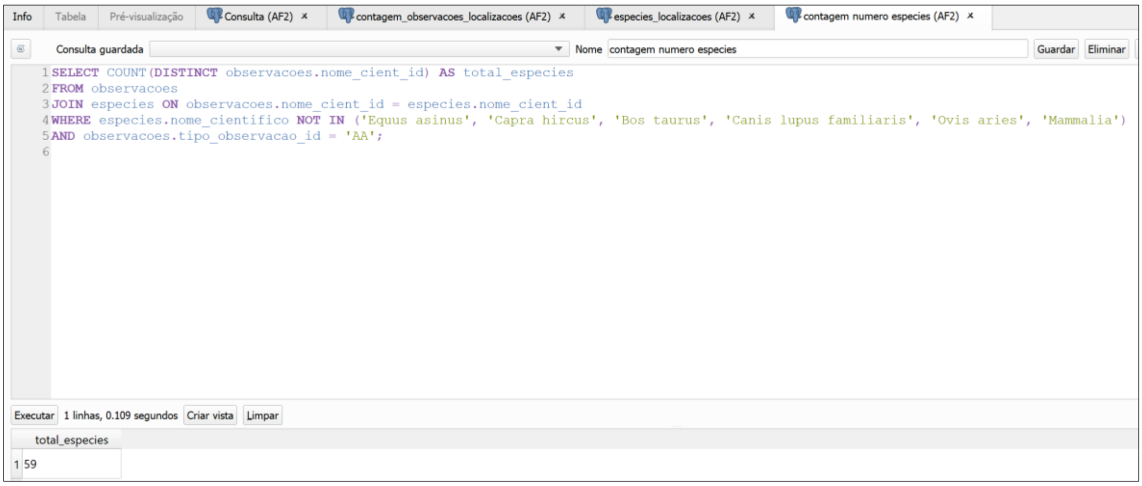


Figure 9 - Consultation of the database to know the total number of species of wild animals, excluding people, domestic animals and Mammalia.

4.1.3. Number of observations by location

To obtain the **No. of total wildlife sightings by each location** of PA, the same type of exclusion mentioned above was carried out and the consultation indicated in the **Figure 10**, where SUM(observations.count) calculates the sum of the animal counts for each local_id and GROUP BY groups the results by local_id and associated geometry to maintain the spatial nature of the data.

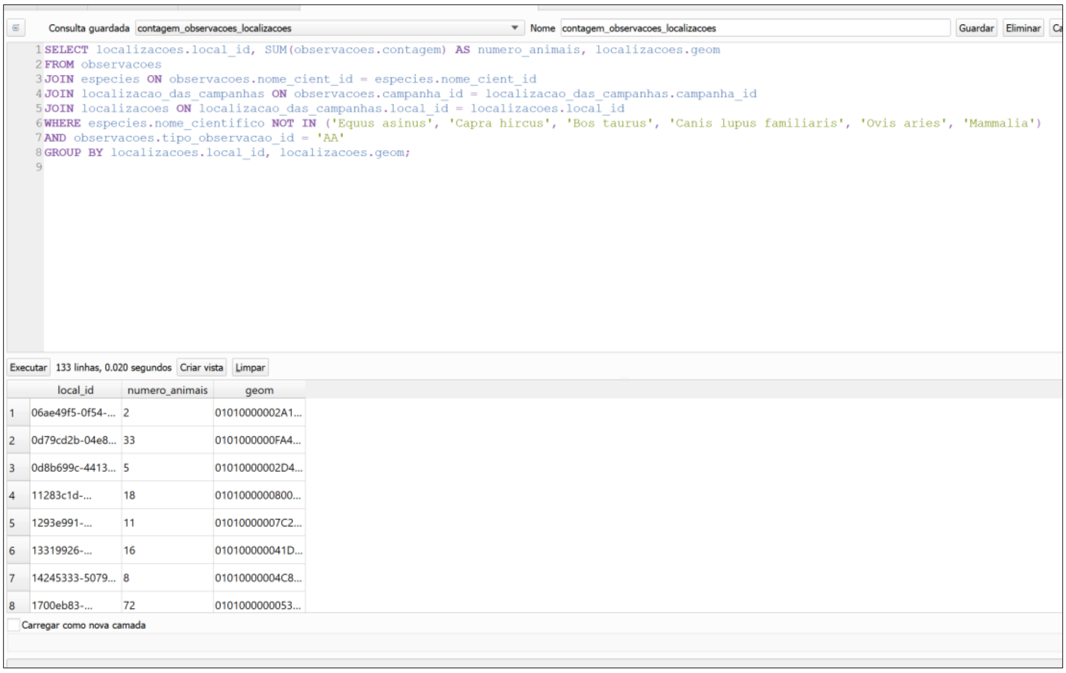


Figure 10 - Query the database to obtain the total number of observations of wild animals, excluding people, domestic animals and *Mammalia*, for each AF location.

To obtain the **Number of distinct species recorded in each location**, another query was carried out, in which COUNT(DISTINCT observacoes.nome_cient_id) counts the distinct number of species (identified by nome_cient_id) in each location (**Figure 11**).

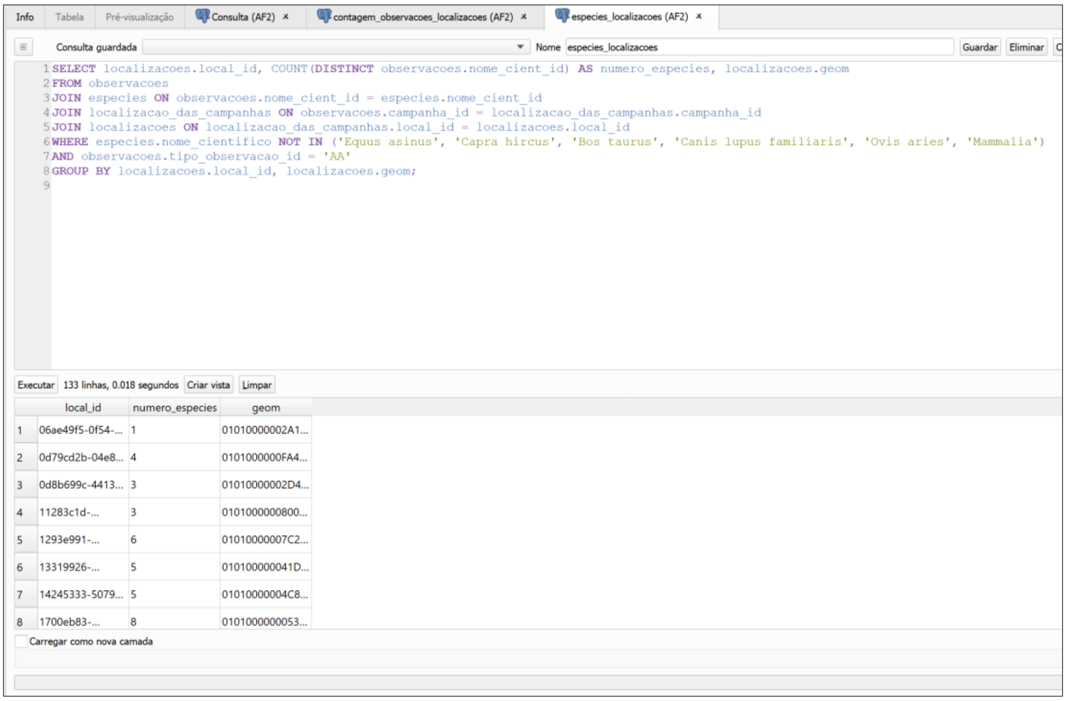


Figure 11 - Query the database to obtain the total number of species of wild animals, excluding people, domestic animals and *Mammalia*, for each AF location.

In order to create a map with the new spatial tables generated, the "load as new layer" field was checked, which effectively generates two new layers in the QGIS project.

The result of this consultation can be found in the **Figure 12** , which represents the distribution of the number of observations, as well as the number of distinct species, recorded at each PA location of the ENET WILD project[5].

The observation of the figure indicates that the northern area of the study area concentrates the largest number of records, but the specific richness has a more homogeneous distribution throughout the study area. This type of data representation helps to highlight the areas with the greatest biodiversity, thus suggesting places of conservation interest. It can also be useful to assess the effectiveness of conservation measures, associated with the projects under analysis, and to understand the distribution of species within the study areas.

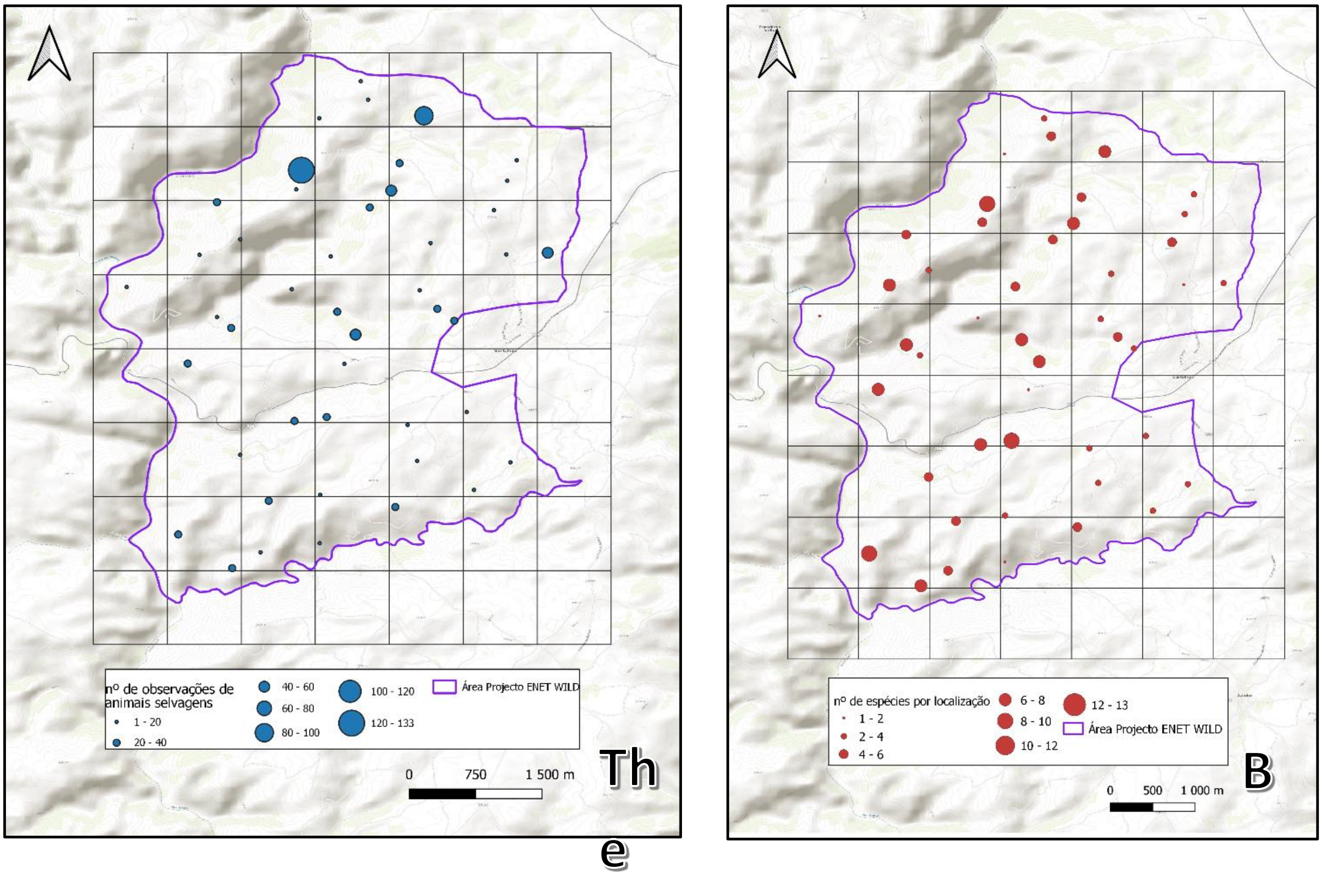


Figure 12 - Spatial representation of the queries made to the database. A: number of wildlife sightings at each location; B - number of distinct wildlife species caught in each location.

[5] It was decided to present only the results obtained in the ENET WILD project, since the scale of the Up4Rehab project is different, which would imply producing more maps so that the results could be readable. It was considered that this extra work would not add value to the objectives of the discipline.

4.2. Geographical distribution of species

In order to evaluate the geographical distribution of the species, it was decided to prepare Presence/Absence maps, which are quite common in Ecology. Due to the high number of species detected, we selected only 3 species to demonstrate how a map can be obtained from this type of data. In this case, in addition to the presence of absence, the number of individuals photographed from the same taxon was added. To make these maps, it was necessary to generate a new query, this time returning the number of observations for the selected species at each AF point. The first consultation was on the number of roe deer observations (*Capreolus capreolus*) (**Figure 13**).

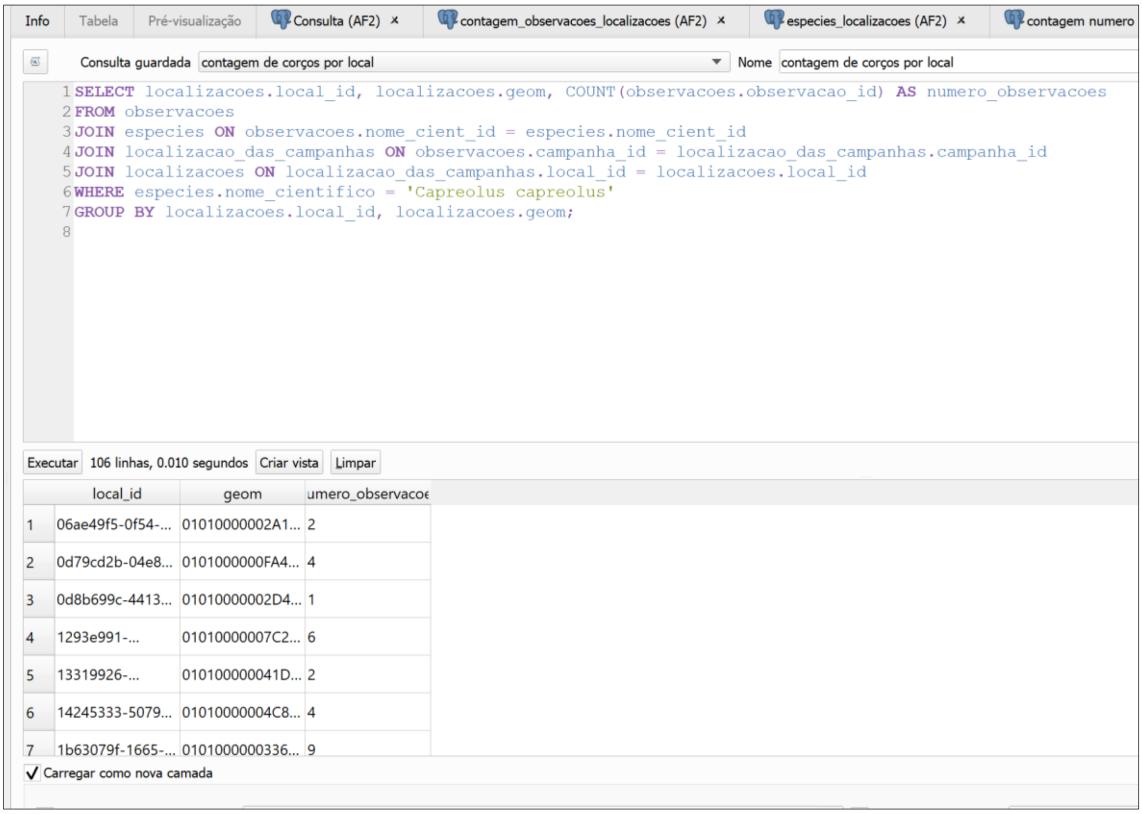


Figure 13 - Consultation on the number of roe deer observations (*Capreolus capreolus*) at each AF location.

After the consultation, the new table generated as a new layer was loaded and the map of presence/absence of the species was produced (**Figure 14**). The visual analysis reveals that the species is well distributed in the study area, but presents a greater number of records in the Northeast zone.

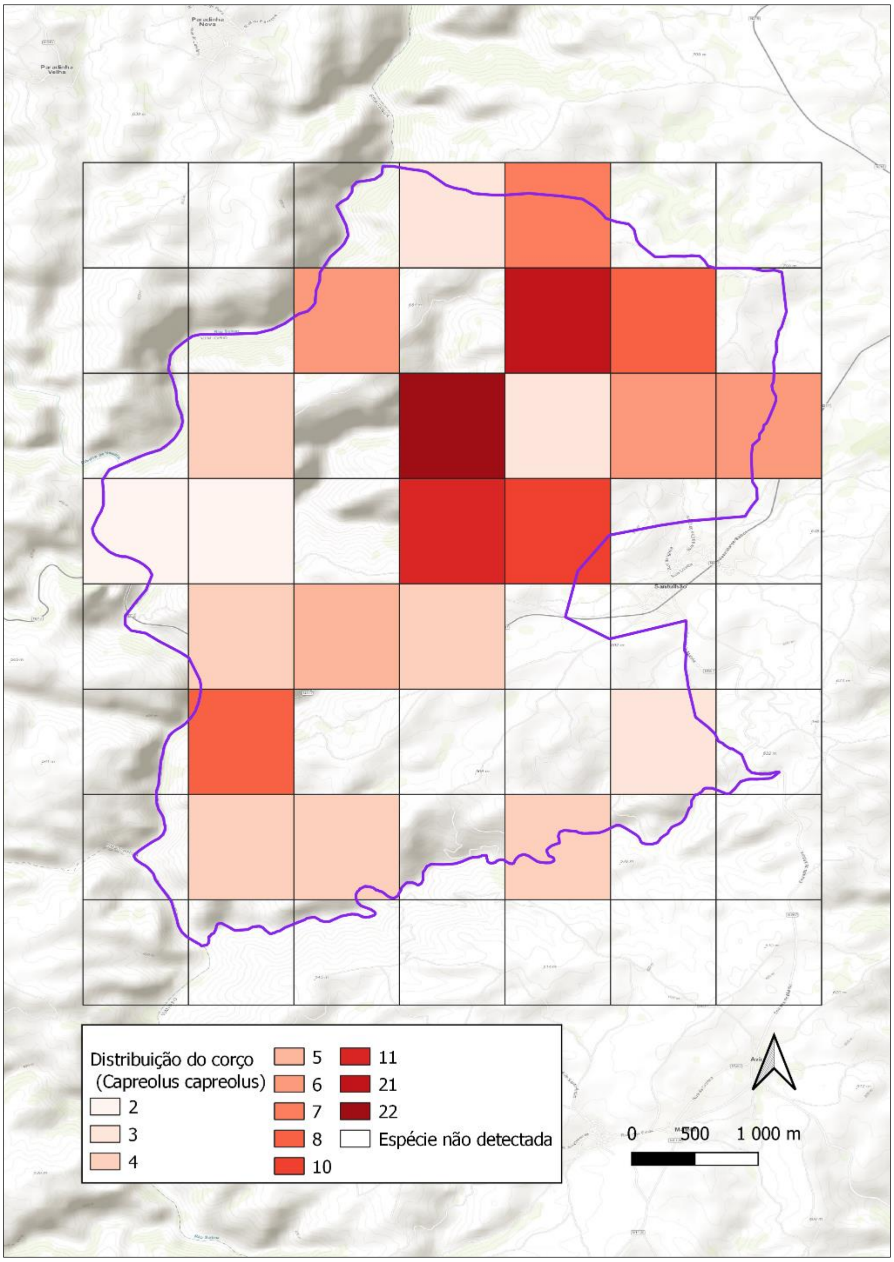


Figure 14 - Map of presence/absence of roe deer (*Capreolus capreolus*) in the ENET WILD project area.

The same consultation was performed for badgers (*Meles meles*) and the fox (*Vulpes vulpes*) (**Figure 15**). The spatial representation of the data shows significant differences in the distribution of the two species and in the number of records of observations. The badger has a very restricted distribution area, while the fox is present in practically all squares. In addition to the number of badger sightings also being smaller, most occur in a single grid. The fox, on the other hand, was captured in a more homogeneous way throughout the study area.

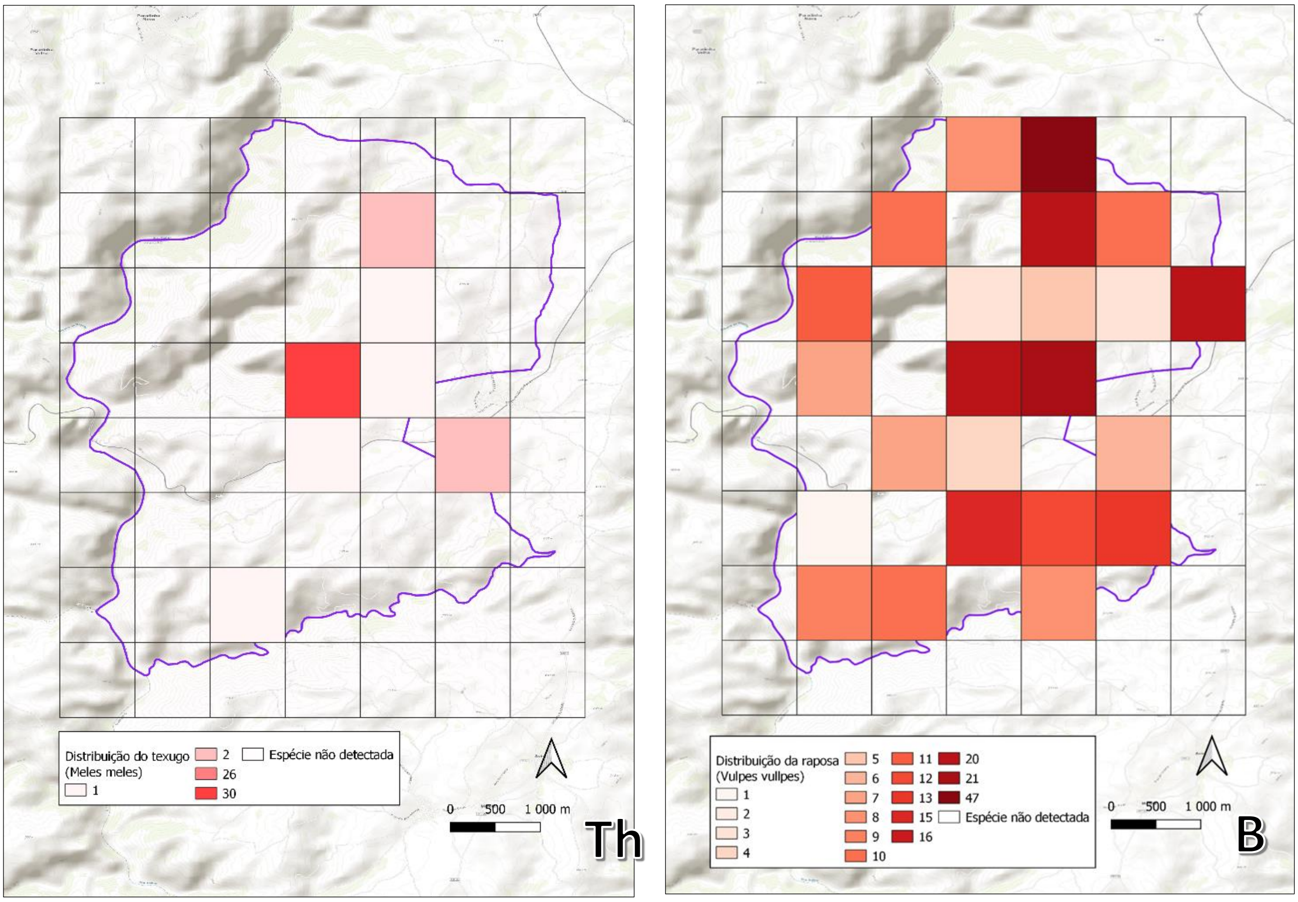
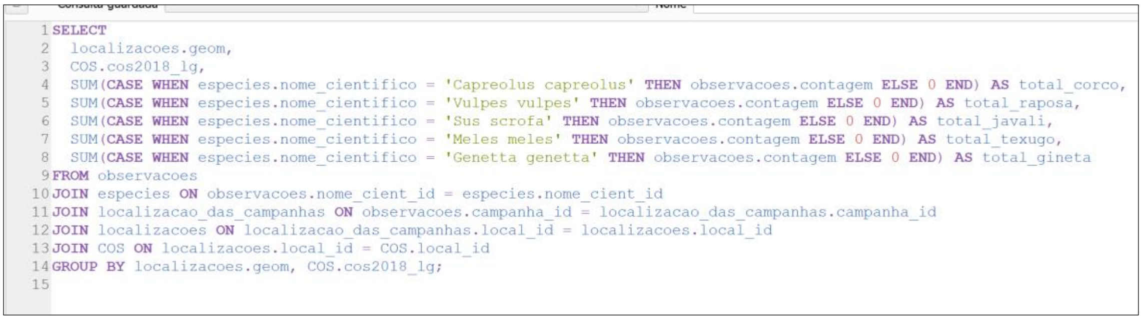


Figure 15 - Map of badger presence/absence (*Meles meles*) (A) and fox (*Vulpes vulpes*) (B), in the ENET WILD project area.

4.3. Land Use Occupation Analysis

In order to analyse the preferences of the species in relation to the classes of land uses, the consultation contained in the Figure 16, in which the SUM function with the CASE clause was used to calculate the total observation count for each of 5 selected species - roe deer, fox, wild boar, genet and badger - in each land use category present in the study area.



```
SELECT
  localizacoes.geom,
  COS.cos2018_lg,
  SUM(CASE WHEN especies.nome_cientifico = 'Capreolus capreolus' THEN observacoes.contagem ELSE 0 END) AS total_corco,
  SUM(CASE WHEN especies.nome_cientifico = 'Vulpes vulpes' THEN observacoes.contagem ELSE 0 END) AS total_raposa,
  SUM(CASE WHEN especies.nome_cientifico = 'Sus scrofa' THEN observacoes.contagem ELSE 0 END) AS total_javali,
  SUM(CASE WHEN especies.nome_cientifico = 'Meles meles' THEN observacoes.contagem ELSE 0 END) AS total_texugo,
  SUM(CASE WHEN especies.nome_cientifico = 'Genetta genetta' THEN observacoes.contagem ELSE 0 END) AS total_gineta
FROM observacoes
JOIN especies ON observacoes.nome_cient_id = especies.nome_cient_id
JOIN localizacao_das_campanhas ON observacoes.campanha_id = localizacao_das_campanhas.campanha_id
JOIN localizacoes ON localizacao_das_campanhas.local_id = localizacoes.local_id
JOIN COS ON localizacoes.local_id = COS.local_id
GROUP BY localizacoes.geom, COS.cos2018_lg;
```

Figure 16 - Query carried out to obtain the number of observations of 5 species in the land use classes of the COS table.

A brief analysis of the table obtained reveals that, overall, 52% of the observations of the 5 species overlap with the class of scrub (n=288), followed by Forests of other oaks (n=155) (**Figure 17**). Temporary rainfed and irrigated crops (n=7) were the soil class with the fewest records.

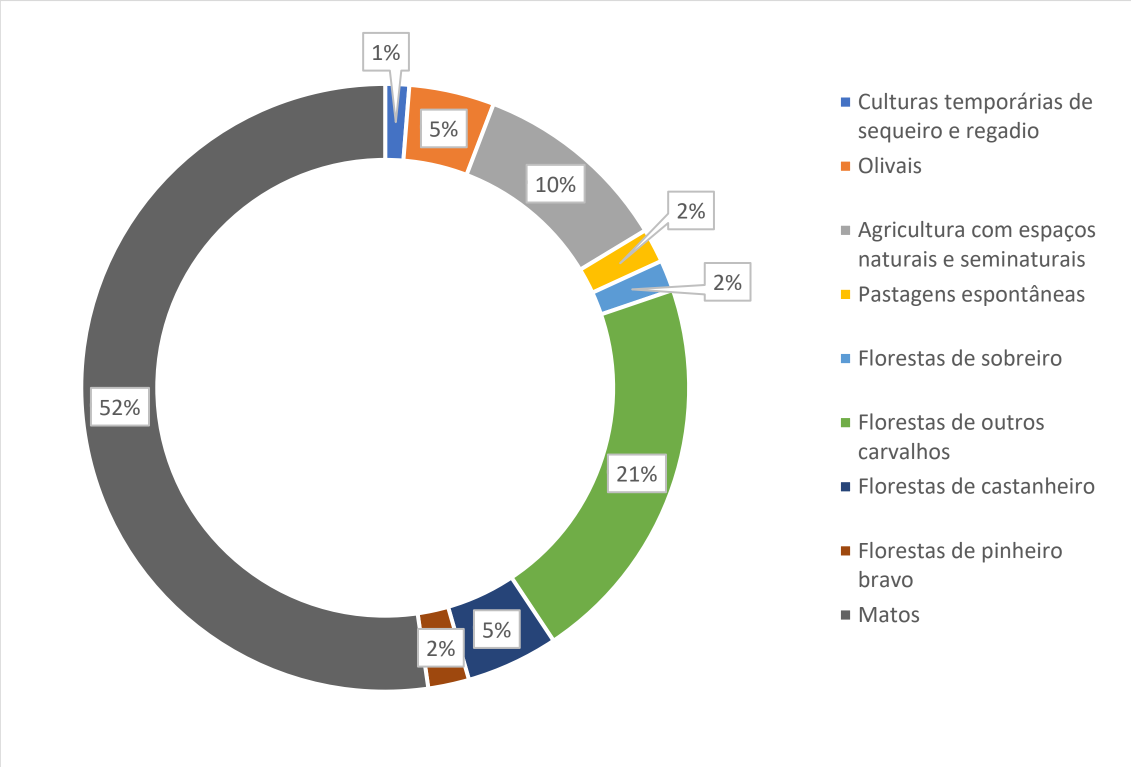


Figure 17 – Number of observations of fox, roe deer, wild boar, genet and roe deer in land use classes in the ENET WILD project

The overlap of the number of records of each species for each class of land use is an indicator of their habitat preference. In this sense, individual maps were prepared for each species and a brief quantitative analysis of the data was carried out.

The analysis of the **Figure 18** and **Figure 19**, reveals that although the fox occurs in a wide range of habitats, most of the observations were recorded in the brush class (58%) and other oak forests (16%), following the global trend set out above. However, this analysis is redundant, since the fox was the most photographed animal in the scope of the project, which contributed decisively to the values of the global trend. The spatial analysis reveals that a significant part of the observations are concentrated in the northern part of the project area.

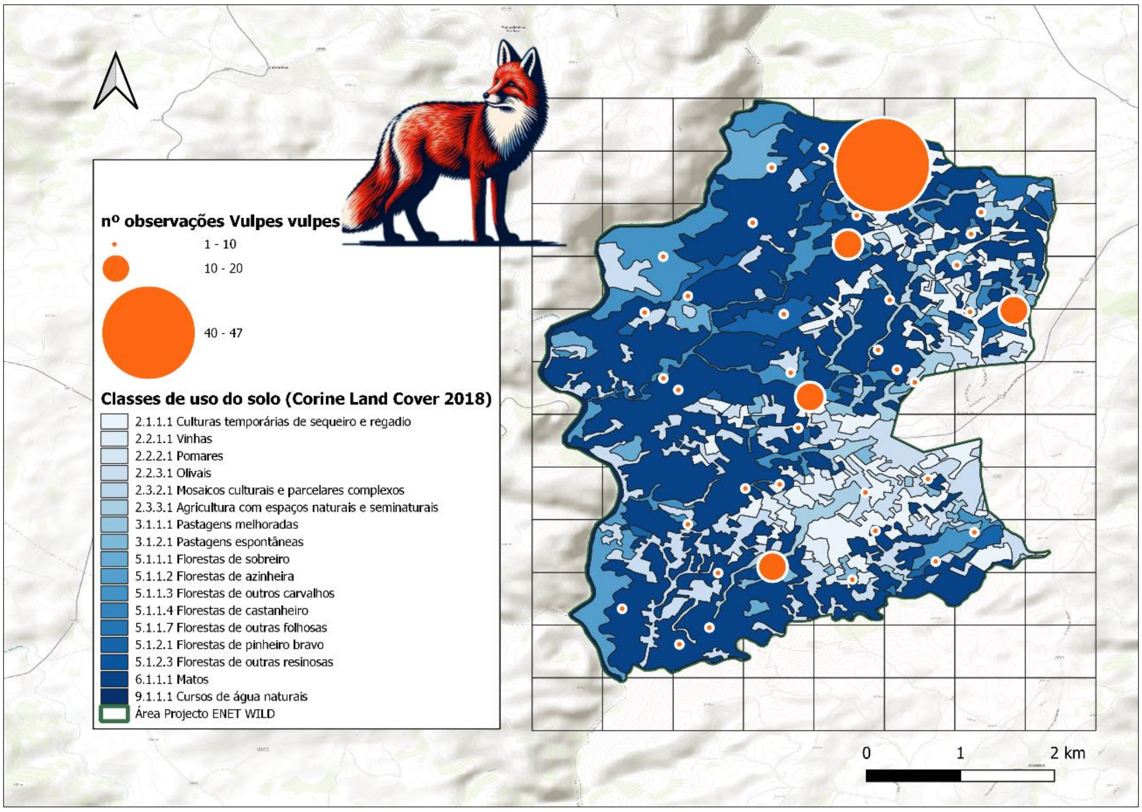


Figure 18 - Number of fox observations, in the different land use classes in the ENET WILD project area.

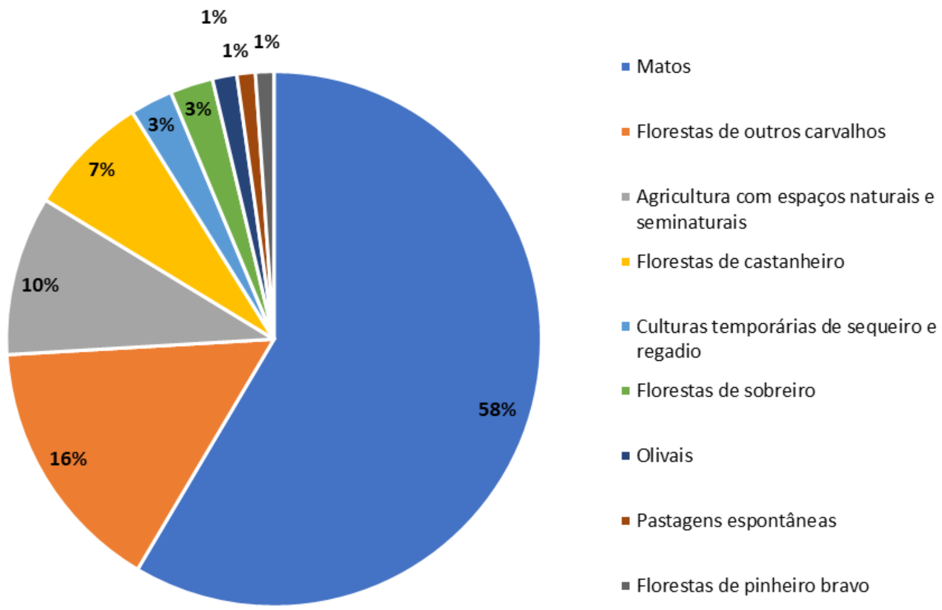


Figure 19 - Percentage distribution of fox by land use classes in the ENET WILD project area.

In relation to roe deer, 158 observations were recorded in the project area. Similarly to the fox and the general trend of the species as a whole, there is a predominance of roe deer in the scrubs and forests of Other Oaks (**Figure 20** and **Figure 21**). There is also a greater number of observations in the northern quadrant of the project area.

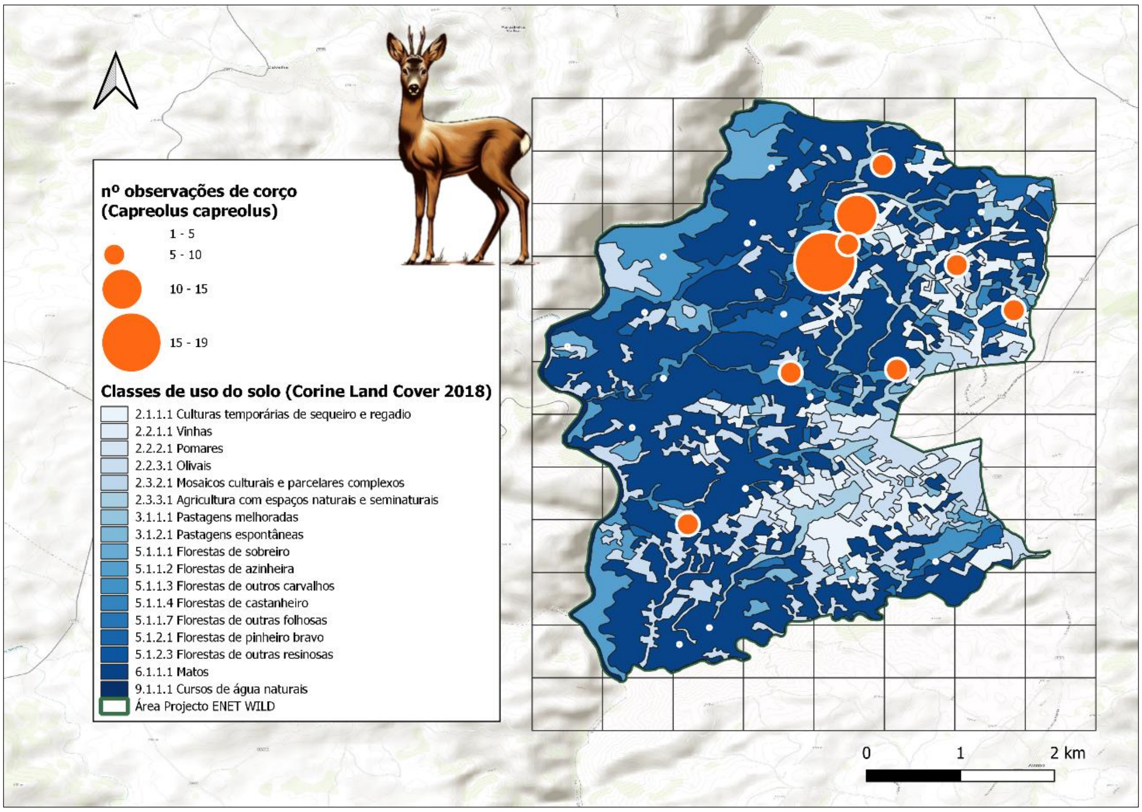


Figure 20 - Number of roe deer observations, in the different land use classes in the ENET WILD project area.

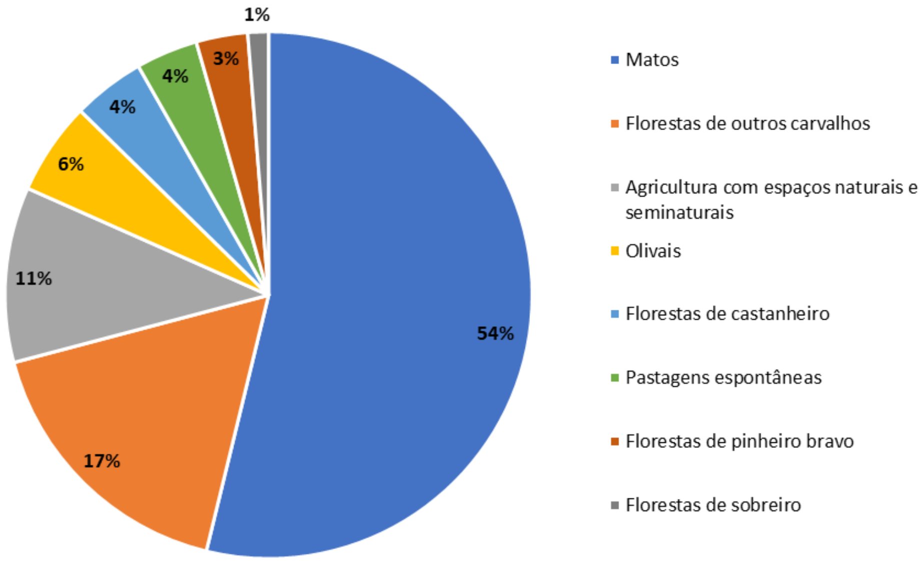


Figure 21 - Percentage distribution of roe deer by land use classes in the ENET WILD project area.

In the case of the wild boar (*Sus scrofa*), fewer observations were recorded, and they are more homogeneously distributed across the project area compared to the previous two species. As for land use, this species also registers a predominance in the shrub classes and in the Other Oak Forests (17%) (**Figure 22** and **Figure 23**).

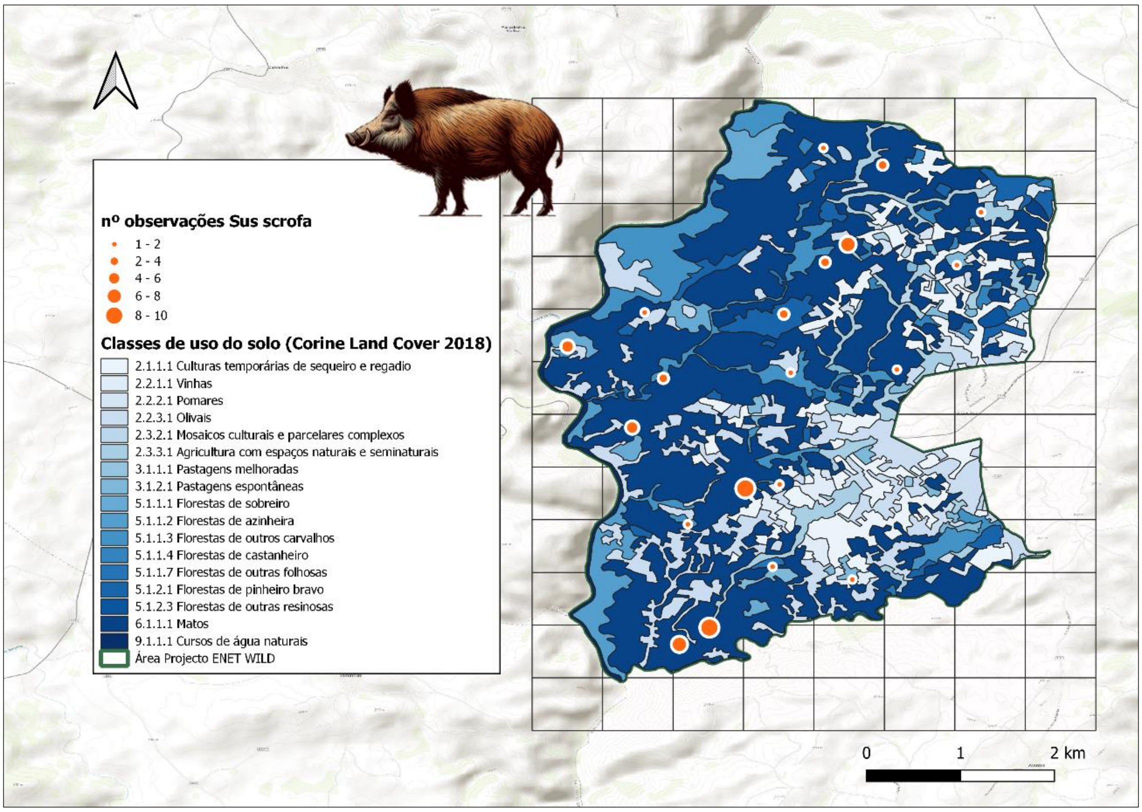


Figure 22 - Number of wild boar observations, in the different land use classes in the ENET WILD project area.

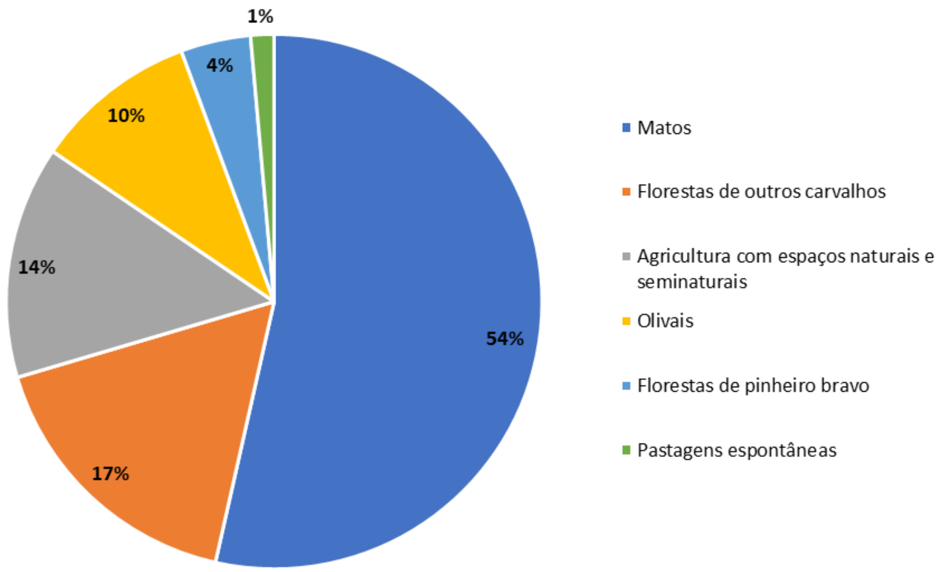


Figure 23 - Percentage distribution of wild boar by land use classes in the ENET WILD project area.

The badger (*Meles meles*) was captured by the PA technique 39 times, 28 of which in a single location located in the central area of the study area, and overlapping with other oak forests (72% of the observations) (**Figure 24** and **Figure 25**).

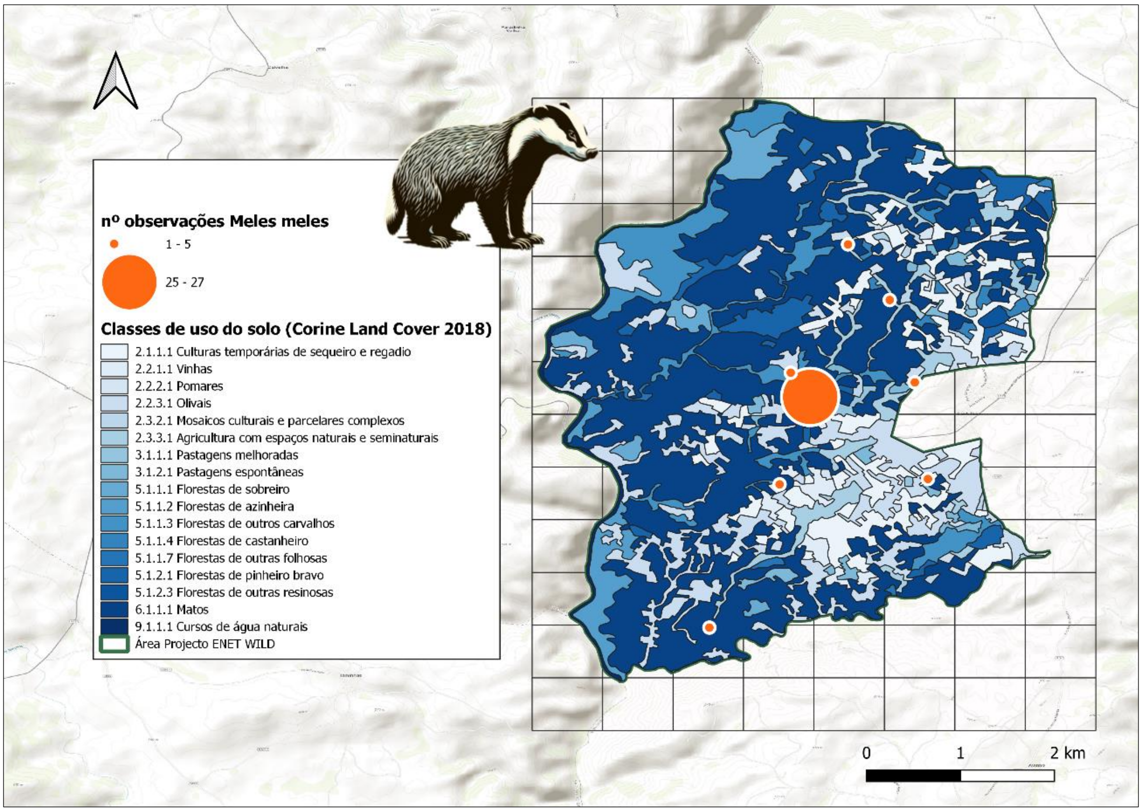


Figure 24 - Number of badger observations, in the different land use classes in the ENET WILD project area.

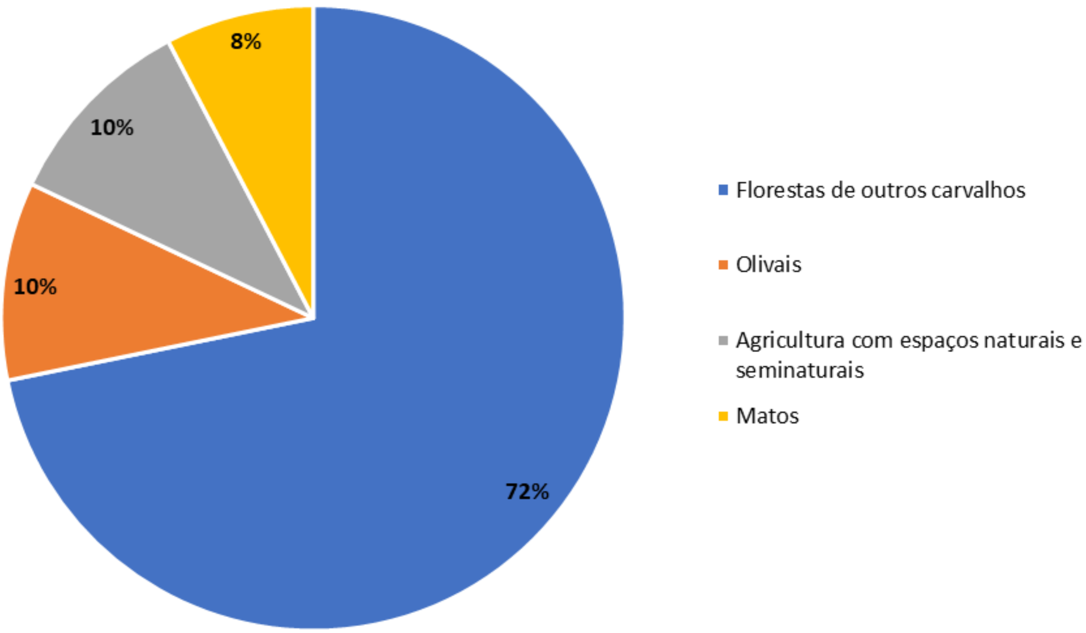


Figure 25 - Percentage distribution of badger by land use classes in the ENET WILD project area.

Of the selected species, the genet (*Genetta genetta*) is the one with the lowest number of observations, with only 13 records. Of these, 6 correspond to Other Oak Forests, which comprises almost half of the observations. This is followed by Matos with 31% of the observations (n=4) (**Figure 26** and **Figure 27**).

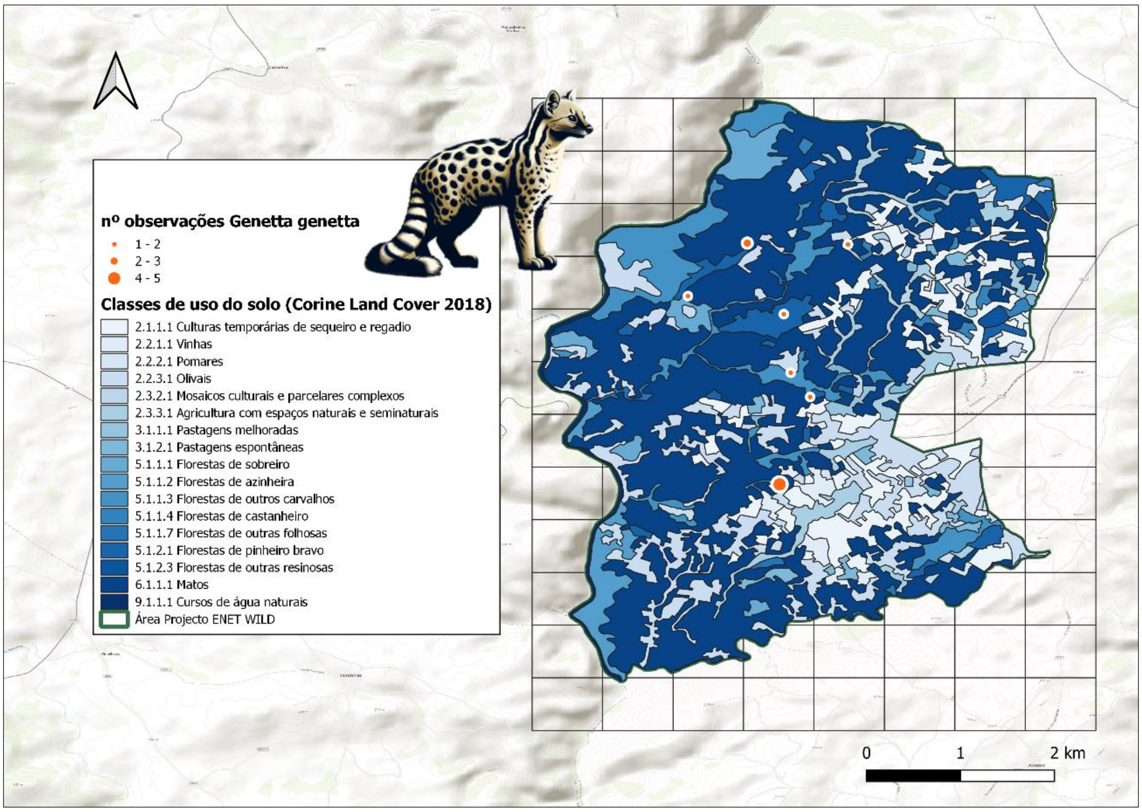


Figure 26 - Number of genet observations, in the different land use classes in the ENET WILD project area.

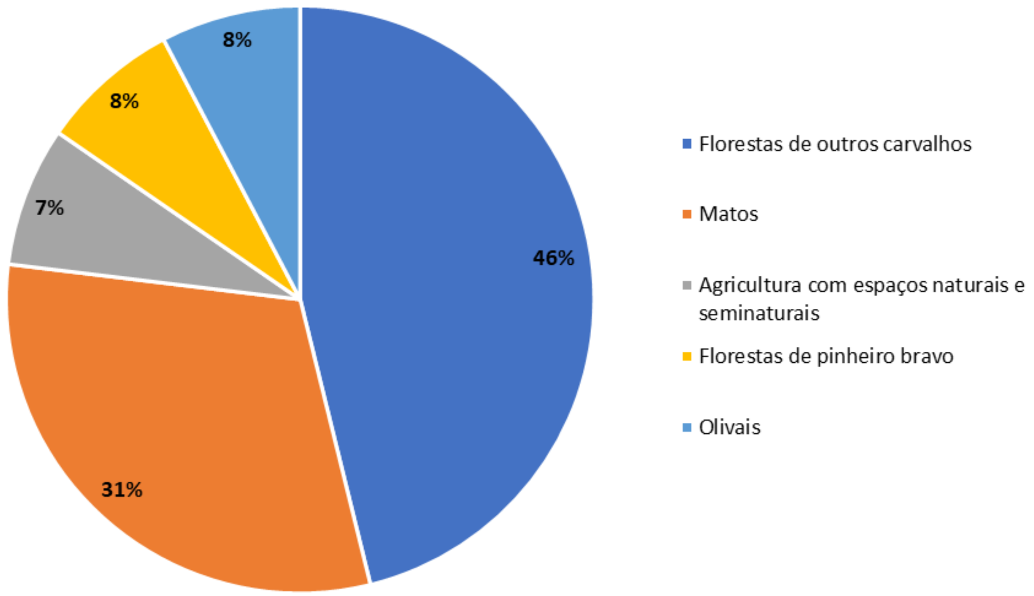


Figure 27 - Percentage distribution of genet by land use classes in the ENET WILD project area.

5. Discussion

The results obtained in the context of this work indicate that the number of observations of the animals and the number of species recorded do not coincide spatially (**Figure 12**). This discrepancy may be due to a number of factors related to the characteristics of the habitats themselves. Areas that have significant extensions of heterogeneous habitats can provide refuge and food for a greater number of species, even if the number of observations in each habitat type is smaller. This is because there are more specialized species, which need specific conditions to establish themselves in a given territory. Another aspect that can decisively influence this difference is the presence of sources of human pressure and disturbance. Areas with greater human disturbance may have many observations, but they come from a limited number of species that are tolerant or adapted to human presence.

However, the answer to the first objective – to identify areas of greater specific richness – is answered by the number of species recorded. In this sense, it was concluded that the western part of the study area is the one with the greatest biodiversity. In fact, and despite the fact that the entire area in question is humanized, the West zone is the one that is closest to the Sabor River, and consequently suffers a lesser impact from the disturbances inherent to human activity in the village of Santulhão.

The second objective – to know the geographical distribution of the species – was also achieved, and 3 demonstrative presence/absence maps were produced for 3 species: roe deer, fox and badger. The 3 maps revealed distinct distributions, with the fox being the most common and best distributed species, while the badger was observed in a smaller number of times and in a very restricted number of squares. The roe deer has a pattern more similar to that of the fox, although it has been captured by the AF technique a smaller number of times. These distribution maps are in line with knowledge of the ecology of the species. In fact, the fox is a generalist and highly adaptive animal, while the badger, despite also being considered a generalist carnivore, is more exposed to the harmful effects of the uncertainty of the availability of trophic resources that comes from agricultural interventions and hunting activity itself (Silva M., 2017).

The third objective of the work was to analyze the habitat preferences of the species. Given the high number of species detected, 5 were selected for demonstrative purposes. Overall, the species were more frequently captured in bush areas, however it should be noted that this type of land use represents approximately 60.7% of the study area. In this sense, the high number of observations in this type of habitat may not be indicative of a preference, but be a mere contingency. On the other hand, the second type of land use with the highest number of observations – other oak forests – occupies only 4.28% of the area concerned, which may indeed indicate a preference for this type of habitat. The fox, wild boar and roe deer were most frequently recorded in the bush areas, while the badger and genet prefer the forests of other oaks.

Although the analysis carried out in this work is quite simple, in general it can be said that all steps and objectives were fulfilled, namely:

- Logical design;
- Physical Design;
- Implementation of the database;
- Consultations and analysis of results.

At a later stage, the data obtained can be used in more in-depth and sophisticated statistical analyses, such as studies of species occupation models, whose maps represent a probability of the species being present in the area as a function of certain environmental variables associated with its etho-ecological preferences. These analyses are of significant complexity, and since the objective of the course was the design and implementation of a database, we chose to focus our efforts on these domains.

In the Habitat Preference Analysis the limitations that have been identified are related to spatial resolution, since COS 2018 is developed at a scale of 1:25 000 (macro scale) while our study area is local. For the purpose of analyzing habitat preference, it would be ideal to have access to the classification of the habitats of the areas developed by specialists in botany, using the system used in the National Register of Classified Natural Values of the ICNF. Another limitation is the outdated data, since COS 2018 is already at least 4 years old, and the data collected from AF date back to 2022 and 2023.

This type of work, which involves the creation and analysis of spatial databases in the area of biodiversity, is important for nature conservation and the study of wildlife. By integrating *software* such as QGIS, PostgreSQL, and PostGIS, it is possible not only to efficiently manage large volumes of data, but also to conduct complex spatial analysis, which is essential for understanding ecological and environmental dynamics.

With this approach, it was possible to identify areas of high specific richness, map the distribution of species and understand their habitat preferences, crucial information for informed decisions in conservation and habitat management. In addition, the ability to store and process geospatial data contributes to the creation of more effective and targeted strategies for the protection of fauna and the preservation of ecological balance.

References

Cadman, M., & González-Talaván, A. (2014, September). *Publishing Camera Trap Data: A Best Practice Guide*. GBIF. https://www.gbif.org/document/1o6HNHuCxKaiAC8yG86gQq

Directorate-General for the Territory (DGT). (2019). Land Use and Occupation Charter for 2018 | DGT. Www.dgterritorio.gov.pt. https://www.dgterritorio.gov.pt/Carta-de-Uso-e-Ocupacao-do-Solo-para-2018

Forrester, T., O'Brien, T., Fegraus, E., Jansen, P., Palmer, J., Kays, R., Ahumada, J., Stern, B., & McShea, W. (2016). An Open Standard for Camera Trap Data. *Biodiversity Data Journal*, *4*, e10197. https://doi.org/10.3897/bdj.4.e10197

ICNF. (2022, January 6). *Boundaries and zoning of UNESCO Biosphere Reserves*. ICNF. https://sig.icnf.pt/portal/home/item.html?id=6d5b9ca6f0e746a28c1a06170a0a76cc

ICNF. (2023, September 15). *Natura 2000.* ICNF. https://sig.icnf.pt/portal/home/item.html?id=a158877a57eb4f5fbad767d36e261fab

Ivan, J. S., & Newkirk, E. S. (2015). C pw Photo Warehouse: a custom database to facilitate archiving, identifying, summarizing and managing photo data collected from camera traps. *Methods in Ecology and Evolution*, *7*(4), 499–504. https://doi.org/10.1111/2041-210x.12503

Krishnappa, Y. S., & Turner, W. C. (2014). Software for minimalistic data management in large camera trap studies. *Ecological Informatics*, *24*, 11–16. https://doi.org/10.1016/j.ecoinf.2014.06.004

NASA Applied Sciences. (2018). *Bringing Wildlife Management into Focus: Integrating Camera Traps, Remote Sensing and Citizen Science to Improve Population Modeling | NASA Applied Sciences*. Appliedsciences.nasa.gov. https://appliedsciences.nasa.gov/what-we-do/projects/bringing-wildlife-management-focus-integrating-camera-traps-remote-sensing-and

Obe, R., & Hsu, L. S. (2021). PostGIS in Action, Third Edition. In Google Books. Simon and Schuster. https://books.google.pt/books?hl=pt-PT&lr=&id=dhs-EAAAQBAJ&oi=fnd&pg=PA1&dq=postgis+postgis+scientific+articles&ots=vG8VQu2U3

U&sig=yD0OBeK0ZP4nNZzp2nQ2rpEZia4&redir_esc=y#v=onepage&q=postgis%20postgis%20scientific%20articles&f=false

Palumbar. (n.d.). *Who we are*. Palumbar. https://www.palombar.pt/pt/palombar/

Palumbar. (2021, September 15). *ENETWILD: Collaboration with IREC, UCLM-CSIC-JCCM - Palombar*. ENETWILD: Collaboration with IREC, UCLM-CSIC-JCCM -. https://www.palombar.pt/pt/projetos/enetwild-colaboracao-com-o-irec-uclm-csic-jccm-2021/

Palumbar. (2022, October 20). *Landscape Unit for the Restoration of Habitats of Algoso - Palombar*. Landscape Unit for the Restoration of Algoso Habitats -. https://www.palombar.pt/pt/projetos/unidade-de-paisagem-para-o-restauro-de-habitats-de-algoso-2022/)

Silva, M. G. (2017). *Special organization of the European badger in Companhia das Lezírias, SA.* In repositorio.ul.pt. https://repositorio.ul.pt/handle/10451/32037

Wearn, O. R., & Glover-Kapfer, P. (2017). *Camera-trapping for conservation: a guide to best-practices*. WWF. https://doi.org/10.13140/RG.2.2.23409.17767

ZASNET. (n.d.). *The Biosphere Reserve | Iberian Meseta Biosphere Reserve*. ZASNET - European Grouping of Territorial Cooperation. https://www.biosfera-mesetaiberica.com/pt-pt/reserva-de-biosfera

Attachments

Annex 1 – Number of individuals photographed, by faunal group and species

Table 2 - Number of individuals photographed, by faunal group and species

Faunal Group	Species	No. of observations
Amphibious	*Snort snort*	2
	Alectoris rufa	103
	Anser sp. z o.o.	1
	Anthus trivialis	1
	Ardea cinerea	1
	Buteo buteo	2
	Caprimulgus europaeus	1
	Carduelis carduelis	7
	Chloris chloris	1
	Columba livia	8
	Columba palumbus	27
	Corvus sp.	1
	Coturnix coturnix	1
	Curruca melanocephala	10
	Cyanistes caeruleus	1
	Cyanopica cooki	10
	Dendrocopos major	1
	Emberiza cia	9
	Erithacus rubecula	118
	Ficedula hypoleuca	6
	Fringilla coelebs	9
Bird	*Galerida cristata*	1
	Galerida theklae	4
	Garrulus glandarius	8
	Linaria cannabina	4
	Oenanthe oenanthe	4
	Parus major	4
	Passeriformes	1
	Phoenicurus ochruros	12
	Phoenicurus phoenicurus	1
	Phylloscopus sp.	2
	Phylloscopus collybita	1
	Picus viridis	23
	Prunella modularis	4
	Saxicola rubicola	11
	Sitta europaea	1
	Streptopelia turtur	2
	Sylvia atricapilla	4
	Troglodytes troglodytes	1
	Turdus sp.	1
	Turdus merula	346
	Turdus philomelos	71

Faunal Group	Species	No. of observations
	Upupa epops	1
mammal	*Apodemus sylvaticus*	10
	Capreolus capreolus	482
	Cervus elaphus	7
	Chiroptera	1
	Genetta genetta	29
	Leporidae	2
	Lepus granatensis	28
	Lutra lutra	1
	Martes sp. z o.o.	26
	Martes foina	92
	Meles meles	44
	Neovison mink	1
	Oryctolagus cuniculus	201
	Rodentia	87
	Sus scrofa	173
	Vulpes vulpes	732

Annex 2 – COS 2018 classes, by some species and number of individuals photographed

Table 3 - COS 2018 classes, by species and number of individuals photographed

Species	COS Class 2018	No. of Individuals
Alectoris rufa	Agriculture with natural and semi-natural spaces	21
	Forests of other oak trees	2
	Matos	20
Apodemus sylvaticus	Matos	7
Capreolus capreolus	Agriculture with natural and semi-natural spaces	17
	Chestnut forests	7
	Forests of other oak trees	27
	Maritime pine forests	5
	Cork oak forests	2
	Matos	85
	Olive groves	9
	Spontaneous pastures	6
Columba palumbus	Maritime pine forests	1
	Matos	8
Curruca melanocephala	Forests of other oak trees	2
	Matos	3
Cyanopica cooki	Agriculture with natural and semi-natural spaces	6
	Matos	4
Emberiza cia	Matos	4
Erithacus rubecula	Chestnut forests	4
	Forests of other oak trees	9
	Matos	12
	Spontaneous pastures	1
Fringilla coelebs	Forests of other oak trees	1
	Matos	5
Genetta genetta	Agriculture with natural and semi-natural spaces	1
	Forests of other oak trees	6
	Maritime pine forests	1
	Matos	4
	Olive groves	1
Lepus granatensis	Temporary rainfed and irrigated crops	2
	Matos	5
Martes foina	Agriculture with natural and semi-natural spaces	2
	Forests of other oak trees	2
	Maritime pine forests	2
	Matos	25
	Olive groves	4

Species	COS Class 2018	No. of Individuals
Meles meles	Agriculture with natural and semi-natural spaces	4
	Forests of other oak trees	28
	Matos	3
	Olive groves	4
Picus viridis	Forests of other oak trees	1
	Matos	12
Saxicola rubicola	Matos	9
Sus scrofa	Agriculture with natural and semi-natural spaces	10
	Forests of other oak trees	12
	Maritime pine forests	3
	Matos	38
	Olive groves	7
	Spontaneous pastures	1
Turdus merula	Agriculture with natural and semi-natural spaces	15
	Temporary rainfed and irrigated crops	2
	Chestnut forests	11
	Forests of other oak trees	34
	Matos	77
	Olive groves	2
Vulpes vulpes	Agriculture with natural and semi-natural spaces	26
	Temporary rainfed and irrigated crops	7
	Chestnut forests	20
	Forests of other oak trees	42
	Maritime pine forests	3
	Cork oak forests	7
	Matos	158
	Olive groves	4
	Spontaneous pastures	3