UNIVERSIDADE DE ÉVORA

ESCOLA DE CIÊNCIAS E TECNOLOGIA

DEPARTAMENTO DE BIOLOGIA

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Inês Malheiro Guise da Silva

Orientação: Doutora Sara Maria Lopes Santos

B.Sc., M.Phil, Simon Roper

Mestrado em Biologia da Conservação

Dissertação

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Características das entradas das tocas do Texugo Euroasiático (*Meles meles*) na propriedade de Sharpham, sudoeste de Inglaterra

Resumo

A fragmentação e a degradação de habitats estão entre as maiores ameaças aos carnívoros. O Texugo-euroasiático (*Meles meles*) é um carnívoro com facilidade de adaptação que, embora não esteja ameaçado globalmente, exige atenção na compreensão das características dos seus habitats. Este estudo pretendeu analisar que fatores ambientais caracterizam e influenciam o uso de entradas de tocas de texugo na propriedade de Sharpham (Reino Unido). A abordagem incluiu variáveis topográficas, de vegetação local, usos de solo e de influência humana. O teste U de Mann-Whitney foi executado para todas as variáveis ambientais. Os resultados sugerem que valores mais elevados de declive, cobertura de vegetação e de distância das áreas com pastagem e estruturas antropogénicas, como as estradas, promoveram uma maior probabilidade de uso das entradas. Devem ser incentivadas políticas de manutenção e conservação das características ambientais propícias à utilização das entradas de tocas, de modo a promover a integridade dos habitats de texugos e a sobrevivência das populações.

Palavras-chave: *Meles meles*, tocas, localização de entrada, Inglaterra, fatores ambientais

Sett entrances characteristics of the Eurasian badger (*Meles meles*) in Sharpham Estate, southwest of England

Abstract

Fragmentation and degradation of habitats are among the most important threats to carnivores. The Eurasian Badger (*Meles meles*) is a very adaptable carnivore that, while is not considered an endangered species globally, requires attention when it comes to understanding its habitats characteristics. This study intended to analyze which environmental factors characterize and influence the use of badger's sett entrances in Sharpham Estate (UK). The approach included topographical, local vegetation, land uses and human-influenced variables. Univariate U Mann-Whitney test was performed for all environmental variables. The results suggest that high slope, high cover provided by vegetation and high distance from pastures areas and anthropogenic structures, such as roads, promoted a higher use probability of entrances. Maintenance and conservation policies of environmental characteristics conducive to the use of sett entrances should be encouraged in order to promote the integrity of badger habitats and the survival of populations.

Keywords: *Meles meles*, setts, entrance location, England, environmental factors.

1. Introduction

Habitat degradation and its successive loss are among the most important threats to biodiversity (Schipper et al., 2008). Habitat fragmentation hampers landscape connectivity both at the level of movement of organisms as well as their associated ecological processes (Taylor et al., 1993). On this issue, the ongoing intensification of agriculture in Europe and concretely in the United Kingdom, has led to serious environmental issues like landscape modification and severe changes in plant and animal populations (Stoate et al., 2001).

Carnivores are among the most threatened groups of species, since they are particularly affected by habitat loss (Ripple et al., 2014). They are responsible for playing a crucial role in the ecosystems functioning (Estes et al., 2011; Ripple et al., 2014; Ritchie and Johnson, 2009); thereby their decline or disappearance may have important implications for possible replacement of their associated ecosystem functions by other species (Estes et al., 2011; Ripple et al., 2014). Specifically, mesocarnivores may intervene in nutrient flows between adjacent habitats and eventually acting as seeds' dispersers (Roemer et al., 2009); therefore, their conservation is vital given their ascension along trophic levels, which in turn is promoted by the decline of top predators (Roemer et al., 2009).

The Eurasian Badger (*Meles meles*) is a mesocarnivore, that belongs to the mustelid family, with a wide distribution across Europe and Asia, that has become a predominant predator in parts of its range, due to the disappearance of larger terrestrial carnivores (Roper, 2010). In the United Kingdom, it is a common and widespread species (Roper, 2010). Badgers manifest physiological and anatomical adaptations to a semi-fossorial existence (Neal and Cheeseman, 1996), which enable them to build underground burrow systems called setts (Roper, 1992a). Such complex structures are used for sleep, social activities, breeding and as a shelter against adverse meteorological conditions (Broseth et al., 1997; Kowalczyk et al., 2000; Roper, 2010). Setts tend to increase in size throughout time as a result of digging and can be maintained by the same social group for many generations (Davison et al., 2008; Roper, 1992b), making them crucial resources to badgers' survival (Roper et al., 1992).

Badgers show ecological plasticity relatively to the habitats they occupy. On this issue, deciduous woodlands, broadly present in temperate and boreal forests of Europe, are among the preferred habitats of badgers (e.g., Bartmańska and Nadolska, 2003; Good et al., 2001; Matyástík and Bicík, 1999; Prigioni and Deflorian, 2005) , thanks to the moist conditions, and high abundance of food and shelter (Bičík et al., 2000; Matyástík and Bicík, 1999; Thornton, 1988). Land use change has led to many areas which were primarily dominated by forests to become mosaics of pastures delimited by hedges and forests (Kruuk, 1989). In European boreal and temperate regions, such a transformation proved to be beneficial to badgers, because of the presence of pastures, which usually contain high abundance of food resources (Broseth et al., 1997; Kowalczyk et al., 2000; Seiler et al., 1995). Coniferous forests of temperate and boreal Europe constitute another relevant habitat for badgers, although less important than deciduous woodland (Bartmańska and Nadolska, 2003; Bičík et al., 2000; Kowalczyk et al., 2000; Matyástík and Bicík, 1999). Despite the lower food availability in coniferous woodlands (Delahay et al., 2007; Kruuk, 1978b; Neal and Cheeseman, 1996), badgers can take advantage of the dense canopy as it may potentially reduce erosion of badgers marking sites derived by rain, differently to deciduous forests (Stewart et al., 2002). When woodlands are unavailable, scrub and hedgerows may be a good alternative, offering food as well as possibilities of sites for sett edification (Neal, 1972; Thornton, 1988). Badgers also dwell in drier habitats, as in the Mediterranean forests of southern Europe (Loureiro et al., 2007; Revilla and Palomares, 2002; Revilla et al., 2001; Rosalino et al., 2005).

Sett site location is determined by a complex interaction of locally-acting factors (Hipólito et al., 2018). Studies in diverse biogeographical regions of Europe (Continental, Atlantic and Mediterranean) showed that sloping ground is advantageous for badgers, as it may allow a greater facility of removing soil from entrances dug into a slope, effective drainage, flooding avoidance and safety from disturbances (Good et al., 2001; Jepsen et al., 2005; Prigioni and Deflorian, 2005; Revilla et al., 2001). Besides that, slope orientation may contribute to more suitable microclimatic conditions (Jepsen et al., 2005; Mysłajek et al., 2012). Specifically, studies regarding Continental biogeographic regions reported a more likely preference of southern and southeastern slope aspect (Biancardi et al., 2014; Broseth et al., 1997; Matyástík and Bicík, 1999; Myslajek et al., 2012), while in Mediterranean regions, northern and eastern slopes were preferred (Revilla et al., 2001). Such variations of selection are likely associated to the different climatic conditions within the species geographical range (Biancardi et al., 2014).

A high vegetation cover also has the purpose of protection; setts become less conspicuous, allowing badgers to enter and leave safely (Roper, 2010), avoiding a possible contact with conspecifics, predators/competitors or humans (Hipólito et al., 2018). Vegetation also shields setts from climatic events (Roper, 2010) and assures better microclimatic conditions over burrows (Fernández and Palomares, 2000; Revilla et al., 2001). Besides cover, roots may help in soil consolidation, thereby relieving drainage and minimizing the chance of occurring collapses in the setts' tunnel system (Fernández and Palomares, 2000; Revilla et al., 2001).

Depending on the altitude, badger activity varies along with geographical range (Roper, 2010). In some European mountain regions, such as in Czech Republic, Poland and Italy, badger activity was recorded up to 1000m (Bartmańska and Nadolska, 2003; Matyástík and Bicík, 1999; Mysłajek et al., 2012; Prigioni and Deflorian, 2005). At higher altitudes, man's disturbance tends to be less prominent, but on the other side vegetation cover and food availability may be lower (Bičík et al., 2000; Neal, 1972). Badger occurrence is also manifested in areas of modest altitude (up to almost 300m), such as in Mediterranean shrubland areas of the Iberian Peninsula (Loureiro et al., 2007; Revilla et al., 2001). Still, at flatter altitudes, agriculture may be more intensified, suitable places for digging less available and human population density higher (Bičík et al., 2000; Neal, 1972).

Badgers are greatly influenced by anthropogenic pressures (Neal, 1972; Roper, 2010). Studies conducted in Italy, The Netherlands and Poland reported that roads network contribute to the increase of badger mortality, isolation between populations and to changes in setts location (Biancardi et al., 2014; Myslajek et al., 2012; Obidziński et al., 2013; Van Apeldoorn et al., 1998). Replacement of habitats previously occupied by the badger by agriculture, livestock and timber production purposes, as in Mediterranean shrubland of the Iberian Peninsula or in western Switzerland, has also compromised the quality and amount of available habitats for this species (Do Linh San et al., 2011; Hipólito et al., 2016; Rosalino et al., 2004). Nevertheless, in some cases, badgers take advantage of human presence, by building their setts in human-made structures, as already reported by studies in Poland, Italy and Spain (Kowalczyk et al., 2004; Mysłajek et al., 2012; Prigioni and Deflorian, 2005; Revilla et al., 2001).

In the United Kingdom, badgers are considered of Least Concern (LC) by the IUCN Red List of Threatened Species (Kranz et al., 2016) and are a protected species under the Protection of Badgers Act 1992. In the United Kingdom, their densities are higher compared to the general range (Cresswell et al., 1989; Thornton, 1988). As in other parts of temperate Europe, badgers select mostly deciduous woodland and pasture habitats (Kruuk et al., 1979; Neal, 1972; Rogers and Cheeseman, 1997), where they feed preferentially on earthworms (Kruuk and Parish, 1982; Kruuk, 1978b), and forage opportunistically other types of food (Roper, 1994).

Growing urbanization also has been problematic to badgers in Great Britain. In addition to habitat degradation promoted by changes in land uses (Cresswell et al., 1989), this species is greatly affected by road networks. Badgers strike high rates of mortality, and experience significant impacts in dispersion movements and sett distribution (Cheeseman et al., 1988; Clarke et al., 1998; Lankester et al., 1991; Skinner et al., 1991a, 1991b). Despite this, there are reports of populations that have adapted to increasingly urbanized environments of Britain, building setts, dwelling and foraging in these environments (Davison et al., 2008; Huck et al., 2008; Tavecchia, 1995). On the other hand, badgers setts are frequently established at moderate altitudes between 100m and 200m and in moderate slopes (Kruuk, 1978a; MacDonald et al., 2004; Neal, 1972; Thornton, 1988). In a National Survey, Neal (1972) reported slope aspects being of little importance in habitat selection, while MacDonald et al. (2004) suggested a selection of west and northwest slope aspects in south-central England; Skinner et al. (1991a) stated that in south-east England south and west slopes were favored. These results suggest that the influence of topography in sett location needs to be further studied.

The aim of this study was to describe the characteristics of badgers' sett entrances and to determine which environmental variables affect the location of these entrances by badgers on the Sharpham Estate, in the southwest of England. Research of badgers' setts and additionally of sett entrances constitutes an important challenge to conservation. They consist of a physical resource of high value for badgers and an important factor for determining the population density of this species (Neal, 1991). If it's possible to better understand their functional value, aspects such as badger's behaviour, physiology, morphology and population dynamics may, this way, be better understood (Roper, 1992a). Realizing the dynamics among these environmental factors may help to determine badgers' ecological requirements in this area, to thereby elaborate necessary management decisions and future conservation strategies (Griffiths and Thomas, 1997).

2. Methodology

2.1. Study area

The study was performed during September 2017, in a part of the Sharpham Estate (approximately 170 ha), in the Count of Devon, Southwest of UK. Sharpham Estate covers a total of 202 hectares and is integrated into the South Devon Areas of Outstanding Natural Beauty (AONBs) of UK. It's bounded by the river Dart to the North and east limits. The town of Totnes is located at North and the Southeastern limit corresponds to the village of Ashprington. The landscape is mainly characterized by a mosaic of agricultural lands and woodland patches (MAGIC Steering Group, 2013; Fig. 1).

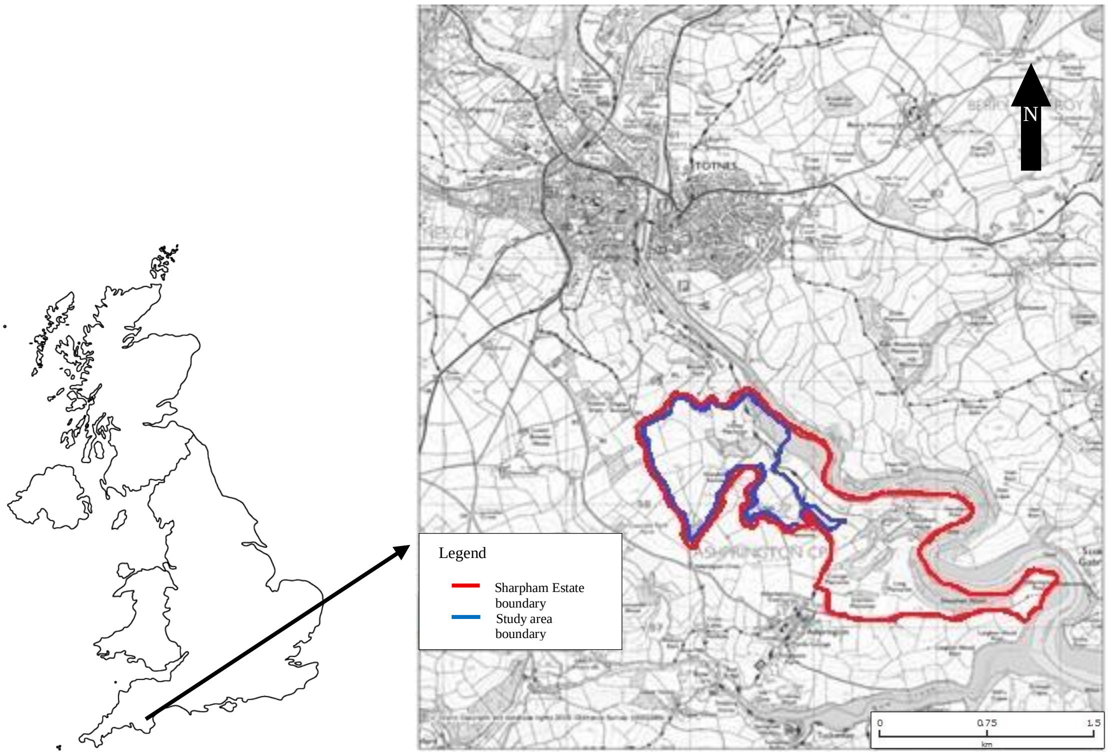

Figure 1 - Map of the study area produced by MAGIC (Defra). Sharpham Estate is delimited by the red line and study area by the blue line.

In the Southwest region of UK, climate is mild; the sea has a strong influence on climate, which induces a mean annual temperature of 11º to 12ºC. February is usually the coldest month, where the mean minimum temperature can reach 1.5ºC; July and August are the warmest months, where daily mean maximum temperature can oscillate from 19ºC to 21.5ºC. Annual rainfall can be of 900-1000 mm or higher (Met Office, 2018).

South Devon elevation can reach the 340m a.s.l. (Natural England, 2014) and soils are mainly loamy (Natural England, 1998). The south of the county is characterized for having some extensive areas of ancient woodland (English Nature, 1999), where oak (*Quercus spp.*) and ash (*Fraxinus excelsior*) are preponderant. Alder (*Alnus glutinosa*) and hazel (*Corylus avellana*) woodlands are also common and there's noticeable occurrence of sweet chestnut (*Castanea sativa*), beech (*Fagus sylvatica*) and sycamore (*Acer pseudoplatanus*) (Natural England, 1998). Mixed farming systems with small fields and pasture on valley sides are too a common feature of this landscape (Natural England, 1998).

2.2. Entrances location of badgers' setts

Data on the occupation of badger setts were obtained in September of 2017. Previous information on badger activity in the past was used from studies conducted on the Sharpham Estate. All the access to information and study area was given in the scope of Ambios Ltd team. This is a nature conservation training organization that aims to provide education, practical action, training in science and technology, and volunteer opportunities associated with nature conservation in the UK and abroad (Ambios Ltd, 2018). These data were collected for the purpose of gathering information on the selection of badger' setts entrances on the Sharpham Estate, where Ambios has one of its areas of action (Lower Sharpham Farm), and where it carries out activities related to conservation and, in particular, projects involving badger's conservation.

. Badgers' setts can be noticed through the existence in the soil of entrances that narrow to form a tunnel, leading to the other tunnels and to chambers, with entrances being normally covered by thick vegetation, like brambles (*Rubus spp.*) and stinging nettles (*Urtica dioica*), and the presence of spoil heaps, containing excavated soil. Latrines were also checked, since they can also assist as a field sign of badger's presence (Roper, 2010). Entrances of setts were examined for evidence of occupation (use) by badgers, such as footprints, hairs at the entrance and traces of recent scrubbing.

Data collection focused on the individual assessment of recent usage of sett entrances (response variable). For each sett entrance, badger's hair was sought in a period of 3 minutes, recording if hairs were present or absent, regardless of the amount found. This had the purpose of verifying the existence of badger's hair to confirm that those were burrows used by badgers. This evaluation around the entrances (and not on the setts) is also related to the behavioural patterns that the badgers present in the maintenance and construction of their setts. Considering that for badgers their setts serve several purposes, as before mentioned, entrances may probably be more related to safety, as badgers use them to enter and leave the sett. The study area is classified in five different sites. Each site may include one or more setts. There is not sufficient evidence to support the idea that each site with the presence of a sett is exclusively frequented by one distinct group of badgers. Given the small extent of the study area (170 ha), individuals are likely to attend different sites and different setts (Revilla et al., 2001). In addition, a selection of random points has been performed, so that, in comparison with sett entrance sites, it would be possible to infer which explanatory variables are more correlated with location of sett entrances.

2.3. Environmental variables

With the purpose of understanding and evaluating the influence of local ecological conditions as well as the human influence on the location of entrances of badgers' setts, several variables were selected. The variables concerning topography around sett entrances were: Slope, Altitude, Sett aspect and Entrance aspect. The variables describing vegetation and landscape structure were: Vegetation cover in three different strata (under 3 meters, between 3 meters and 6 meters, above 6 meters), tree and shrub species (Ash (*Fraxinus excelsior*), Beech (*Fagus sylvatica*), Blackthorn (*Prunus spinosa*), Elder (*Sambucus nigra*), Field Maple (*Acer campestre*), Hawthorn (*Crataegus monogyna*), Hazel (*Corylus avellana*), Holly (*Ilex aquifolium*), Lime (*Tilia cordata*), Pedunculate Oak (*Quercus robur*), Sweet Chestnut (*Castanea sativa*), Sycamore (*Acer pseudoplatanus*) and Brambles (*Rubus spp.*)) and Distance from pastures. Other variables studied were related to the human influence: Distance from urban settlements and Distance from roads (Table 1).

For all entrances, sett aspect and sett entrance aspect were calculated using a compass. Sett aspect was measured directing compass to the main slope of the sample point. In entrance aspect, it was used a stick that was inserted in the entrance until reaching the closest wall, so that this would point to the orientation of the entrance. The compass was then placed upon the stick, to stabilize the compass support surface. Both variables were calculated considering a 10m radius circle from each entrance (Table 1).

The mean slope of each sample point was measured using a default cell phone tool that allows to examine declivity through the screen of the device, when placing the cell phone on surface of the intended point of analysis (Huawei Technologies Co. Ltd, 2018; Table 1).

A visual estimation by a single observer of the percentage of the vegetation cover in each sample point was done in different height strata (under 3 meters, between 3 meters and 6 meters, above 6 meters), inside a 10 meters radius circle around the same point. All trees and shrubs species inside the radius circle were identified. The percentage of Brambles (*Rubus spp.*) has been estimated through the same method; the inclusion of brambles as a variable separated from the Vegetation cover variables was justified to understand if this type of shrub in particular was relevant in the location of sett entrances, compared to the other vegetation species, since the brambles can make sett entrances more inconspicuous (Roper, 2010; Table 1).

At each sample point, measurements were performed having in consideration distance from surfaces or structures that may have an influence on badger's sett entrances selection, such as pastures, urban settlements and roads. These measurements were determined using Google Earth tools (Google, 2018) and have considered the minimum distance in meters. Also altitude was obtained using Google Earth tools. All measurements involving distances were executed with these tools so that the error would be homogeneous for all sample points (Table 1).

2.4. Additional environmental variables

Using the QGIS Desktop 3.0.0 (Quantum GIS Development Team, 2018), a map was created by inserting all sampling point coordinates and land uses from Corine Land Cover (Cole et al., 2015). Figure 2 shows the different existing land uses in the study area: Discontinuous urban, Non-irrigated arable land, Pastures, Salt marshes and Intertidal flats (Fig. 2). A buffer of 50 meters was created around each sample point (sett entrance or random point) to allow the evaluation of the composition of the buffer zone and thus assess the percentage of each soil use area. The sampling points fall only into Non-irrigated arable land or Pasture. These two land use classes were added to the environmental variables list. Non-irrigated arable land are cultivated land parcels submitted to rainfed agriculture for non-permanent crops harvested annually, usually under a crop rotation system. Pastures are permanent grasslands characterized for being used for agricultural purposes or for having strong human disturbance (European Environment Agency, 2012). The study area is mainly agricultural. However, the visible open spaces are separated by patches of hedgerows and groves, which are not evident in Figure 2, but still have a strong influence on landscape (Fig. 3). In Table 1 are gathered all the variables under study, discriminating which ones are associated to topography, local vegetation, land uses and human influence.

2.5. Sett entrance points

For each entrance, geographical coordinates were recorded using a Garmin GPSmap62s. GPS error was 5 meters, on average. A total of five sites were considered inside the study area: Higher Sharpham, Hedge Close to Burial, Lower Gribble, Higher Gribble and Mainsett LSF (a site known to have intensive activity of badgers inside of the boundaries of Lower Sharpham Farm; Fig. 3). Thirty seven setts entrances were surveyed distributed unevenly by the sites.

2.6. Random points

In order to access which explanatory variables could explain the location of sett entrances, it was necessary to define random points all over the study area. Using a random number generator, a random set of map coordinates for these sites was then created, having in consideration the coordinates of the geographical boundaries of the study area. Random points were located in the field using the GPS. Thirty-two random sites were considered appropriate for analysis. Ideally the number of sett entrances and random points would be the same. In this study, there are 54% sett entrances and 46% random points, therefore there’s an approximated ratio, which means that there’s no impacting imbalance of presences and absences of data.

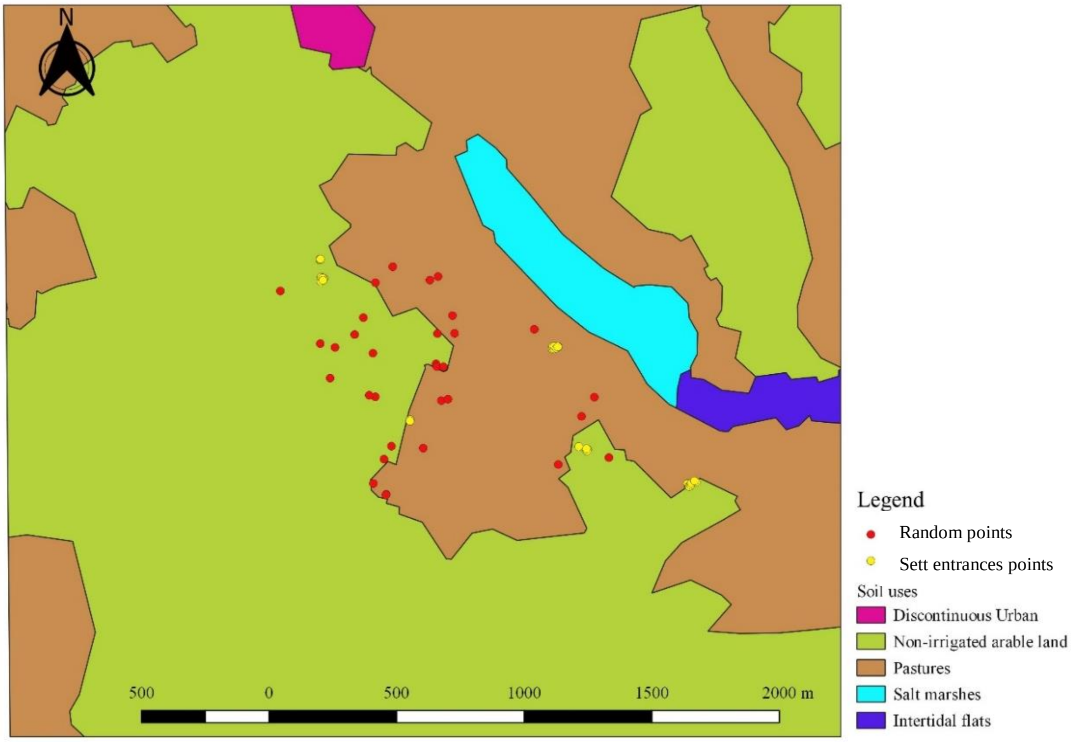

Figure 2 - Graphical map obtained by QGIS Desktop 3.0.0, presenting the location of sett entrances points (yellow dots) and random points (red dots), and the land uses in the study area). Notice that not all sett entrances points can be observed due to the overlap of points in the considered scale (close proximity of points). All points coincide only with two types of land use: Non-irrigated arable land and Pastures.

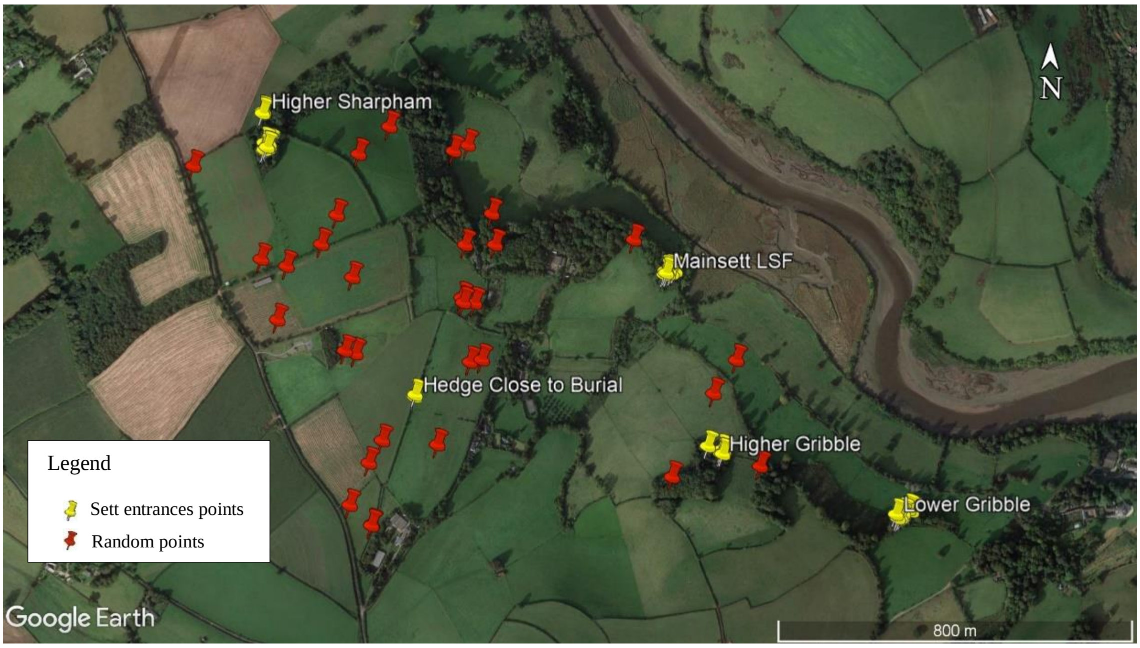

Figure 3 – Aerial photography extracted from Google Earth, with the distribution of sett entrances points (yellow marks) and random points (red marks), as well as the identification of the name of each sett site. Notice that not all sett entrances can be observed due to the overlap of marks in the considered scale (close proximity of marks).

Table 1 - List of environmental variables under study, their inclusion or not in random points (yes: available for entrances and random points; no: only available for entrances) and its definition.

Variable Type	Variable Abbreviation (units)	Random points	Variable definition
Topography	Slope (%)	Yes	Mean slope of the sample point in a 10 meters radius circle
	Altitude (m)	Yes	Elevation above mean sea level of the sample point obtained from Google Earth in meters
	Sett Asp (º)	Yes	Compass direction of the main slope of the sample point in a 10 meters radius circle from the sample site
	Ent Asp (º)	No	Compass direction of the sett entrance in a 10 meters radius circle from the sample point
Local vegetation	Veg 3 (%)	Yes	Percentage of the area covered by trees and shrubs under 3 meters high in a 10 meters radius circle from the sample point
	Veg 3 6 (%)	Yes	Percentage of the area covered by trees and shrubs 3 – 6 meters high in a 10 meters radius circle from the sample point
	Veg 6 (%)	Yes	Percentage of the area covered by trees and shrubs above 6 meters high in a 10 meters radius circle from the sample point
	Brambles (%)	Yes	Percentage of the area covered by brambles in a 10 meters radius circle from the sample point
	Ash (presence/absence)	Yes	Record of the presence of Ash in a 10 meters radius circle from the sample point
	Beech (presence/absence)	Yes	Record of the presence of Beech in a 10 meters radius circle from the sample point
	Blackthorn (presence/absence)	Yes	Record of the presence of Blackthorn in a 10 meters radius circle from the sample point
	Elder (presence/absence)	Yes	Record of the presence of Elder in a 10 meters radius circle from the sample point
	F maple (presence/absence)	Yes	Record of the presence of Field maple in a 10 meters radius circle from the sample point
	Hawthorn (presence/absence)	Yes	Record of the presence of Hawthorn in a 10 meters radius circle from the sample point
	Hazel (presence/absence)	Yes	Record of the presence of Hazel in a 10 meters radius circle from the sample point
	Holly (presence/absence)	Yes	Record of the presence of Holly in a 10 meters radius circle from the sample point
	Lime (presence/absence)	Yes	Record of the presence of Lime in a 10 meters radius circle from the sample point
	P Oak (presence/absence)	Yes	Record of the presence of Pedunculate Oak in a 10 meters radius circle from the sample point
	S Chestn (presence/absence)	Yes	Record of the presence of Sweet Chestnut in a 10 meters radius circle from the sample point
	Sycamore (presence/absence)	Yes	Record of the presence of Sycamore in a 10 meters radius circle from the sample point
Land uses	D pastures (m)	Yes	Minimum distance in meters of the sample point from the edge of the closest pasture
	N irrigated (%)	Yes	Percentage of use of soil "Non-irrigated arable land" in a 50 meters radius circle from the sample point
	Pastures (%)	Yes	Percentage of use of soil "Pastures" in a 50 meters radius circle from the sample point
Human influence	D urban (m)	Yes	Minimum distance in meters of the sample point from the edge of the closest urbanized structure
	D roads (m)	Yes	Minimum distance in meters of the sample point from the edge of the closest road

2.7. Statistical Analysis

Normal distribution of all variables was verified employing histograms and boxplots. Outliers were examined and identified, to avoid any distortion of statistic values in the analysis or to avoid data entry errors (Boslaugh and Watters, 2008). Excess of zeros was checked, in order to prevent generation of biased parameter estimates and standard errors in posterior analysis (Zuur et al., 2009). Some variables (D pastures, Brambles, Veg 3, Veg 3 6, Veg 6, N irrigated and Pastures) revealed non-normal distribution, so they were transformed, in order to reduce the effect of outliers, stabilize variance and linearize relationships (Zuur et al., 2009). Accordingly, D pastures was log transformed while the remaining variables (Brambles, Veg 3, Veg 3 6, Veg 6, N irrigated and Pastures) were arcsine transformed (Zuur et al., 2009).

2.7.1. General characteristics

In order to briefly describe the number of entrances per site, a bar plot was applied. For circular data (Sett Asp and Ent Asp), appropriate tools and/or circular statistics were applied (rose diagram).

2.7.2. Influence of environmental variables in location of sett entrances

In order to understand which explanatory variables influence the location of sett entrances by badgers, the univariate U Mann-Whitney test was performed for all recorded variables. The use of a non-parametric test was due to the fact that entrances were spatially clustered in a small number of locations; this way, a non-parametric test could better deal with spatial limitations.

To avoid interpretation of variables that may introduce repetition of information, an analysis of collinearity (pairwise Pearson correlation test) among explanatory variables was performed, thus highlighting only the most independent and significant ones.

All analyses and graphical outputs were performed with R version 3.3.0 (R Development Core Team, 2011). Circular data were handled with "circular" package (Agostinelli and Lund, 2017).

3. Results

3.1. General characteristics

The number of badgers' sett entrances per site ranged from two to thirteen; Higher Sharpham site recorded the highest number of sett entrances while Hedge Close to Burial site the lowest (Fig. 4). Setts aspect was mostly exposed to Southwest (Fig. 5), while setts entrances aspects were mostly oriented to Northeast, East and Southwest (Fig. 6). The most frequent tree species present near sett entrances were Ash, Elder, Hazel, Pedunculate Oak and Sycamore (Table 2).

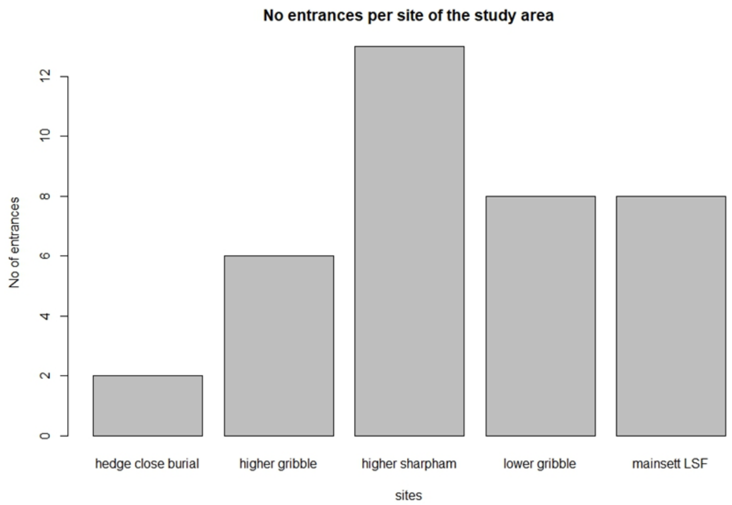

Figure 4 - Graphic showing the number of entrances per site: Hedge Close to Burial recorded 2 entrances; Higher Gribble recorded 6 entrances; Higher Sharpham recorded 13 entrances and both Lower Gribble and Mainsett LSF recorded 8 entrances.

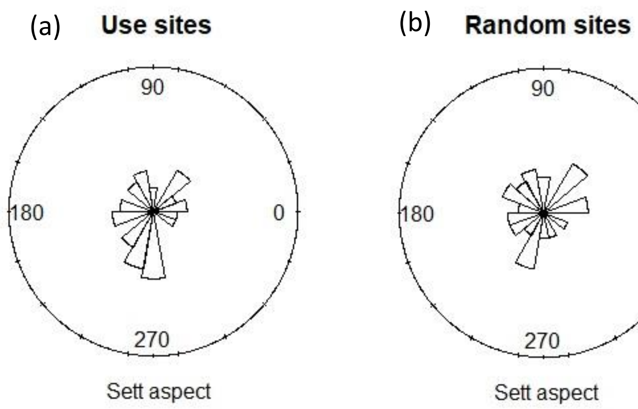

Figure 5 - Circular plots of Sett aspect (º) in use sites (a) and random sites (b). Degrees and respective cardinal direction are as follows: 0-45º - North; 45-90º - Northeast; 90-135º - East; 135-180º - Southeast; 180-225º - South; 225-270º - Southwest; 270-315º - West; 315-360º - Northwest.

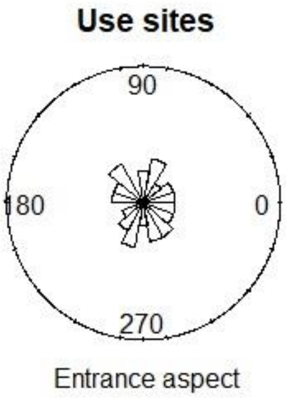

Figure 6 - Circular plot of Entrance aspect (º) in use sites. Degrees and respective cardinal direction are as follows: 0-45º - North; 45-90º - Northeast; 90-135º - East; 135-180º - Southeast; 180-225º - South; 225-270º - Southwest; 270-315º - West; 315-360º - Northwest.

3.2. Influence of environmental variables in location of sett entrances

Sett entrances were found more likely in areas of lower altitude (77m) and higher slope (23%; Table 2; Fig. 7). All three height vegetation strata had higher cover values in sett entrances (Veg 3 - 27%; Veg 3 6 - 32%; Veg 6 - 43%) when compared with random sites (0% for all, Table 2). Sett entrances had higher cover of brambles (23%), and higher presence probability of Ash, Beech, Elder, Hazel, Holly, Pedunculate Oak, Sweet Chestnut and Sycamore (Table 2). Sett entrances were farther away from pastures (15.26m), urban settlements (389.65m) and roads (826.92m) when compared with random points (0m, 218.16m, 392.07m, respectively; Table 2, Fig. 7). The analysis of correlation between environmental variables revealed that some gave repeated information (correlation value above 0.7). Thus, altitude and distance from roads were highly correlated; the same for the three vegetation height strata (Veg 3, Veg 3 6, Veg 6); Veg 3 6, Brambles, Elder, and D pastures; Veg 6, Ash and D pastures; Brambles and P Oak; Hazel and Sycamore; Sycamore and D roads; N irrigated and Pastures; Pastures and D urban. According to these results, we will focus the discussion on significant variables that represent more unique information (low correlation with remaining variables): Slope, D roads, Veg 3 6, Brambles, Ash and Elder (Table 3; Fig. 7).

Table 2 - Median, Range (Minimum-Maximum) and Wilcoxon-Mann-Whitney U test values for each explanatory variable for use and random sites; statistical significance was set at $p < 0.05$.
[(a)] – Circular Analysis of Variance: Likelihood Ratio Test was performed, due to the circular value data.
[(b)] – Not possible to calculate.
[(c)] – Arcsine transformed values were used.
[(d)] – Log transformed values were used.

		Use		**Random**			
Variable Type	**Variable**	**Median**	**Range (Min-Max)**	**Median**	**Range (Min-Max)**	**U**	**p-value**
Topography	Slope	23	12-44	9	1-25	100	3.16e-09
	Altitude	77	16-125	111.5	2-156	806	0.01017
	Sett Asp	117	60-218	96	15-330	2.39 [(a)]	0.1221 [(a)]
	Ent asp	130	19-348	-	-	[(b)]	[(b)]
Local vegetation	Veg 3	27	2-66	0	0-31	105 [(c)]	3.327e-09 [(c)]
	Veg 3 6	32	18-60	0	0-39	54.5 [(c)]	4.906e-11 [(c)]
	Veg 6	43	0-76	0	0-42	79 [(c)]	2.583e-10 [(c)]
	Brambles	23	0-85	0	0-33	145.5 [(c)]	3.053e-08 [(c)]
	Ash	1	0	0-1	0-1	194.5	1.599e-08
	Beech	0	0	0-1	0-1	689.5	0.04542
	Blackthorn	0	0-1	0	0-0	544	0.1057
	Elder	1	0-1	0	0-1	69	3.385e-13
	F maple	0	0-1	0	0-0	560	0.1921
	Hawthorn	0	0-1	0	0-1	607	0.7904
	Hazel	1	0-1	0	0-1	300.5	4.218e-05
	Holly	0	0-1	0	0-1	391.5	0.00187
	Lime	0	0-0	0	0-1	629	0.1307
	P Oak	1	0-1	0	0-1	311.5	4.432e-05
	S Chestn	0	0-1	0	0-1	370.5	0.0002753
	Sycamore	1	0-1	0	0-1	369.5	0.001783
Land uses	D pastures	15.26	1.73-28.24	0	0-50.27	125[(d)]	7.948e-09 [(d)]
	N irrigated	84	0-100	48	0-100	473[(c)]	0.1382[(c)]
	Pastures	16	0-100	52	0-100	711[(c)]	0.1382[(c)]
Human influence	D urban	389.65	147.4-480.53	218.16	29.07-573.74	355	0.003976
	D roads	826.92	171.04-980.35	392.07	7.10-940.19	356	0.004139

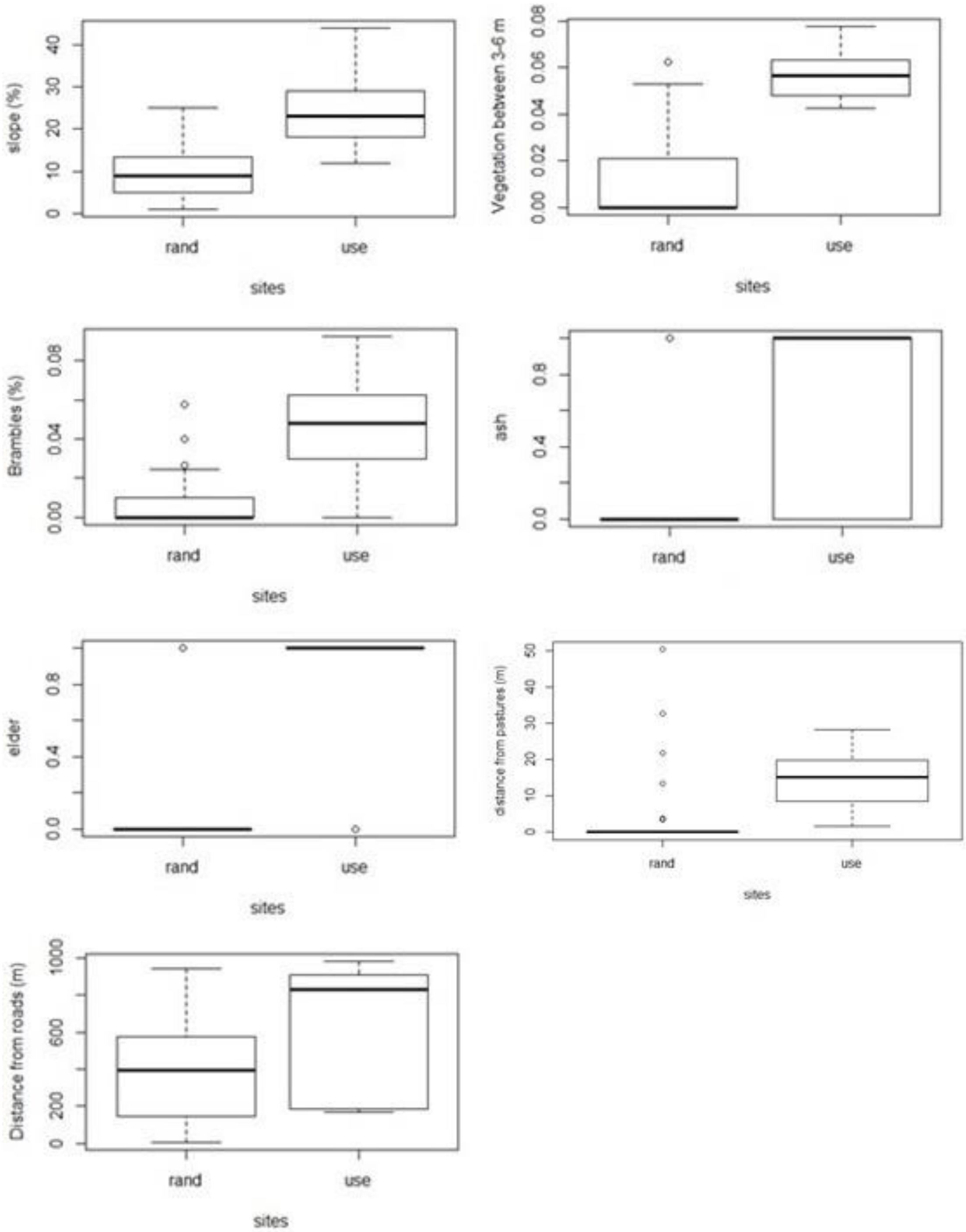

Figure 7 – Boxplots of comparison of environmental values for random sites and use sites obtained for the following variables: Slope, Veg 3 6, Brambles, Ash, Elder, D pastures, D roads.

Table 3 - Pearson correlation matrix among significant environmental variables evaluated in this study. The correlations higher than ± 0.7 are signalled in gray.

	Altitude	Veg 3	Veg 3 6	Veg 6	Brambles	Ash	Beech	Elder	Hazel	Holly	P Oak	S Chestn	Sycamore	D pastures	D urban	D roads
Slope	-0.3029	0.6713	0.6694	0.6449	0.5512	0.4542	-0.0460	0.5431	0.3460	0.3771	-0.0750	0.4395	0.1077	0.5487	0.1044	0.3054
Altitude	-	-0.4671	-0.3046	-0.3130	-0.0709	0.0431	-0.0367	-0.3154	-0.5838	-0.4794	0.0266	0.1032	-0.6208	-0.3649	0.2070	-0.8232
Veg 3	-	-	0.8093	0.7786	0.6831	0.3698	0.0523	0.6820	0.6074	0.6311	0.4666	0.1701	0.5936	0.7209	0.0872	0.4359
Veg 3 6	-	-	-	0.8712	0.7356	0.6141	0.0984	0.7670	0.4829	0.2922	0.5892	0.4230	0.4531	0.7964	0.2926	0.2972
Veg 6	-	-	-	-	0.6196	0.7175	0.0748	0.6962	0.4798	0.2579	0.5300	0.5812	0.4748	0.8597	0.3986	0.3122
Brambles	-	-	-	-	-	0.3878	-0.1519	0.6432	0.1509	0.2655	0.7914	0.3694	0.0266	0.5574	0.0692	-0.0753
Ash	-	-	-	-	-	-	-0.1342	0.6265	0.3400	-0.0289	0.2873	0.6853	0.1596	0.5391	0.6271	0.1097
Beech	-	-	-	-	-	-	-	-0.3302	0.0190	0.0503	-0.2828	-0.2128	0.1933	-0.0611	-0.1560	0.0706
Elder	-	-	-	-	-	-	-	-	0.4975	0.2480	0.5571	0.5110	0.3797	0.6785	0.3797	0.2476
Hazel	-	-	-	-	-	-	-	-	-	0.4611	0.0563	-0.0504	0.7026	0.4241	0.0538	0.6320
Holly	-	-	-	-	-	-	-	-	-	-	-0.0415	-0.3387	0.5925	0.3580	-0.3462	0.5670
P Oak	-	-	-	-	-	-	-	-	-	-	-	0.3919	-0.0670	0.4106	0.1766	-0.2128
S Chestn	-	-	-	-	-	-	-	-	-	-	-	-	-0.0504	0.4723	0.5990	-0.1343
Sycamore	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5413	0.0468	0.7359
D pastures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3105	0.3917
D urban	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.0262
D roads	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4. Discussion

Evidence from results indicates that the entrances location of setts in this study is jointly influenced by variables from all analyses groups, namely topography, local vegetation, land uses and human influence.

It's notable that all entrances were significantly represented by all the vegetation strata, regardless of the type of strata height. Moreover, entrances with a minimum vegetation cover, namely the one situated in a hedgerow (e.g. Hedge Close to Burial site) were adequate for sett entrances location. This might suggest that even scarce cover is sufficient for offering protection as well as avoiding possible conflict with humans (O'Corry-Crowe et al., 1993). In particular, entrances in places with lower vegetation cover may have been the consequence of landscape change from forests to pastures mosaics, possibly derived from excessive fragmentation (Kruuk, 1989), implying that the existing vegetation in the past may not correspond to the current vegetation structure. In such a context, rural landscapes are usually less subject to disturbances than urbanized environments (Huck et al., 2008). However, existing neighbouring pastures in the study area are actively used by cattle and people. Therefore, entrances may be better protected if they are inconspicuously located.

Results showed that the presence of cover of the three vegetation strata was important; conversely, sett entrances locations are more influenced by the type of vegetation species. Indeed, considering the response to the most significative species (e.g. Ash tree and Elder shrub), these findings confirm a predominance of entrances in deciduous forests. Humidity levels and low wind speed conditions in deciduous woodlands may be able to facilitate earthworms activity including surface foraging (da Silva et al., 1993), which in turn is considered the principal component in badgers' diet in the United Kingdom (Kruuk and Parish, 1982; Kruuk, 1978b). Additionally, the presence of deciduous vegetation around entrances might provide badgers diverse food availability besides earthworms (da Silva et al., 1993; Do Linh San et al., 2011) and appropriate bedding material (Prigioni and Deflorian, 2005). Entrances were likewise significantly linked with brambles. In addition to the benefit of entrances coverage (Balestrieri et al., 2006), brambles' close availability to entrances may provide food (e.g. berry fruits; Roper, 2010) without the need of foraging much distant from entrances. Moreover, this type of plants thrive on disturbed soils as the ones that undergo through constant digging (Neal, 1972; Obidziński and Głogowski, 2005). They can also reflect the effect of badgers occupying sites with this plant species. Badgers' urine and faeces make soils richer in nitrogen and phosphate content, which in turn favour brambles and others species' growth; furthermore, when badgers eat berries, it's likely that seeds will pass unchanged through the badger gut, being deposited in faeces and given the opportunity to germinate (Neal, 1972; Obidziński and Głogowski, 2005) near the sett entrances.

Considering the fragmented landscape in the study area, it's likely that badgers take advantage of woodlands' topographical conditions (Good et al., 2001) and cover (Neal, 1972) for sett entrances location, while accessing neighbouring pastures habitats for greater foraging facility (Kruuk et al., 1979; Neal, 1972). Distance from pastures has determined sett entrances location (corroborated by no significant differences when selecting pastures land cover). Nevertheless, despite in the United Kingdom badgers need pastures given the greater availability of earthworms, pastures provide weak protection and hamper the use of entrances throughout the associated cattle and agro-forestry activities (Hipólito et al., 2016; Neal, 1972). Lastly, flat terrain hinders sett entrances excavation (Neal, 1972) as well as increasing susceptibility to occasional flooding (Virgós and Casanovas, 1999), which makes pastures habitats less appropriate for setts edification.

Topographical variables, such as slope, influenced significantly the location of sett entrances. Entrances normally occur in a horizontal line across the slope (Roper, 2010) and excavation on higher slopes enables badgers to remove more easily soil from entrances (Neal, 1972). Flatter slopes demand greater efforts to attain more workable substrata during excavation or enough depth for excavating proper chambers that assure better sheltered conditions (MacDonald et al., 2004). Additionally, slope might provide a better drainage, preventing flooding (Neal, 1972). It may act as an extra protection factor for badgers (Good et al., 2001); during excavation, it's formed a soil mound outside the entrance on a slope, favouring clearance of entrances' excavated soil. The soil mound catches wind swirls coming from any direction, enabling a badger to become aware of danger (e.g. potential predation) through olfactory or visual indicators without exposing itself totally (Good et al., 2001; Neal, 1972). However, critical higher slope degree may interfere at the structural level; for example, Neal (1972) suggested when entrances lead to vertical tunnels, those are more prone to collapse. Thus, steeper slopes may hinder access in entrances for badgers (MacDonald et al., 2004).

Sett entrances were significantly distant from roads and this may be due to roads' sources of disturbance, as intensive human penetration and traffic noise (Bennett, 1991). Besides this, roads' major negative effect on badgers' populations is direct mortality, and in Great Britain it is considered badgers' largest single cause of recorded death (Clarke et al., 1998). Road barrier effect may, in addition, discourage individuals' attempts to cross roads, which may be linked with a potential badger movement restriction (Clarke et al., 1998). Furthermore, it's noteworthy that expansion of roads network may promote fragmentation of the landscape, and may lead to increasing suitable patch isolation for populations' expansion (Clarke et al., 1998).

5. Study limitations and management perspectives

In the last decades, the ongoing landscape changes have fostered degradation of badgers' habitat, which may compromise population survival (Lankester et al., 1991). The reduced cover associated with the loss of woodlands and hedgerows in the landscape, combined with the social stress from disturbances and roads negative impacts may have limited the availability of badgers' habitats (Skinner et al., 1991b). Thus, it's necessary to consider the enforcement of measures that may ease these pressures. In parts of the study area, Ambios association already promotes several wildlife and biodiversity conservation measures (Ambios Ltd, 2018). Moreover, recommended conservation actions should not only be executed for setts inside the study area but also in others areas of Great Britain that present the same type of environmental characteristics influencing the location of entrances. We are aware that the present study was conducted with a small and spatially limited dataset. However, it was a first approach on the importance of several variables correlating with location of sett entrances.

It also may be pointed out that, to prevent badgers population isolation, policies promoting maintenance and connection between woodlands patches, preferentially deciduous forests, should be implemented (Rosalino et al., 2008). Plantation of hedgerows and woodlands might be encouraged, as these can act as dispersal corridors and provide places of sett entrances and food (Broekhuizen et al., 1986; Van Apeldoorn et al., 1998). On the other hand, badger survival is negatively associated with intensive agricultural practices (Lankester et al., 1991; Skinner et al., 1991a). Therefore, traditional (low intensity) agriculture may have important implications in landscape management for supporting badger conservation (Virgós and Casanovas, 1999). Moreover, educational activities should be promoted in order to increase public acquaintance and sensibility. Such tolerability may be also boosted throughout monetary compensation, for example, when land owners accept badgers activity on their land (Lankester et al., 1991; Van Apeldoorn et al., 1998). Construction of badgers' tunnels across roads and fences along roads may also contribute to a reduction in road mortality and an increase of movement rates, such as it should the reduction of speed limits on particular roads and road signs installation (Lankester et al., 1991; Van Apeldoorn et al., 1998).

Although environmental characteristics may be important for understanding which are the suitable conditions for entrances, some limitations may emerge. This is principally related in monitoring the suitable conditions in which setts may occur. In fact, these limitations are related to the impossibility of collecting data inside the sett without involving an invasive approach. By the Protection of Badgers Act 1992 of the United Kingdom, interfering with a badger sett, by means of damaging, destroying, obstructing or disturbing, purposely or not, is considered a transgression.

Using techniques such as Ground-penetrating radar may compensate these restrictions (for further details, see Nichol et al. (2003)). This is a non-invasive tool that has been used successfully and may be useful to survey and map badger setts (Nichol et al., 2003) besides only entrances. It helps to identify the extension of diggings, and the network of the tunnels and chambers of badgers, connecting these to the sett entrances located on the surface (Nichol et al., 2003). The use of this technology may be pertinent to conceive the best procedures to be followed when setts' safeguard is compromised (structural integrity, human intervention, etc; Nichol et al., 2003). This technique can be also useful in detecting some types of soil existing in the sites (Cortez et al., 2013; Nichol et al., 2003; Swinbourne et al., 2015), as well as it can help in the replication of structures for the construction of artificial setts which, for example, may be particularly useful in the translocation of displaced social groups (Harris et al., 1990) or relocation of badgers in cases of buildings development (Roper, 2010). It can also aid developing indices of population abundance and monitoring animal movements (Cortez et al., 2013; Swinbourne et al., 2015).

6. Conclusions

This study sought to understand which environmental conditions are suitable for badgers' sett entrances location. It was observed that the location of sett entrances by badgers relies on the dynamics between diverse environmental factors. Although there are several studies on the selection of habitats occupied by the badger, it's necessary, still, further investigation in this field. Entrances may act as good indicators of badgers' presence in the outer space of the sett without an invasive approach. This type of approach may possibly avoid greater damages of their setts and subsequent populations' persistence in setts, which is desirable when it comes to badgers' setts conservation.

Decisions concerning the intervention of setts should involve a prior and weighted assessment in order to comprehend if the viability and survival of badger populations may be compromised. Although the badger is a species with a conservation status of lesser concern, the overestimation of the impact of anthropogenic factors, not only on the direct instrumentation of the setts, but also on the landscape level - such as the expansion of road networks and agricultural intervention - can generate negative outcomes that are increasingly difficult to reverse on the maintenance of the setts and, consequently, of the populations. Future researches should take into account the cumulative effect of these factors, throughout the years, as they are likely to intensify in affecting badgers habitats.

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