Is polecat (Mustela putorius) diet affected by “mediterraneity”?

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Abstract

Carnivores in Mediterranean ecosystems respond to the inherent heterogeneity of these systems by tracking the spatial and temporal availability of food resources. This feeding strategy, however, has been associated primarily with generalist carnivores and little is known for specialist species such as the European polecat. We collected polecat scat to determine the diet of this species, how it matches the seasonal availability of food resources, and how it is affected by population spatial structure and anthropogenic disturbance. Polecats were present in only 34% of the surveyed area and were clumped into three main population nuclei. Despite the spatial segregation of the populations, they had no significant differences in food items consumed. Polecats mostly fed on mammals (percentage of occurrence (P.O.)=43%) and arthropods (P.O.=49%). Biomass intake was also mostly from mammals (percentage of biomass (P.B.)=96%), followed by birds (P.B.=3%), with arthropods contributing less than 1%. Lagomorphs were the most consumed prey (P.O. = 25% and P.B. = 87%), which is consistent with the marked spatial overlap between scat with high content in lagomorphs and the areas with high wild rabbit availability. These results indicate that polecats are specialists in the consumption of wild rabbits, spatially track the availability of this prey, and may be affected by the decrease in abundance of the prey populations. Future conservation of polecats in Mediterranean regions of southern Portugal may be achieved through the restoration of hunted and diseased wild rabbit populations.

Keywords: European polecat; Wild rabbit; Conservation; Alqueva dam; Guadiana basin

Introduction

Mediterranean-type ecosystems are a mosaic of landscape patches. This inherent heterogeneity is a result of varying natural disturbance regimes (for example see, Rundel et al. 1998) combined with long-term anthropogenic influence (Blondel 2006). This has resulted in a biotic community with high resilience (Lavorel 1999). The dynamism of these systems, induced by natural fire regimes, deforestation, land conversion and multi-use subsistence agriculture, poses challenges to the wildlife depending on these ecosystems. Mammalian carnivores have large home ranges, which makes them greatly affected by habitat heterogeneity and loss. Thus, they are often indicator species and their populations require urgent conservation actions (Singleton et al. 2002). Carnivores are also important regulators of ecosystem function because of their role in controlling prey populations (Terborgh et al. 1999), and have evolved different feeding strategies to match the resource availability within the ecosystem they inhabit.

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In Mediterranean-type ecosystems, it has been demonstrated that carnivore species have evolved behavioral and ecological traits to respond to the long-term anthropogenic presence (Rundel et al. 1998), a phenomena named “mediterraneity” (Virgós 2002). Mediterranean-type ecosystems are resource poor environments (Virgós 2002), limiting carnivore populations. As a response to low resource availability, some carnivores have switched their feeding strategies to an omnivorous diet, with higher abundance of fruits in their diet during the summer, and insects and mammals in the winter, which matches the seasonal abundance of these food resources (Rosalino et al. 2005a; Rosalino and Santos-Reis 2008; Rosalino et al. 2009). For example, Eurasian badger (Meles meles), stone marten (Martes foina), and red fox (Vulpes vulpes) in the Iberian Peninsula are highly plastic in their food preferences and track seasonal resource availability (Ciampalini and Lovari 1985; Loureiro et al. 2009). Also, exotic species such as the Egyptian mongoose (Herpestes ichneumon) and the common genet (Genetta genetta), naturalized in these regions for over 500 years (Dobson 1998), seem to have adapted to a similar behavior of tracking available food resources (Palomares and Delibes 1991; Virgós and Casanovas 1997). However, a clear knowledge gap exists for less common species, such as the European polecat (Mustela putorius).

Polecat populations in Europe show a declining trend, according to the 2008 IUCN census, and a fragmented distribution (Santos-Reis 1983; Roger et al. 1988), except for the UK, where they are expanding as a result of a successful recovery plan implemented in the mid-20th century (Birks and Kitchener 1999). This unfavorable population status has limited our knowledge of this species; only a few relevant studies concerning the diet of the species exist, but most are focused on its central European range. These have shown that the polecat is a specialist predator, preying mostly upon rodents (P.O. = 56%) and anurans (P.O. = 17%) (Lodé 1997; Baghli et al. 2002; Lanszki and Heltai 2007), whereas in the UK the main prey are wild rabbits (Oryctolagus cuniculus) (P.O. = 85%) (Birks and Kitchener 1999). In Mediterranean-type ecosystems of southern Europe, polecat population trends are largely unknown (Santos-Reis 1983; Lodé 1994; Cabral et al. 2005; Mestre et al. 2007) - locally the species has been given the status of Data deficient according to the Portuguese Red Book of Vertebrates (Cabral et al. 2005) - but empirical evidences suggest a similar pattern to that observed in continental Europe. Furthermore, the recent (2000-2002) construction of Alqueva dam in southeastern Portugal (creating the largest artificial lake in Europe) has exacerbated the fragmentation of polecat populations in the region (Santos et al. 2008), and it may also have affected prey availability (Mestre et al. 2007). Given their population structure, it is predicted that polecats respond to mediterraneity by targeting the seasonally available food resources (small mammals, fruits and insects) instead of maintaining the dietary specialisms (mainly focusing on wild rabbits) observed in other European areas of their range.

Since several carnivore species are known to change their dietary preferences considerably in Mediterranean ecosystems in response to “mediterraneity”, we wanted to test if the same pattern was observed for the polecat using the Alqueva Dam area as a case study. Our working hypothesis was that polecats in Mediterranean landscapes would follow the same pattern observed for other meso-carnivores in tracking the available resources and thus having a more omnivorous diet. Our specific goals were to: (1) quantify the main prey items of the polecat diet, and (2) assess if polecats are affected by mediterraneity. Finally, we interpret our results in the light of informing management and mitigation measures to promote polecat population persistence and counteract negative impacts such as those of the Alqueva Dam.

Material and methods

The study was conducted in the 155,428 ha Alqueva Dam impact area (Alentejo, SE Portugal) (Fig. 1). The landscape of this region is characterized by a patchwork of agricultural fields (cereal grounds, orchards and olive groves), holm oak (Quercus ilex) and cork oak (Q. suber) woodlands, and eucalyptus (Eucalyptus globulus) and pine (Pinus spp.) forest plantations. The climate is characterized by mild winters (mean temperature <18 °C) and extremely hot summers (maximum temperature >40 °C) (Chicharo et al. 2001; Carmel and Flather 2004; Santos and Miranda 2006), with annual precipitation levels between 400-600 mm (Chicharo et al. 2001). Human settlements are concentrated in few cities and farmhouses scattered throughout the landscape.

Polecat scat collection

We subdivided the study area into a grid of 5 × 5 km² cells. In each cell, two experienced observers surveyed for signs of polecat presence along transects. Transects were selected to sample land-cover types in proportion to their occurrence within each 5 × 5 km² cell, with a total transect length of 10 km per cell. Due to the reported association of polecat with riverine and riparian habitats (Lodé 1993), a directed sampling design was applied to the portions of transects that crossed waterways in which an additional 600 m transect was walked along each side of the waterways to complement the survey. We conducted sign surveys every month during 1999 and 2000, before the flooding of the Alqueva reservoir. Scat were collected and the geographical location recorded for a posteriori mapping. Polecats have a sympatric distribution with stone
Martens and weasels (*Mustela nivalis*), whose scat sizes overlap at widths between [1.3-1.5 cm] and [0.5-0.7 cm], respectively (Bang and Dahlström 1974). To prevent misclassification of scats, we only selected those that not only had the characteristic polecat odor, but also whose maximum width was <1.3 cm and >0.7 cm. Unfortunately, specific primers for genetic identification of both the polecat and its sympatric species were not yet available at the time of this data collection (Fernandes et al. 2008). This resulted in a collection of a total of 78 scats, which could be interpreted as a relatively low number with which to assess the species diet. However, this number is in accordance with the low population density in the area (1 capture for a trapping effort of 1443 trap/nights, M. Santos-Reis unpublished data) and is close to that used in analogous diet studies; for example, in Luxembourg 121 scats of polecats were collected over three years of study (Baghli et al. 2002). Furthermore, we tested if the number of scats was sufficient to determine prey items by plotting the cumulative number of randomly selected scats versus the number of new prey items added by each scat, which reached a sill at 4 prey items, indicating the scat sample was sufficient for further analysis.

Fig. 1. Alqueva Lake location in the Alentejo Region, southern Portugal. Alqueva Lake corresponds to the area flooded and surrounding impacted area corresponds to the total monitored area. Overlaid are the scat spatial distribution and polecat population nuclei polygons (fine contour lines).
Polecat scat laboratory analysis

The collected scat samples were analyzed following standard procedures (Reynolds and Aebischer 1991). Scat were dried in an oven, washed through a mesh, and non-digested remains were separated under a magnifying scope. Non-digested vertebrate and invertebrate body parts and vegetable remains (e.g., number of seeds, number of insect legs, etc.) were used to identify consumed prey and estimate the minimum number of individuals (Madureira and Ramalhinho 1981; Brom 1986; Barrientos 1988; Teerink 1991). Identifiable undigested remains were dried and weighted to obtain the dry weight for each prey-group and for five broad food item categories: mammals, birds, reptiles, arthropods, and fruits.

Data analysis

The minimum number of prey was expressed as percentage of occurrence (P.O.), calculated as follows:

\[ P.O. = \left( \frac{n_i}{N} \right) \times 100 \]

Where \( n_i \) is the number of individuals or fruits of the same species or taxonomic group (\( t \)) and \( N \) is total number of consumed items. P.O. estimations were based on the sum of the minimum number counts of individuals/fruits identified in each polecat scat. For percent biomass (P.B.) calculations, we applied known digestibility coefficients for polecat to each prey-group dry weight (Jedrzejewska and Jedrzejewski 1998); for additional prey items not previously assessed, we used digestibility coefficients determined for sympatric carnivore species (Palomares and Delibes 1990; Rosalino et al. 2003). Digestibility coefficients were estimated as the ratio between biomass of the ingested prey to the biomass of the prey remains after digestion, as estimated by food supplementation experiments. These were used to estimate intake biomass, which then was used for the P.B. calculations as follows:

\[ P.B. = \left( \frac{b_i}{B} \right) \times 100 \]

Where \( b_i \) is the consumed biomass, estimated by multiplying the weight of undigested remains found in scat for each food item \( i \) by their digestibility coefficients and \( B \) is total biomass, estimated as the sum of the individual biomass estimates (\( b \)) for each sample.

The scat spatial location and its clustering in the study area were used to determine population geographical range and key nuclei. Population distribution range was determined using a fixed kernel method applied to 100% of the geographic locations of scat and population nucleus boundaries were defined by the contours of the 50% kernel, which is a standard criterion to define the area of maximum activity (Worton 1989). Scat location data was considered as independent data points (Swihart and Slade 1985, 1986) when locations were obtained at a distance greater than the maximum length (700 m) of the species’ average home range (Lodé 1993). Data was analyzed in ArcView® version 3.1 using Animal Movement SA Version 2 for ArcView (USGS-BRD, Alaska, USA) (Hooge and Eichenlaub 1997).

Since our scat sample size was relatively small, we first tested if there were significant differences between distributions of each prey item in polecat diet in the two years. Since there was no significant year effect, we pooled the data to test if there were differences in the diet of polecats attributable to the nucleus spatial location using ANOVA. If significant differences were found we compared each nucleus pair with post hoc Tukey tests (Zar 1999) to assess which nuclei were most different in terms of overall diet preferences and prey items consumed. All analyses were performed using the statistical package SPSS 13.0 for Windows (Chicago, USA).

Finally, to assess the degree to which polecats track available resources we used available data on wild rabbit. Despite the scat analysis only identifying lagomorphs’ hairs and not distinguishing between hares and rabbits, we believe that wild rabbit is most likely to be polecats’ major prey in the area. Wild rabbit has a higher density in the study area and its reduced speed when compared to a hare makes rabbits easier to capture by a polecat. We used the predicted distribution of wild rabbit presence within the study area, as created by a predictive logistic regression model (for model details see Santos et al. 2008), and overlaid it with the polecat scats that had lagomorphs content. Overlap analysis (Brito et al. 1999) was used to determine if prey consumption was spatially coincident with prey availability. This method allows estimating the degree of overlap between two resources or spatial variables to measure the extent of co-dependence measured as the percent overlap between the predator and the prey spatial distribution.

Results

We detected polecats in 34% of the surveyed area. The total number of scat collected in each year was not significantly different (\( P > 0.05 \)) and showed a clumped spatial distribution that was partitioned into three population nuclei: north (Northern segment of Guadiana River – Pardais stream; \( n = 14 \)), central (Central area of Guadiana River – Azevel, Álamo and Alcarrache Streams; \( n = 26 \)), and Degebe River (\( n = 35 \)) (Fig. 1).

Polecat diet (Table 1) was mainly composed of mammals (P.O. = 43.31%; P.B. = 95.78%), which were only surpassed by arthropods, and only for P.O. (49%). The least consumed prey items were reptiles. The most consumed mammals were lagomorphs, for both P.O.
and P.B., followed by *Apodemus sylvaticus* and *Rattus* spp. (Fig. 2). There were no significant year differences in the diet of polecat (F = 2.2, p = 0.12).

There was no spatial segregation in polecat diet amongst the nuclei. The proportions of each of the food items consumed in each of the nuclei were not significantly different (F<sub>mammals</sub> = 0.8, p = 0.35; F<sub>birds</sub> = 0.4, p = 0.67; F<sub>reptiles</sub> = 0.08, p = 0.89; F<sub>arthropods</sub> = 0.6, p = 0.42; F<sub>fruits</sub> = 1.2, p = 0.25). Lagomorphs were the most consumed prey in all nuclei, indicating that there is no spatial partitioning of prey resources. Moreover, rabbits did not show an even distribution in the study area and a high spatial overlap (78%) was observed between areas with higher likelihood of wild rabbit’s presence and consumption of lagomorphs (Fig. 3).

**Discussion**

Our results show that polecats in Mediterranean areas of southern Portugal are specialists in the consumption of lagomorphs, most probably wild rabbits, spatially tracking the availability of this prey. Our findings suggest two interpretations: (1) despite the seasonal fluctuations in prey availability that characterize Mediterranean-type ecosystems, polecats did not follow a similar feeding strategy of other carnivores in such systems, and instead were highly specialized in the consumption of lagomorphs; (2) to maintain this high food specialization, polecats spatially track the areas with higher wild-rabbit abundance and this may explain the fragmented distribution and declining populations of polecats in the region.

Scat surveys have long been used to describe and compare the diets of many species. Commonly attributed biases of this analysis include the sample size, diversity of individuals sampled, size of the geographic area, and time of year of scat collection (Trites and Joy 2005). These authors state that a sample size of 59 scats is sufficient to identify main prey, and our sample size matches this criterion. We believe that out study area (155,428 ha) is sufficiently large to encompass the variability of the diet and to meet the diversity of individuals sampled, due to the observed spatial distribution of the collected scats (See Fig. 1). Since we were assessing yearly patterns of omnivory, we pooled all the data from an entire year, thus seasonal differences were not analyzed. A concern, however, is the ability of scat sampling to represent all prey items equally as non-digested remnants are prey specific, with higher incidence of hard structures like bones and exoskeleton. Previous reports of polecat diet have not indicated a high consumption of prey items that are completely digested (Baghli et al. 2002; Lanszki and Heltai 2007); however, this may simply be because of lack of

![Fig. 2. Mammal species consumed by the European polecat in the Alqueva Dam. (a) P.O. (Percentage of Occurrence) and (b) P.B. (Percentage of Biomass; Mammals NI – Non-Identifiable mammal remains).](image-url)
detection. We believe that lagomorphs provide for most of polecats energetic needs, thus reducing the likelihood of consuming other prey, including those that are highly digestible. Our analysis, however, was not able to differentiate between hares (\textit{Lepus granatensis}) and wild rabbits from scat samples (lagomorph hairs). However, it is most likely that these hairs belong to wild rabbit because of the lower likelihood of capturing hares and the higher density of wild rabbits in any given location. Nonetheless, our findings that wild rabbit comprise about 95\% of the ingested biomass are not surprising, since in the UK this has been reported as the most consumed prey (Birks and Kitchener 1999), which is available throughout the year (Palomares and Delibes 1997; Angulo and Villafuerte 2004; Calvete et al. 2004; Moreno et al. 2004).

One of the "requirements" for species co-existence is the diversification of species' realized niches. This diversification may occur through a division of the carnivore community into, for example, rabbit specialists and non-rabbit-specialists. We believe this is the reason why polecats are still successful specialist predators of wild rabbits in Portuguese Mediterranean-type ecosystems. Polecats are known to be exceptional predators of rabbits, since their body shape and configuration is well adapted to "visit" rabbit dens and facilitate the capture of this prey (Lodé 1994; Parker and Birks 1999; Baker et al. 2005). Furthermore, the availability of rabbit has been described as a major factor driving polecat habitat selection (Lodé 1994; Baghli et al. 2005). Three other species of the Portuguese carnivore fauna also follow the wild rabbit specialist strategy: another mustelid, the weasel (\textit{Mustela nivalis}) (Santos-Reis 1989); and two felids, the wild cat (\textit{Felis silvestris}) (Sarmento 1996; Gil-Sanchez et al. 1999) and the Iberian lynx (\textit{Lynx pardinus}) (Palomares et al. 1995). The felids' specialization strategy may be explained by their need for higher energy content as may be provided by wild rabbits. In contrast, the weasel and the polecat seem to specialize on wild-rabbits because their body shape enables them to enter rabbit dens, a characteristic not shared with other Mustelid family members of bulkier body shape.

However, the maintenance of this highly specialized diet further hinders the long-term persistence of polecat populations in Portuguese landscapes. As the wild rabbit populations decline due to myxomatosis and viral haemorrhagic disease (Mutze et al. 2002), take by other predators such as wildcat (Sarmento 1996; Gil-Sanchez et al. 1999), and take by humans through over-hunting (Angulo and Villafuerte 2004), the already
fragmented polecat populations may be hindered in their recovery by the concurrent decline of their main prey. A potential solution may be a strategy of prey restocking and wildlife immunization programs (Calvete 2006), which has been proposed for the maintenance of Iberian lynx populations (Moreno et al. 2004), and can aid the future persistence of polecat populations.

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