Camera trap data to estimate wildlife census and habitat use: preliminary results in the Dynamo Oasis (Pistoia, Italy)

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Abstract

Camera trapping has been a popular wildlife monitoring method since the 1990s and has been increasingly used to study elusive species indirectly and non-invasively. Camera trapping data can provide helpful information regarding population estimates, behavioural aspects and habitat use. This practical, reliable, and low-cost method allows management and conservation assessments to be made on the target species. Pursuing these objectives, a study was conducted within the Dynamo Oasis in the Municipality of San Marcello-Piteglio (Province of Pistoia). Thirteen georeferenced camera traps were placed opportunistically in a study area of approximately 1000 ha for four months. Through video analysis and the use of the QGIS software, the Python libraries GeoPandas and PySal, the presence (Catch per unit of effort) and spatial distribution of the target species (roe deer, mouflon, fox, wolf, fallow deer, deer, wild boar) based on land use were identified. Species distribution based on land use was carried out by calculating the Moran index, which represents the level of clustering for each species concerning a specific land use. **Keywords**: camera trapping, spatial distribution, moran index, wildlife survey

Introduction

The Dynamo Oasis is a nature reserve located in Tuscany in San Marcello Piteglio, in the Province of Pistoia. It comprises 1000 hectares of land extending from 700 to over 1000 meters above sea level in the Pistoia Apennines. In partnership with the WWF, the Oasis is responsible for defining appropriate actions to achieve the objectives of conservation and planning of rural territory, sustainable agriculture and animal husbandry. Significant is the development of conservation projects aimed at wildlife, with a particular focus on the Red-Backed Shrike (*Lanius collurio*), in addition to the constant census of the main species that live in the 1000 hectares of the reserve (Tasselli *et al.*, 2015). Providing the presence and abundance of animal species is the first step in realising a wildlife monitoring plan or a conservation plan for species threatened with extinction, as well as understanding the ecology of the species. This work aimed to estimate the presence of wildlife species in the Dynamo Oasis Nature Reserve through camera trapping and compare their attendance in correlation with the different land uses. During the study, data from 13 camera traps in a period ranging from 02/01/2023 to 05/24/2023 were taken into consideration. Statistical analyses were subsequently carried out using the PySal library, particularly the Global Spatial Correlation methodology, a method used to quantify the level of similarity between observations in space, proper to show clustering areas on geo-referenced data.

Material and methods

Study Area

Dynamo Oasis is located in Tuscany, in the province of Pistoia, in the municipality of San Marcello Piteglio. It has an extension of approximately 1000 ha developed between 700 and 1100 meters above sea level. Oasis's vegetation is quite diversified, although mainly woodland, it greatly varies depending on the altitude, exposure and human interventions. In the areas at lower altitudes, broad-leaved forests prevail, characterised by the presence of Oaks, especially Turkey Oak (*Quercus cerris*) and Downy Oak (*Quercus pubescens*), European Hornbeam (*Ostrya carpinifolia*), European Chestnut (*Castanea sativa*). At these altitudes, there are also mesophilic grasslands, hay meadows and shrublands. Meadows and pastures cover 15% of the total surface area. At higher altitudes, the arboreal vegetation is mainly made up of Beech woods *(Fagus sylvatica)* and stands of conifers, especially White Fir (*Abies alba*), Douglas Fir (*Pseudotsuga menziesii*) and Black Pine (*Pinus nigra*) deriving from reforestation activities of former crops and pastures. Several species of wildlife populate the area. There are many ungulates, such as Red Deer (*Cervus elaphus*), Roe Deer (*Capreolus capreolus*), Fallow Deer (*Dama dama*), Mouflon (*Ovis musimon*) and Wild Boar (*Sus scrofa*). Among the carnivorous mammals, the most important and monitored is the Apennine Wolf (*Canis lupus italicus*), as well as mesocarnivores such as the Red Fox (*Vulpes vulpes*), Stone Marten (*Martes foina)*, Badger (*Meles meles*) and Weasel (*Mustela nivalis*). The avifauna is rich and diversified; diurnal birds of prey such as the Short-toed Eagle (*Circaetus gallicus*), Goshawk (*Accipiter gentilis*), Honey Buzzard (*Pernis apivorus*) and Golden Eagle (*Aquila chrysaetos*) are present in the area. Here, we can find the Black Woodpecker (*Dryocopus martius*) and numerous small passerines linked to woodland and open environments, including the Red-Backed Shrike (*Lanius collurio*), interesting from a conservationist point of view.

Camera traps

Camera trapping is a wildlife monitoring method that has been increasing. The fulcrum of the camera trap is represented by the sensor, i.e. the element that detects the passage of the animal and triggers the camera release (Rovero et al., 2013; Raganella et al., 2013). The Passive InfraRed sensor (P.I.R.) base their mode of operation on the thermal detection of the framed space. Depending on the type of illuminator, we can distinguish between camera traps with infrared LEDs, which take black and white videos and photos at night, and those with a visible white flash, Xenon or LED, which, however, do not allow to take colour night videos, but allow to capture colour images even in the absence of light. The choice of positioning varies greatly depending on the type of study: we may prefer a random arrangement, on a geographical grid, or an opportunistic one (where there are signs of the presence of a given species). Using these devices brings significant advantages: quick results, low maintenance and reduced personnel use for checks. It should be underlined that they work in weather conditions that are often prohibitive for humans and at temperatures from -20°C to 60°C. Technological evolution has made camera traps more sophisticated, reliable and cheaper (Rowcliffe & Carbone, 2008; Tobler et al., 2008a). The camera traps used for wildlife monitoring in the study area were of 3 types: Scout Guard SG2060-T 48MP, Bushnell Natureview 14 Mp, Keep Guard KW561.

Software GIS

In this study, the geographical information software QGIS 3.28.10 ('Florence') was used to prepare a vegetation map of the Oasis and to geolocate the camera traps.

Pandas and Geopandas Python for data cleaning

Pandas is a traditional Python library used to perform data cleaning and other important data operations in Python (McKinney, 2010). Geopandas is a Python library derived from Pandas, and its main objective is to perform the same operations as Pandas library with Geospatial data (Jordahl et al., 2020). Data cleaning is the preliminary step before performing any statistical analysis: eliminating undesirable data or data irrelevant to a specific statistical treatment or visualisation from the organised table. We can include common operations to handle missing information on the dataset at this step. More specifically, data organisation is to arrange the data in a table format for easy understanding and fast data processing to prepare a vegetation map of the Oasis and for the geolocation of the camera traps.

PySal Library

The PySal library was used to perform the statistical analysis. PySal (Python Spatial Analysis Library) is a Python library developed to compute spatial statistical methods (Rey and Anselin, 2007). Applications of this software include methods for diagnostics of spatial correlation in linear regression models and estimating spatial error specifications. The Spatial Correlation Methodology was applied in this work and will be discussed in the next item.

Methodological protocol

The study involved the wildlife survey within the Oasis through camera trapping between 01/02/2023 and 24/05/2023. Thirteen camera traps were positioned opportunistically based on the signs of the species' occurrence or by placing them in areas with a high probability of attendance (grasslands, waterholes) (Fig. 1). The camera traps were checked every seven days, and the recording data were organised into a database. All camera traps were set to video mode, lasting 30 seconds. The date, time, species and number of individuals were noted for each video.

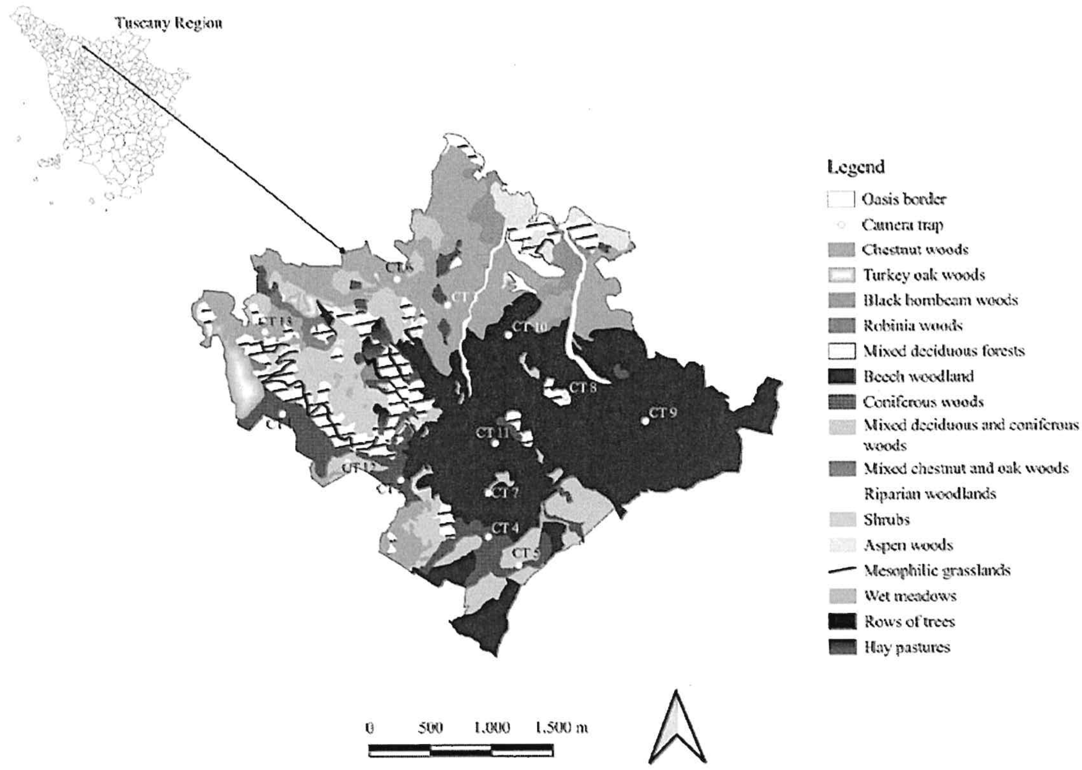

Figure 1: Study area, camera traps position and land uses

The camera traps were georeferenced using a Garmin GPS; subsequently, the coordinates of the monitoring sites were inserted into the GIS project. Once the videos were archived, they were grouped based on the most present and significant species of the Oasis: Red Deer (*Cervus elaphus*), Roe Deer *(Capreolus capreolus)*, Mouflon *(Ovis musimon)*, Fallow Deer *(Dama dama)*, Wolf (*Canis lupus italicus*), Wild Boar *(Sus scrofa)* and Fox *(Vulpes vulpes)*. The data resulting from camera trapping were analysed in terms of the number of detections per camera trap, number of events per species, catch rate per unit effort and number of events per species/month.

Statistical analyses were conducted using the PySal library, particularly the Spatial Correlation Methodology. Global Spatial Correlation is a regional counting data method used to quantify the level of similarity between different observations in space. Consequently, this method is helpful to show clustering regions on data organised by geographic information. It is applied in this study because, in addition to indicating the different clustering areas, this method allows comparing the clustering areas of different species and calculating the confidence level in the Moran index. Moran Index is the index of autocorrelation. This index may vary from -1 to 1, where -1 represents completed data sparseness on the map, and 1 represents a region of clustering on the map (Coluzzi et al., 2010). The following equation calculates the Moran Index (Moran, 1948):

$$I = \frac{n}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2}$$

Where n is the number of observations (number of regions on the map), z_i is the standardised value of the variable of interest (animals) at location i and w_{ij} is the corresponding cell to the *i-th* row and *j-th* column of a W spatial weights matrix. Using the Python Library PySal, the Moran Index can be calculated by the command `Moran`. However, the spatial weights matrix must be calculated. Using the PySal library, the matrix can be calculated by the command `weights.distance.Kernel.from_dataframe` using as input information the table processed after the data cleaning step as input information. Finally, the PySal library returns important information concerning the Moran Index's confidence level (Chi-Square test), the p_value. In other words, the p_value is used to measure the certainty about how likely it is to obtain the result presented on the map. A small enough p_value ($<= 0.05$) associated with Moran's Index of a map allows rejecting the hypothesis that the distribution on the map is random. This work used the Python Library GeoPandas to plot the map quickly with regions and several animals. The legend plotted on maps was programmed to create attractive maps that place an equal number of observations in each class.

Results and Discussion

The sampling effort, called camera trap days, is the sum of the number of days the camera traps were active, which was 1204 days. During this period, 1188 videos were catalogued. The graph in Figure 2 shows that three camera traps (CT1, CT6 and CT8), positioned in areas dominated by beech and conifer woods, obtained a more significant number of recordings.

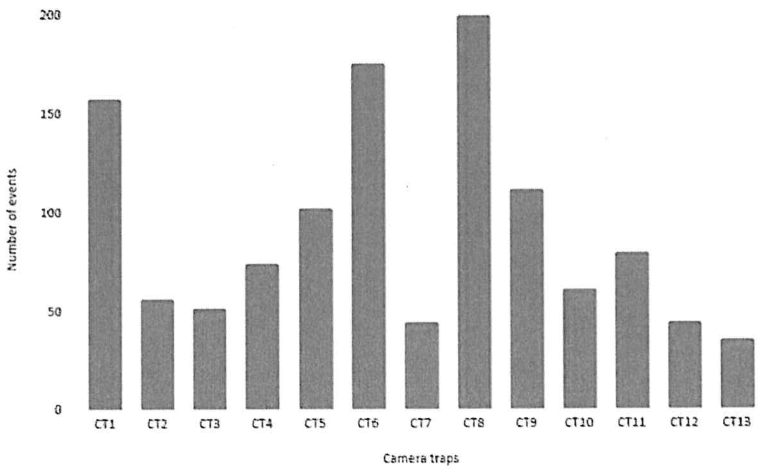

Figure 2: Number of events for each camera trap

The most detected wildlife species mainly belong to the ungulate group (Fig. 3). The most recorded species is the Red Deer, followed by Fox and Roe Deer. The least recorded species are the most elusive and small, such as mustelids and rodents.

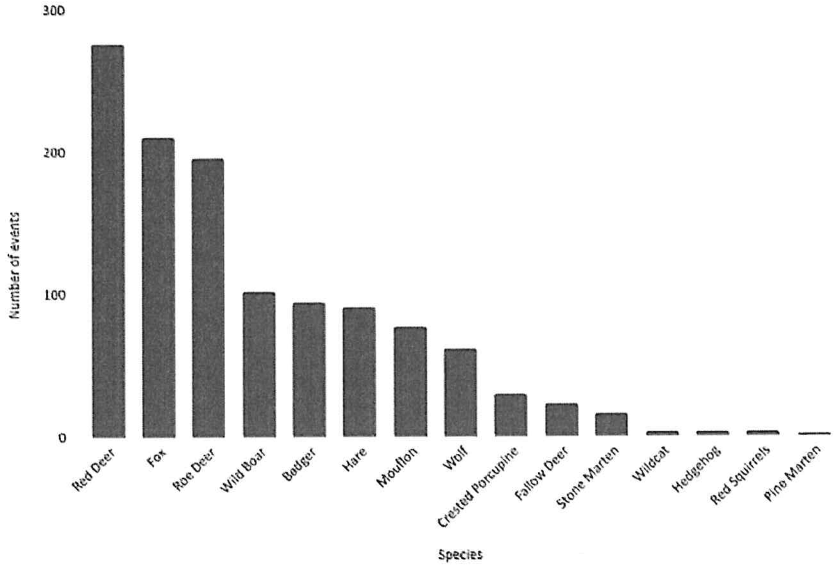

Figure 3: Number of events for species

Based on these data, as can be seen in Table 1, the catch rates for each species were calculated using the formula:

Catch rates for unit effort:

Cpue (Catch per unit effort) = C/X

Where:

- C = Video Catch Rates, i.e. the sum of contacts for each species;
- X= Total Unit Effort, i.e. the sum of days each camera was operational throughout the session (*trap days*)

Table 1: Number of contacts and Catch rates for each species

Species	Number of Events	Catch Rates
Roe Deer	196	0.163
Red Deer	276	0.229
Wild Boar	102	0.085
Fallow Deer	23	0.019
Stone Marten	16	0.013
Wildcat	3	0.002
Crested Porcupine	30	0.025
Hare	91	0.076
Wolf	62	0.051
Pine Marten	1	0.001

Mouflon	77	0.064
Hedgehog	3	0.002
Red Squirrel	3	0.002
Badger	94	0.078
Fox	211	0.175

Catch rates per unit effort confirm what is shown in Figure 3, i.e., that the most detected species were the Red Deer (0.229), the Fox (0.175), and the Roe Deer (0.163). Further monthly distribution and catch intensity analyses were conducted on the Roe Deer, Red Deer, Wild Boar, Fallow Deer, Wolf, Mouflon, and Fox. In the graph of Figure 4, the wild species divided by month have been analysed.

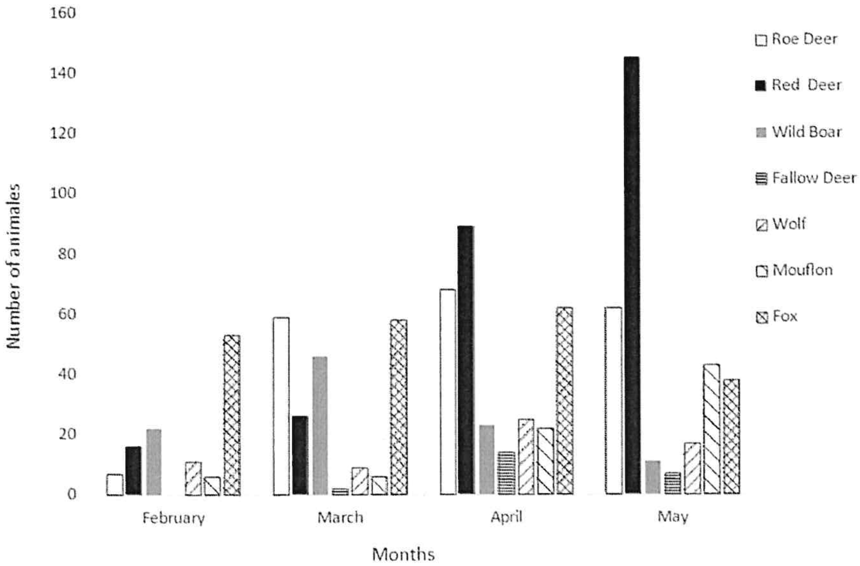

Figure 4: Number of events for month.

Especially for ungulates, the notable increase in events in spring is probably due to the births that occurred in April/May and to a more significant activity of the animals coinciding with the vegetative growth. Using the vegetation map of the study area (Fig. 1), the presence of animals was analysed according to land uses in the areas of the camera trapping sites. By analysing the sightings of the target species (Red Deer, Wild Boar, Fallow Deer, Mouflon, Fox, Roe Deer and Wolf), we identified overall intensity classes and intensity classes for each species. By applying the global spatial correlation to the overall events, it is possible to observe their distribution in different land use types. In Figure 5 (a), we can observe how most sightings are concentrated in stands of conifers and beech woods. In contrast, sightings decrease in areas dominated by chestnut trees and mesophilic grasslands. Figure 5 (b-h) represents the spatial distribution of the clustering areas divided by species, highlighting different intensity classes in relation to the number of total sightings.

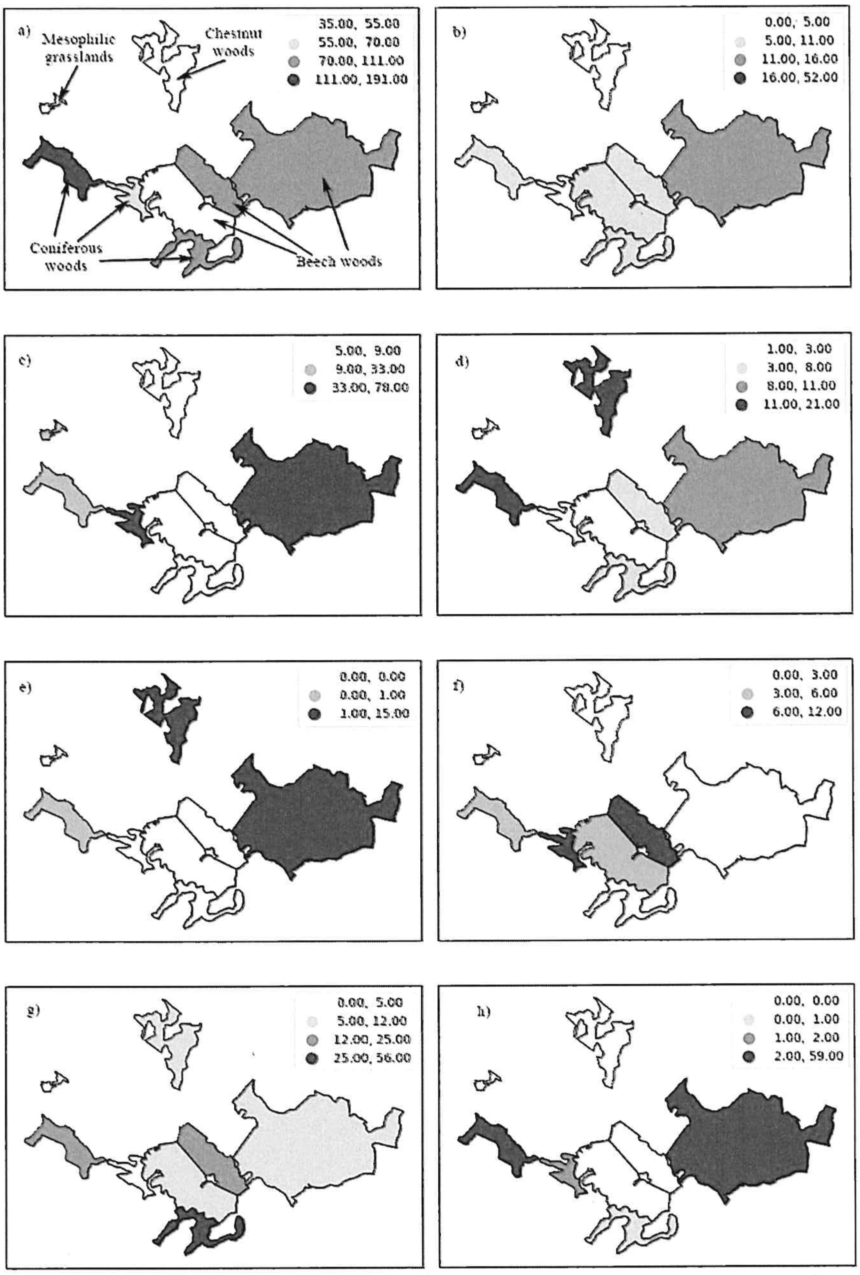

Figure 5: Clustering areas distribution for all the target species (a), Roe Deer (b), Red Deer (c), Wild Boar (d), Fallow Deer (e), Wolf (f), Fox (g) and Mouflon (h)

Table 2 shows the Moran Index and p value for each species on the map. This table helps us to understand if a determined animal map presented in Figure 5 has a level of clustering and its confidence level. Table 2 indicates that all animal maps have high Moran's Index values, indicating that the animals are concentrated in specific regions. Moreover, Table 2 reveals that only the map presented for Fallow Deer has a statistical confidence level near 5%. The maps presented for Red Deer and Fox have a statistical significance level near 10%. For the other maps, the uncertainty level is too high (p-value higher than 20%).

Table 2: Moran index and confidence level for each target species.

Animal map	Moran Index	P Value
Roe Deer	0,77	0,27
Red Deer	0,80	0,12
Wild Boar	0,77	0,28
Fallow Deer	0,82	0,06
Wolf	0,73	0,42
Fox	0,80	0,12
Mouflon	0,71	0,48

Conclusions

The Dynamo Oasis, being a nature reserve, requires wildlife monitoring that can explain the dynamics of the wildlife populations within it. Understanding the presence and abundance of animal species in a given place is essential to implementing a conservation plan for species threatened with extinction or to understanding their presence/absence, abundance, and ecology.

The present study aimed to analyse the videos collected through 13 camera traps in the Dynamo Oasis between 02/01/2023 and 05/24/2023. Red Deer (catch rate = 0.229) appears to be the most observed species, followed by Fox (0.175) and Roe Deer (0.163); during the spring months (April and May), sightings increased significantly, especially for ungulates. Using the QGIS software and the Python libraries GeoPandas and PySal, we studied the distribution of the species in relation to land use, trying to understand if there were some cluster areas within the Oasis. The calculation of the Moran index for spatial autocorrelation highlighted a tendency towards grouping all the species considered. Through statistical validation, a statistical significance was found only for the Fallow Deer (p value = 0.06). This type of research is very useful for understanding various aspects of population dynamics. The non-invasive method of monitoring through camera trapping allows to investigate parameters, such as the presence, abundance and distribution of species, to census them and to indirectly know their habits without interacting directly with the animal, causing low disturbance, also acting in environments that are not easily accessible and often reducing costs. Structuring an excellent methodological protocol for the best positioning of the camera traps is very important to have a good number of shots. The opportunistic protocol chosen for this study consists of positioning the camera traps near specific sites, such as a den, a watering point, on transit routes or where the remains of a meal have been found, thus avoiding the problem of the difficulty of reaching inaccessible places. Even more critical and consistent information could result from extending the time frame to at least 12 months and, with the positioning of a more significant number of camera traps and maintaining the same protocol. Camera trapping data from a period equal to or greater than one year can return useful information to study, for example, the circadian activity rhythms of species for each season of the year. Future studies could include behavioural data analyses and individual species' population structure. The data obtained over the years, being more representative and comparable, can be compared to understand the trends of the species over time, important data in terms of wildlife management and conservation. From a statistical point of view, it would be interesting to calculate the Local Moran Index, which can return helpful information for studying local correlations between the different species and the dynamics created between them.

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