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Research paper

Diet footprint of Egyptian mongoose along ecological gradients: effects of primary productivity and life history traits

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ABSTRACT

The Egyptian mongoose (*Herpestes ichneumon* Linnaeus, 1758) is an expanding species, whose presence in Europe is restricted to its western extreme. Mongooses are generalist and opportunistic carnivores which is reflected by their anatomical features and nutritional preferences. With the purpose to fully characterize mongoose diet and ascertain if game species overlap within the guild of consumed food items, a total of 122 stomach contents of animals resulting from hunting activities and accidental road kills from seven provinces of mainland Portugal were identified. In order to identify which factors influence the nutritional requirements and food preferences of the Egyptian mongoose, several individual parameters (body condition, spleen weight, age class, fat levels and sex) were related with bio-ecologic features, as seasonality, region, habitat primary productivity, climate, human disturbance and environmental conditions.

The results suggested that the diet of the Egyptian mongoose is mainly composed of mammals. Mammals and amphibians were predominant in males' stomach contents, while reptiles and invertebrates overlapped other food categories in females' diet. Diet (food categories) variations across age groups were registered. The consumption of prey also varied throughout the year, according to availability and mongoose energy uptake needs, with a higher consumption of more energetic prey during the breeding season. Mongooses consumed more mammals and reptiles in areas with higher primary productivity. Our data thus suggest that the consumption of reptiles, predominantly by females, results in heavier spleens, possibly driving to greater investment in immunity and better animal performance during the breeding period.

In a general way, the obtained results suggest that mongooses do not exclusively focus their diet on game species although this does not necessarily mean a low impact of this carnivore on game species.

Introduction

The Egyptian mongoose (*Herpestes ichneumon* Linnaeus, 1758) is a medium-sized carnivore that is in expansion mainly due to land use changes over time throughout the Iberian Peninsula [Portugal (Barros and Fonseca, 2011; Barros et al., 2015) and Spain (Talegón and Parody, 2009; Recio and Virgós, 2010; Balmori and Carbonell, 2012)]. This game species in Portugal is negatively perceived by hunters, who consider it responsible for the predation of small game species, which include the European rabbit (*Oryctolagus cuniculus*) and the red-legged partridge (*Alectoris rufa*).

Mongooses are described as generalist and opportunistic carnivores. A geographically-limited study of the diet of the Egyptian mongoose in Portugal showed a variation between sexes (Rosalino et al., 2009). Females were found to include more reptiles on their diet, while males consumed more mammals (Rosalino et al., 2009). In contrast, in Doñana National Park in Spain, no differences between sexes were reported (Delibes et al., 1984; Palomares and Delibes, 1991a). Seasonal differences have also been described

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(Delibes et al., 1984; Palomares and Delibes, 1991a; Rosalino et al., 2009), emphasizing the opportunistic feeding behavior of the species. However, Santos et al. (2007) argued that prey were not consumed according to availability, suggesting preference for some food resources, whereas Palomares (1993) did find a clear relation between consumption and availability.

All these apparently contradictory results suggest that the feeding behavior of the Egyptian mongoose is context-dependent. Large-scale studies on diet ecology can thus help to clarify this kind of scenarios. Furthermore, large-scale studies can incorporate factors such as primary productivity of the environment, which is expected to shape diet diversity and other components of the food ecology of the species (Lozano et al., 2006; Zhou et al., 2011). Moreover, life-history traits of individuals (such as sexual dimorphism, body size, body condition or immunity) can influence foraging decisions and this could also be correlated with geographic location or habitat attributes (Pyke et al., 1977; Thom et al., 2004; Zhou et al., 2011). Then, large spatial studies integrating individual characteristics of specimens can offer new and valuable data to understand how species can change feeding behavior along ecological gradients.

Regarding the diet of the Egyptian mongoose, some young rabbits were recorded as captured within their own burrows (Palomares, 1993). Even with the decrease of wild rabbit populations caused by viral hemorrhagic fever, its consumption by mongooses was apparently not affected as in other carnivores (Ferreras et al., 2011). Likewise, rabbit intake was also registered during myxomatosis outbreaks (Delibes and Beltran, 1985). Further south, in the Doñana Biological Reserve, the diet composition seems to differ due to the lower consumption of rabbits compared to the other food categories (Palomares and Delibes, 1991a).

In this study, we aimed to characterize mongooses' diet using a collection of specimens for which a series of additional biological information was also gathered (spleen weight, body size and body condition). Individuals were collected along a large and diverse ecological gradient covering the most part of habitats and climate conditions found for mongooses in their European range. In particular, we tested the effect of primary productivity of habitats, season, sex, age and individual traits, including spleen weight, body size and condition on diet variation of the Egyptian mongoose. We predict that males consume more energetic prey (e.g. mammals), and that this consumption will increase proportionally with age. We conjecture that the consumption of different prey categories varies geographically and seasonally according to prey availability. Additionally, we presume that animals with better condition and body size, greater spleen weight and living in areas with higher primary productivity will capture and consume larger and more energetic prey, while animals with divergent biological parameters will invest in the intake of less energetic prey, which require less effort in capture and manipulation. Finally and with the goal of clarifying the general doubts within the hunting community we aim to answer if game species are indeed the most commonly consumed prey by mongooses.

Material and methods

Study area

This work gathered wild Egyptian mongoose from seven of the nine provinces of mainland Portugal, where the species is present. The Tagus River divides the study area in two regions that differ in terms of ecological, climatic and human pressure parameters (Bandeira et al., 2016). Regarding land use of each region, flora found in the south is mainly characterized by *Quercus suber*, also with *Olea europaea* and *Quercus ilex* areas, where agroforestry ("montado") and shrubs habitats predominate (Alves et al., 2009). Climate of the southern region generally presents higher temperatures and lower levels of rainfall compared with the northern region (Hijmans et al., 2005). In the north, the prevailing flora consists of monocultures of *Eucalyptus* spp., which replaced a large part of the areas occupied by *Pinus pinaster*, *Quercus robur*, *Salix* spp. or *Alnus glutinosa* (Alves et al., 2009). Here, human pressure is higher, with more urbanized areas, population density, road network, and a larger number of fragmented habitats with great variability (Alves et al., 2009; European Commission, 2015; IGP, 2015). Also, the northern region of Tagus River has a greater number of ridges and kilometers of hydrographic network (SNIRH, 2015).

Sampling procedures

Between January 2008 and December 2014, 678 Egyptian mongoose carcasses were collected from hunting activities (box-trapped under legal game management actions aiming the control of predator densities) or accidental road kills, and their use was approved by national authorities. The carcasses were labeled with the date and place of collection, and frozen at −20 °C. According to the origin of the sample, one of two regions was assigned to each specimen – north or south, divided by the Tagus River. For the present study, we used the stomach contents of 122 animals. The 556 rejected samples were from animals without stomach contents or whose content was only composed of bait used in hunting activities, or even from individuals whose age could not be determined by dentition.

Thawed carcasses were sexed, weighed, measured [snout-tail length (terminal hairs not included), right hind leg length, right hind foot length, shoulder height, neck perimeter and head width] and dissected. The spleen and stomach were collected and weighed separately. The stomach was opened and all of its contents were washed over a sieve (1 mm mesh), and weighed (Cavallini and Volpi, 1996). The components were macroscopically separated in nine different categories: mammals, birds, reptiles, amphibians, fish, invertebrates, plant material, eggs and carrion (Cavallini and Volpi, 1996; Rosalino et al., 2009), excluding the bait used in traps (e.g. thighs or plucked chicken wings) (Azevedo et al., 2006). Each undigested component was macroscopically or microscopically analyzed, and the corresponding species or the closest taxon was identified through keys, guides, reference collections (Landry and Van Kruiningen, 1979; Cavallini and Volpi, 1996; Rosalino et al., 2009), and whenever necessary DNA barcoding was used (Santos et al., 2015). The minimum number of individuals per stomach was estimated through the number of heads, teeth, tails, legs, and the number of fruits by the amount of seeds or peels. The components of each category were weighed and placed in the oven to dry at 77 °C, for 24 h (Lewis et al., 2010). After drying, each component was weighed again to the nearest scale 0.0001 g (Santos et al., 2007).

Indices of visceral and subcutaneous fat, on a scale from 0 to 4 (method adapted from Braun, 2005) were assigned to each mongoose, wherein the amount of fat index increases proportionally with the increase of the thickness of each of these two types of fat (Bandeira et al., *submitted*). The age of each specimen was determined by analysis of the dental development (Bandeira et al., 2016). Each specimen was assigned to one of four age classes: adults (over one year of age), sub-adults (between nine and twelve months), juveniles type II (between five-and-a-half and nine months), and juveniles type I (between two-and-a-half and five-and-a-half months of age) (Bandeira et al., 2016). The date of collection determined the season assigned to each individual. Individuals collected between January and March were considered as individuals collected in winter; spring, between April and June; summer, between July and September; and autumn, between October and December.