Do fine-scale factors shape the use of riparian galleries by carnivores in a Mediterranean agro-forested environment?

Filipa Grilo[1], Eduardo Ferreira[2], Sandra Alcobia[3], Luciana Simões[4], Margarida Santos-Reis[5]

Centre for Ecology, Evolution and Environmental Changes (cE3c), Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisbon, Portugal

***Abstract*—** *Riparian galleries are key structural elements of Mediterranean landscapes and their importance for carnivores has been widely demonstrated. However, humanization of the landscape has led to their degradation with consequences not fully understood. In this study we assessed the response of mesocarnivores to the fine-scale variation in the quality of a riparian gallery (Vale do Cobrão stream, central Portugal), evaluated on the basis of the QBR index ('Qualitat del Bosc de Ribera' in spanish) and an adaptation of the same considering mesocarnivore ecological requirements. These were represented through four parameters that could influence habitat quality for these species, namely refuge (total riparian cover, cover structure), disturbance and food availability. For the latter we considered the known main food resources for Mediterranean mesocarnivores: small mammals, lagomorphs, insects and fruits. Mesocarnivore use was evaluated through camera-trapping and sign surveys. For both indexes a concordance was observed between quality variation and its use by carnivores, and we also found a positive correlation between both indexes. The adapted QBR, being more laborious but also more realistic, could serve as guidance for conservation practice at the local scale, benefiting both land managers environmentally concerned, conservation practitioners and carnivore populations inhabiting humanized landscapes. However, for spatially wider approaches the original QBR proved to be a good indicator for the presence of mesocarnivores, being useful in the development of restauration or conservation strategies, as well as for research and monitoring activities of carnivore guilds.*

Keywords*— *Habitat quality, mesocarnivores, QBR Index, riparian systems, conservation management.

I. INTRODUCTION

The Mediterranean basin is considered to be a biodiversity hotspot (Médail and Quézel 1999), being a mosaic of natural and cultural altered-landscapes, resulting from the long coexistence of human civilization and wild nature (Cuttelod et al. 2008).

These landscapes have been shaped by human activities for millennia (Naveh and Vernet 1991; Lavorel et al. 1998), yet, more recently, they have been subject to increasing anthropogenic pressures and disturbances which have led to drastic changes at the landscape level (Myers et al. 2000). Men actions, such as deforestation, cattle breeding, conversion of natural systems in agro or planted forest systems, intensification of agricultural practices and road construction, have shaped and transformed Mediterranean landscapes (e.g. Lepart and Debussche 1992; De Aranzabal et al. 2008; Geri et al. 2010), leading to the decline of many species of both the floral and faunal communities, and its replacement for a smaller number of exotic and expanding ones, a process known as biotic homogenization (e.g. McKinney and Lockwood 1999). This anthropogenization of the landscape has shown negative impacts on biodiversity, especially important in areas where the management is not adequate, and does not equally affect all landscape components.

Agriculture, lodging, fire and livestock grazing are the main drivers of deforestation and forest degradation (e.g. Hosonoma et al. 2012), impacting a significant part of the land's surface, but other side effects are also reported. This is the case of riparian galleries, which are unique and key structural elements in the landscape, maintaining regional biodiversity (e.g. Naiman et al. 1993, Ferreira et al. 2005). Established normally along river margins, forming dense patches of vegetation adapted to water and soil fluctuation dynamics (Naiman and Décamps 1997), they serve multiple roles, including the regulation of temperature and light regimes (Naiman and Décamps 1997), water provision (Malanson 1993; Naiman and Décamps 1997), nutrient retention (Jacobs et al. 2007), refuge for species (Sabo et al. 2005), provision of food and conditions for the reproduction of many animal species (Matos et al. 2009; Pereira and Rodriguez 2010), acting also as movement and dispersal corridors (Machtans et al. 1996; Burbrink et al. 1998), providing connectivity between isolated habitat fragments (Beier and Noss 1998; Santos et al. 2011). In regions of semi-arid climate, as some found in the Mediterranean, riparian galleries are the only habitat that remains less human intervened at the large scale (Virgós 2001a; Matos et al. 2009; Santos et al. 2011), holding high biodiversity levels (Sabo et al. 2005) considering their small land area (Naiman and Décamps 1997).

The response of wildlife to riparian corridors has been investigated by many authors, in different environmental contexts and for diverse animal taxa, from invertebrates (e.g. Da Silva et al. 2011), to amphibians and reptiles (e.g. Suazo-Ortuño et al. 2011), birds (e.g. Bennett et al. 2014) and mammals (e.g. Sullivan et al. 2014).

The conservation value of these linear habitats for carnivores in human-altered landscapes has also been highlighted (Virgós 2001b; Santos-Reis et al. 2004; Maiorano et al. 2006; Matos et al. 2009; Pereira and Rodriguez 2010), having been demonstrated that species richness and abundance is quite higher in riparian corridors, compared to an intervened matrix (Virgós 2001a; Matos et al. 2009), being also higher in conserved galleries than in degraded ones (Hilty and Merenlender 2004).

Although mammalian carnivores can persist in several habitat types, they are particularly sensitive to anthropogenic impacts, due to their vast spatial requirements and low population densities (Sunquist and Sunquist 2001). This makes them particularly vulnerable to human persecution and susceptible to changes in the structure and dynamics of their habitats (Schonewald-Cox et al. 1991; Hargis et al. 1999), being largely affected by habitat destruction and fragmentation (Schaller 1996). Their position at the top of the food chain, and impact on different human activities such as agriculture, hunting and livestock raising (Reynolds and Tapper 1996; Treves and Karanth 2003, Baker 2008), make conservation and management actions especially important.

Climate change projections for the Mediterranean, indicating a heat stress intensification (e.g. Diffenbaugh et al. 2007), makes riparian zones the only places where water and water-dependent resources can be found and therefore key landscape elements for carnivores (Virgós 2001a; Matos et al. 2009). Their association with these habitats is further explained by the inherent patchiness of the landscape (Schonewald-Cox et al. 1991; Hargis et al. 1999) and its seasonally variable resources (Rosalino et al. 2005; Loureiro et al. 2009).

Considering the importance of these habitats for carnivores (Pereboom et al. 2008; Pereira and Rodriguez 2010), and assuming that some of the ecological processes that affect more significantly populations and communities operate at local spatial scales (Huston 1999; Soto and Palomares 2015), species richness and abundance can vary depending on the availability of local resources, vegetation structure and size of the habitat patch (Wiens 1989; Dunning et al. 1992). For conservation purposes, it is therefore important to fully understand the factors driving carnivores' use of riparian ecosystems. The importance of riparian quality at landscape (Malanson 1993; Virgós 2001a) and regional (Naiman et al. 1993) scales have been demonstrated but, to our knowledge, carnivore response to variation in quality at the stream level was never investigated.

Considering that riparian galleries can have different ecological quality, A. Munné and collaborators (Munné et al. 2003) developed an index of riparian quality (QBR - 'Qualitat del Bosc de Ribera' in Spanish), to evaluate, in a expedite way, the quality of these habitats, regarding their physical and biological characteristics, namely the vegetation composition. However, the construction of this index and the derived management recommendations for riparian galleries, have been focusing on the importance of maintaining these systems at landscape level, not having yet analysed their importance and management needs at local level (Hilty and Merenlender 2004; Matos et al. 2009). Their foliage is supported by the high availability of water, and therefore man-made actions resulting in irregularities in the flow have negative impacts, for both riparian habitat (Salinas et al. 2000), as for its associated biota, including mammalian carnivores (Matos et al. 2009).

In this study we compared riparian ecological quality variation with the use made by carnivores, predicting that species occurrence and intensity of use is related to its fine-scale quality. We further tested if the QBR index developed by Munné et al. (2003 – hereafter termed as original QBR), and an adaptation of the same based on carnivore ecological requirements, may be used as prompt indicators of the occurrence of carnivores, serving as a guide for land managers and conservation practitioners.

II. METHODOLOGY

2.1 Study area

This study was conducted between June 2012 and June 2013, at Charneca do Infantado (hereafter only termed Charneca) in Companhia das Lezírias, S. A., the largest agro-forestry farmstead in Portugal (Fig. 1). Located on the left margin of the Tagus River, 40 km northeast of Lisbon, Portugal's capital, the Charneca is characterized by a typically Mediterranean climate, with dry and warm summers and wet and cold winters. It represents a managed agro-silvo pastoral system, mostly covered by cork oak woodlands (approx. 67%), which are also important for cattle production, interspersed with forest stands of pine trees and agricultural fields (e.g. olive yards, corn) (Gonçalves et al. 2009). The area stands over poor and shallow soils, with drainage problems.

Taking into consideration the extensive management the matrix is subjected to, the riparian zones constitute one of the few natural (or less disturbed) habitats in the area. Due to the above referred conditions, most waterways are small, have an intermittent regime and are highly disturbed, being Vale do Cobrão stream, the only waterline with relatively large width, regular flow and vegetation integrity in most of its extension, being selected for this study (Fig. 1).

Flowing three kilometers inside the farmstead, Vale do Cobrão runs east to west, being delimited upstream by a small dam and downstream by rice fields. It has undergone restoration actions in the past, including the plantation of white poplars (*Populus alba*) on its banks (Correia and Mexia 2011), now forming a riparian gallery that encompasses the riverbed itself, which varies from narrow to wide, the riverside and the floodplain, with smoothed out slopes being seasonally subject to flooding (Ribeiro et al. 1987; Santos 2013). Besides the planted poplars, the tree layer is dominated by willows (*Salix sp.*) and a dense shrub stratum, mostly consisting of brambles (*Rubus ulmifolius*), which often fully occupy the space adjacent to the watercourse (Gonçalves et al. 2009).However, selective cut of riparian vegetation is still in place to extend grazing area, thus creating heterogeneity at the fine-scale and varying riparian ecological status.

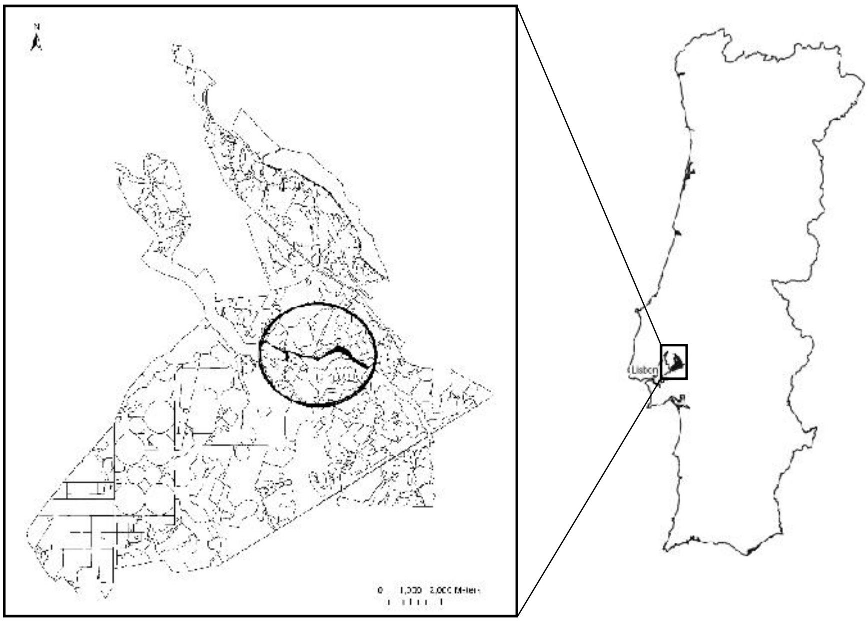

FIGURE 1: LOCATION OF COMPANHIA DAS LEZÍRIAS IN PORTUGAL (SQUARE) AND VALE DO COBRÃO STREAM (CIRCLE).

2.2 Field sampling scheme

Field surveys involved the fine-grained assessment of the variations in riparian quality of Vale do Cobrão, along 2500 m of extension, and the quantification of the intensity of use by carnivores, considering five sampling sections of 500 m each.

2.2.1 Assessment of the riparian gallery's quality

Each sampling section was divided in five consecutive transects (100 m each), used for the characterization of the riparian vegetation applying the QBR Index (Munné et al. 2003) and calculating its four parameters: total riparian cover – percentage of tree's canopy and connectivity with the surrounding woodland area; cover structure – percentage of trees and shrubs; cover quality – number of native tree's species and native tree continuity; channel alterations – related with anthropogenic actions. Each section's score was obtained by averaging the result of the five transects analysed. As explained by the QBR authors, grasses were excluded of this index due to their annuity and their variable cover.

Considering the requirements of carnivores, not fully expressed in the QBR index, an adaptation was proposed and calculated for the same five sections and also considering four parameters: total riparian cover, cover structure, disturbance factors and food availability. Both total riparian cover and cover structure were assessed in transects of 100 m and then averaged for the entire section, while the remaining two were assessed per section. Cover percentage of trees and shrubs, was considered due to their importance for the provision mostly of shelter but also food for carnivores (Mangas et al. 2008), and further valued by the width of the riparian zone, assuming that thicker galleries, with dense vegetation, are more attractive for carnivores (Santos et al. 2011). Herbaceous plants were not considered for not being key features for carnivores (Schmitz et al. 2000). Considering the referred preference of these mammals for large corridors of shrubs (Gittleman and Harvey 1982; Santos et al. 2011), for the second parameter, we considered the existence of extensive shrub patches, considering the percentage of cover by continuous shrubs in 100 m, in comparison with empty spaces or isolated shrubs, and then averaging for each section. The existence of trees with holes in each section was also scored due to the arboreal habits of some Mediterranean carnivores that find refuge in these natural features (e.g. Santos-Reis et al. 2004).

Considering that human disturbance is known to influence the presence and abundance of mesocarnivores (Sunquist and Sunquist 2001), for the third parameter, we considered three factors acting in the study area and known to negatively influence carnivores: i) proximity to grazing areas, due to biotic homogenization (Pita et al. 2009; Gonçalves et al. 2012) and deleterious effects on small mammals, indirectly influencing carnivores due to predator/prey bottom-up effect (Moreno-Rueda and Pizarro 2010); ii) flooding risk, due to the geomorphological characteristics of the area (Santos 2013), contributing to the inundation of the floodplain (Naiman and Decamps 1997) and consequently affecting the availability of shelter and food (Klinger 2006; Moreno-Rueda and Pizarro 2010; Golet et al. 2013); and iii) distance to the nearest road path, due to the avoidance of some carnivores of crossing open land (Virgós and Garcia 2002), its dependence of a structurally diverse vegetation (Galantinho and Mira 2009), the risk of being killed by other animals (Palomares and Caro 1999) and the risk of collision with vehicles, considering each section as being under road's influence if closer than 50 m from the path.

Regarding food availability, we included the four resource categories most frequently referred in the diet studies of mesocarnivores in Mediterranean landscapes (e.g. Santos-Reis et al. 2004; López-Martin 2006; Santos et al. 2007; Rosalino and Santos-Reis 2009) – small mammals, rabbits, insects and fruits, information locally validated through the analysis of collected and genotyped scats.

Food resources sampling was performed seasonally due its phenological variation (Rosalino et al. 2005). For small mammals, 20 folding traps (H. B. Sherman Traps, Inc.–Tallahassee, USA) were placed in a line in each section, with a trap spacing of 10 m, alternating a small trap (LFATDG–8x9x23 cm) with a large one (XLF1500–10x11x38 cm) to maximize the capture of different species; trapped animals were individually marked with a combination of fur clips (Gurnell and Flowerdew 2006) and their relative abundance calculated using the Pounds index (1981), that relates captures with capture effort. For rabbits, we counted latrines (> 20 droppings within a 20 cm radius – Virgós et al. 2003) along a path parallel to the stream; existing latrines were cleared prior to the first sampling event and relative abundance was expressed as the number of latrines per km (IKA – Index of Kilometric Abundance, Vincent et al. 1991). Insect sampling was done by placing a line of four pitfalls per section, that remained operative eight days on site; pitfalls were spaced two meters apart and protected by a plastic plate to prevent the effect of rain and debris, and a mixture of cooler liquid and water was used to preserve the captured individuals. Only insects of Coleoptera and Orthoptera orders were counted once these are the most consumed by carnivores (López-Martin 2006; Santos et al. 2007). For fruits, an inventory was conducted along each sampling section and all individuals producing fruits known to be consumed by carnivores were counted; relative abundance was then calculated, according to their fruitification season. For index purposes, in this parameter, we attributed a partial score (from 1 to 5), according to the minimum and maximum relative abundance found for each food category, being its final score the sum of the four partial ones, representing the section quality in terms of food availability.

For both indexes, each parameter could vary between 0 and 25. However, the 25 points could be exceeded, due to the extra scores considered, being in these cases, attributed the maximum score. The final QBR scores were calculated through the sum of the values found for each criteria considered, varying between 0 and 100. For further details see the form in annex.

2.2.2 Assessment of the riparian gallery's use by carnivores

To assess riparian gallery use by mesocarnivores two field methods were employed: camera-trapping and sign surveys (Wilson and Delahay 2001; Lyra-Jorge et al. 2008).

Ten Bushnell® Trophy Cam Digital scouting camera UV562, equipped with motion sensors and infrared night lighting, were placed along the riparian vegetation of Vale do Cobrão, 250 m apart from each other (two per section), aiming to record the presence of terrestrial mesocarnivores inhabiting the area: red fox (*Vulpes vulpes*), stone marten (*Martes foina*), badger

(*Meles meles*), Egyptian mongoose, (*Herpestes ichneumon*) and genet (*Genetta genetta*). Otters (*Lutra lutra*), also present in the area, were not considered in this study due to their aquatic lifestyle. Five of the 10 used cameras were in place since the summer 2012, 500 m apart from each other (one camera per section) and other five cameras were field-placed in the autumn 2012 to increase detection rate. Cameras were inspected every two weeks and the percentage of frequency of occurrence (%FO) of each mesocarnivore was calculated (Kelly and Holub 2008); results of the two cameras were summed to find the %FO per section. To minimize data replication single captures of the same species where only considered if a 30min (same camera) or 60min (two cameras) interval was registered, unless more than one individual could be clearly distinguished (Davis et al. 2011).

For the sign surveys, the 2500 m length of the stream margin was searched for counting and collecting carnivore scats with a dual purpose: species molecular identification and analysis of food resources consumed. Prior to effective sampling a previous round allowed the elimination of old scats. Molecular analysis followed the protocol of Fernandes et al. (2008) using the red fox's molecular marker, due to its known abundance in the area (Gonçalves et al. 2009) and conspicuous scats, deposited in easily detectable sites (Brown et al. 2004). Scat analysis, for dietary purposes, was performed using a standard protocol (e.g. Reynolds and Aebischer 1991; Rosalino et al. 2005) and available species identification keys (e.g. mammalian fur - Pinto 1978; Teerink 1991) or guides (e.g. insects - Chinery 1997), complemented with reference collections.

2.3 Data and statistical analyses

Due to the reduced number of replicates, and the unavoidable spatial autocorrelation, data was analysed on the basis of descriptive statistics. Using chi-square test ($\chi 2$) we tested differences between scat sample sizes in the different sections. Non-parametric correlations (Spearman) were calculated between the adapted QBR and the frequency of use by carnivores, and between both indexes (original and adapted). Statistical tests were performed in StatSoft STATISTICA 10 Inca software and GraphPad Prism 6. For all tests statistical significance was accepted for probability values lower than 0,05.

III. RESULTS

Considering the original QBR, sections 1 and 5 presented the highest ecological quality, while section 2 was the most disturbed (Table 1). Section 5 was also the one that demonstrated to better fulfill carnivore ecological requirements, while section 3 almost consistently scored lower values (Table 2). The adapted QBR consistently scored less than the original index and no agreement was found for the two indexes when referring to lowest quality section.

3.1 Assessment of the riparian gallery's quality

Both QBR indexes revealed variations in the quality of the riparian gallery along the different sampling sections.

In the original QBR**,** after considering the four analysed parameters, we concluded that the first parameter, total riparian cover, varied the most among sections. Sections with the lowest score in this parameter presented the lowest final scores, and therefore, worst habitat qualities (Table 1).

TABLE: 1
ORIGINAL QBR INDEX FINAL SCORES, FOR EACH OF THE FOUR PARAMETERS CONSIDERED, FOR THE FIVE SAMPLING SECTIONS.

	Total riparian cover	Cover structure	Cover quality	Channel alterations	Total
Section 1	17	16	25	25	**83**
Section 2	1	16	25	23	**65**
Section 3	5	18	25	25	**73**
Section 4	15	19	22	25	**81**
Section 5	15	19	24	25	**83**

The same did not applied for the adapted QBR, as variations were found in all parameters, including the one referring to food availability (Tables 2 and 3). In this index, the parameters that varied the most between sections were cover structure and disturbance factors. No evident seasonal variations were found.

TABLE: 2
ADAPTED QBR INDEX SCORES FOR EACH OF THE FOUR PARAMETERS CONSIDERED, FOR THE FIVE SAMPLING BUFFERS. IN THE PARAMETER "FOOD AVAILABILITY" THE FINAL SCORE OF EACH SEASON IS SHOWED, ALONG WITH THE MEAN THROUGHOUT THE YEAR.

	Total riparian cover	Cover structure	Disturbance factors	Food availability					Total
				Summer	Autumn	Winter	Spring	Mean	
Section 1	25	21	5	20	13	12	10	**13,75**	**64,75**
Section 2	22	15	5	20	13	13	11	**14,25**	**56,25**
Section 3	15	4	5	14	9	9	6	**9,5**	**33,5**
Section 4	25	13	10	21	13	15	11	**15**	**63**
Section 5	25	5	25	14	10	9	12	**11,25**	**66,25**

TABLE 3:
MINIMUM AND MAXIMUM RELATIVE ABUNDANCE, PER SEASON, OF SMALL MAMMALS, INSECTS, LATRINES OF LAGOMORPHS AND INDIVIDUALS OF FRUIT TREES, CONSIDERING THE FRUITIFICATION SEASON OF EACH FRUIT SPECIES.

	Summer		Autumn		Winter		Spring	
Diet items	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Small mammals	65,97	200,87	84,46	127,42	85,71	296,35	25,32	230,70
Lagomorphs	0,4	6,4	0	1,2	0	0,4	0	0,4
Insects	0,12	0,36	0	0,38	0,09	0,36	0,05	0,55
Fruits	86	114,4	3,2	66,8	0	8,8	0	0

The graphical comparison between the scores obtained with the original QBR and the mean scores of the adapted QBR illustrates that, for all sections, the first consistently scored higher that the second, over-valuing its quality (Fig. 2). Also, concordance is shown between sections with the highest scores for both QBR's, but not between sections with the lowest scores. Nevertheless, the original QBR was positively correlated with the adapted one (r_s=0.87; p-value 0.05; N=5).

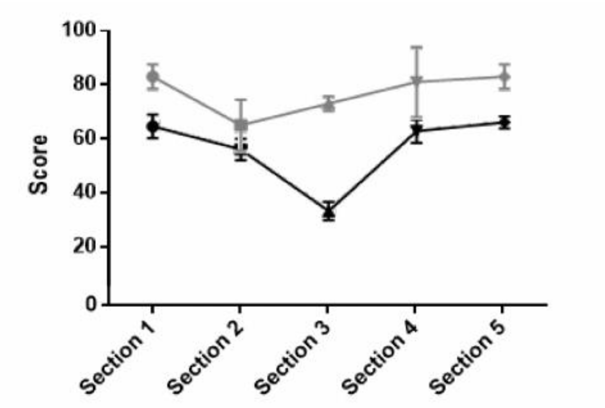

FIGURE 2: MEANS AND STANDARD DEVIATION OF THE FINAL SCORES OF BOTH INDEXES: IN GREY, THE ORIGINAL QBR; IN BLACK, THE ADAPTED QBR (CONSIDERING FOUR SAMPLING SEASONS FOR THE FOURTH PARAMETER).

3.2 Assessment of the riparian gallery's use by carnivores

During the study period, with a camera-trapping effort of 366 camera-trapping nights, 5279 photographs of mesocarnivores were registered, and 62 scats were collected.

All the most common five species of terrestrial mesocarnivores known to inhabit the study area (Gonçalves et al. 2012) used Vale do Cobrão riparian gallery, but the intensity of use among sections varied, as demonstrated by the results of both methods.

Camera-trapping results show that, as expected, the red fox was the species most frequently captured (52% of total independent captures), with a significant variation in the intensity of use among sections (Fig. 3). Sections 1, 4 and 5 had the highest number of photos (n=1179; n=1128; n=1056, respectively) and also of scats collected (n=14; n=23; n=14, respectively), while sections 2 and 3 had the lowest numbers, both for photos (n=915 and n= 1001) and scats (n=4 and n=7). Also, the results showed significant differences for the number of scats found for sections 1 and 3, 3 and 5 (χ^2=4,60; *p*=0,032 for both), and 3 and 4 (χ^2=8,53; *p*=0,004). We did not considered section 2, for having less scats than the minimum considered for the test (n=5).

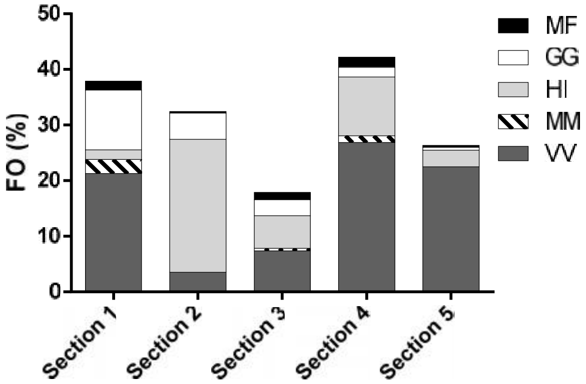

FIGURE 3: FREQUENCY OF OCCURRENCE (%) OF MESOCARNIVORES, ESTIMATED BY CAMERA-TRAPPING, IN EACH OF THE FIVE SAMPLING SECTIONS OF VALE DO COBRÃO STREAM (VV= *VULPESVULPES*; MM = *MELESMELES*; HI = *HERPESTES ICHNEUMON*; GG = *GENETTAGENETTA*; MF = *MARTESFOINA*).

Based on the contents' analysis of the collected scats, evidence was found of a higher consumption of insects (FO=65%), fruits (FO=63%) and mammals (FO=58%), both small mammals (FO=47%) and rabbits (FO=22%), validating the selected food resources considered for evaluating the fourth parameter of the adapted QBR. To a much smaller extent, birds (FO=5%), reptiles (FO=3%) and crayfish (FO=3%), were other resources consumed and therefore considered as occasional food sources.

The molecular identification of the collected scats indicated that 34% were from red fox, confirming, along with the referred camera-trapping results, the higher intensity of use, and presumed higher abundance, of this species in the study area.

3.3 Riparian gallery quality vs. carnivore's use

Considering the results of both QBR indexes, the riparian sections with the highest quality were those more intensively used by carnivores, both considering the camera-photographs and the number of scats. However, results did not show a fully agreement between both indexes, once section 2 had the lowest score in the original QBR, despite of showing a high number of carnivore occurrences. Inversely, considering the adapted index, the poorest quality sections had also the lowest number of scats and camera-photographs. When considering all seasons, the adapted QBR scores were positively correlated with the mesocarnivore's %FO either considering the camera-trapping results (rs=0.34; p-value 0.14; N=20) or the number of scats collected (rs=0.56; p-value 0.01; N=20).

IV. DISCUSSION

Our study confirmed that most terrestrial mesocarnivore species known to inhabit the study area (Gonçalves et al. 2009) used the studied riparian gallery, being in lign with previous research in other Mediterranean areas (Virgós 2001a; Santos-Reis et al. 2004; Santos and Beier 2008; Matos et al. 2009; Pereira and Rodriguez 2010), but improving our knowledge on how use intensity relates with habitat quality.

Large scale factors have been widely considered when studying carnivore species or communities (Oehler and Litvaitis 1996; Barea-Azcón et al. 2007), but here we were able to demonstrate a variation in the intensity of use of carnivores when considering different and contiguous sections of the same riparian gallery and its quality. Results therefore support our initial hypothesis that fine-scale quality factors do shape the use of these corridors by carnivores, in a Mediterranean agro-forested environment, due to several factors that include the physical characteristics of the stream and the gallery itself (width and road proximity), differences in resource availability along its extension (availability of food and shelter) and the structural complexity of the gallery (riparian cover).

For both QBR indexes, a consistent relation was observed between sections with better habitat quality and a more frequent presence of carnivores. However, the original QBR resulted in considerably higher scores than the adapted one, overstating the composition and structure of the vegetation found at each location.

The adapted QBR, driven by the requirements of carnivores, presented a more realistic approach, due to the incorporation of factors that are known to influence the choice of habitat by these species (Sunquist and Sunquist 2001; Mangas et al. 2008; Santos et al. 2011), being a better indicator of the habitat quality for carnivores.

In this index calculations, data analysed varied seasonally and correlations calculated for each season were non independent. However, these variations did not contribute to the variance of the scores found in the adapted QBR, due to a compensation when considering a decrease (or increase) in the abundance/consumption of a group, by an increase (or decrease) of another group, as shown in several other studies (Fedriani et al. 1999; Rosalino et al. 2005; Rosalino and Santos-Reis 2009).

The positive correlation between the original and adapted QBR indexes, despite the limited statistical significance (most probably due to the small number of replicates), suggests a clear trend in the association between the indexes. If confirmed, it could enable the large-scale application of the original QBR as a good habitat quality indicator for mesocarnivores, supporting this paper’s complementary hypothesis.

This study presents a more structurally complex approach, when compared with past studies that did not considered carnivore’s specific requirements (Hilty and Merenlender 2004; Matos et al. 2009; Santos et al. 2011), including the variety of food resources chosen and validated through scats’ analysis. However, we suggest the application of the adapted index in a larger spatial context, increasing the number of replicates to better support the working hypothesis. Including areas with different characteristics, e.g. contrasting quality matrixes and/or non-Mediterranean landscapes, would further increase the study’s interest for land managers and conservation practitioners.

In the area analysed, riparian habitats are essential for the studied species, in view of the current land use and management options of the Charneca (Gonçalves et al. 2009; Santos 2013). The demonstrated relevance of a fine-scale approach shows that proper management includes the necessity of promoting not only the existence of these habitats, but also their quality, once shown that their degradation influences its use by carnivores. Thus, we believe that this study provides important clues for proper management and planning of agro-forested areas, being also useful in defining research and monitoring actions of carnivore guilds in humanized landscapes.

V. CONCLUSION

Considering the current growth of the world’s human population, that leads to an increasing need for food production areas, riparian zones are of extreme importance for providing adequate habitat for many species, carnivores included, and for long-term sustainability of agro-forestry systems. With a fine-scale functional approach, we concluded that better habitat quality of riparian vegetation translates in a higher use by carnivores, evidence that, if confirmed at a larger geographic extent, could endorse that actions of preservation and enhancement of riparian systems along the stream, at a local level, would certainly benefit the conservation of Mediterranean landscapes.

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ANNEX: FIELD SHEET

QBR Index: Adaptation to the requirements of carnivores

Score of each part cannot be negative or exceed 25

Section	
Date	

Parameter 1: TOTAL RIPARIAN COVER	
Score	***Category***
25	≥ 80% of riparian cover
10	50−80% of riparian cover
5	10−50% of riparian cover
0	<10% of riparian cover
Extra score	
15	Width of the riparian gallery higher than 30 meters
10	Width of the riparian gallery between 20 and 30 meters
5	Width of the riparian gallery between 10 and 20 meters
1	Width of the riparian gallery lower than 10 meters
Parameter 1 final score	

Parameter 2: COVER STRUCTURE	
Score	***Category***
25	≥ 80% of extensive shrub matrix
10	50 - 80% of extensive shrub matrix
5	10 - 50% of extensive shrub matrix
0	<10% of extensive shrub matrix
Extra score	
5	With trees with holes
− 5	Without trees with holes
Parameter 2 final score	

Parameter 3: DISTURBANCE FACTORS			
Score	***Category***		***Factor(s)***
25	Area without disturbance	Without influence of any factor	
10	Moderately disturbed areas	With influence of one of the factors	
5	Slightly disturbed areas	With influence of two of the factors	
0	Very disturbed areas	With influence of all factors	
Parameter 3 final score			

Parameter 4: FOOD AVAILABILITY				
Score	***Category***			
	Small mammals	**Lagomorphs**	**Insects**	**Fruit trees**
5	≥ 200	≥ 15	≥ 9	≥ 100
4	150 - 200	10 - 15	6 - 9	75 - 100
3	100 - 150	5 - 10	3 - 6	50 - 75
2	50 - 100	1 - 5	1 - 3	25 - 50
1	< 50	< 1	< 1	< 25
Attributed score for each item				
Parameter 4 final score				

Final score: