



## Research paper

## Geographic variation and sexual dimorphism in body size of the Egyptian mongoose, *Herpestes ichneumon* in the western limit of its European distribution

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## ABSTRACT

The Egyptian mongoose (*Herpestes ichneumon*) is a carnivore game species in Portugal, whose fundamental ecology remains to be fully explored. For instance, the physical features of this species have not yet been studied through a continuous wide area, as an entire country. In this work, the averages of eight biometric parameters and body mass of both genders were determined for 559 free-ranging animals from four age classes that were established by dental growth.

Sexual dimorphism in body size of adult Egyptian mongoose is reported for the first time in the Portuguese territory, with males being larger than females. Differences across regions are also evidenced, with animals from south of Tagus River being larger than those from the north.

Comparison with similar data available from other mongoose populations of the Mediterranean basin suggests that adult specimens from Portugal are less heavy than animals from Doñana in Spain and Israel, while males appear to be larger in body length.

Statistically significant differences encountered among gender, age and region, suggest that sexual selection, prey availability, human constraints and different habitat use patterns regulate the body size of this species.

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## 1. Introduction

The Egyptian mongoose, (*Herpestes ichneumon*, Linnaeus, 1758) (Mammalia, Carnivora, Herpestidae) (Corbet, 1984; Wozencraft, 2005), is the only representative species of the *Herpestidae* in the Iberian Peninsula (Delibes et al., 1984; Dobson, 1998; Cabral et al., 2005). In Portugal, it is expanding quickly from south to north and from inland to the coastal areas (Barros and Fonseca, 2011) due to transitions of land-use and climate changes over time (Barros et al., 2015). Similarly, expansion also seems to be occurring in Spain (Talegón and Parody, 2009; Recio and Virgós, 2010; Balmori and Carbonell, 2012). It is a small hunting species under the Portuguese law (“Decreto-Lei n° 201/2005”) that is captured through density correction actions.

In Portugal, there is only one study focusing on Egyptian mongoose biometrics, being restricted to 38 adult specimens from Serra

de Grândola, in the south, which reported that the species is not sexually dimorphic (Rosalino et al., 2005). Another study in Spain presented a significant difference in body mass between genders, but none in other metrics (Palomares, 1990). To our knowledge, there are no studies with mongooses across a wide region covering different ecological and climate amplitudes, which could elucidate if and how both body traits and sexual dimorphism change along with variations in environmental conditions.

Generalist and versatile carnivore species commonly have wide geographic distributions where the different populations are under contrasted climatic and environmental conditions, including large differences in the presence and abundance of prey species and competitors (Lucherini et al., 2006). Under such scenario, each population is subjected to diverse kinds of selection pressures, which can result in variations of body size and sexual dimorphism (eg. Ralls and Harvey, 1985; Thurber and Peterson, 1991; Lucherini et al., 2006; Yom-Tov et al., 2007a, 2007b; Virgós et al., 2011). Dissimilarities in biometric measurements may thus be related with differences in food availability and energy metabolism due to temperature variation or climatic change (Yom-Tov et al., 2006, 2008, 2010a, 2010b; Virgós et al., 2011). On the other hand, effects of

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anthropogenic habitat fragmentation and introduction of new competitors have been identified as drivers for body size variations (Sidorovich et al., 1999; Lomolino and Perault, 2007). Because body size is a pivotal trait related to other life history traits and, ultimately, to fitness (Peters, 1983; Calder, 1984), studies dealing with geographic changes in body size are in the core of evolutionary ecology.

Sexual size dimorphism has usually been explained by niche separation and sexual selection (Ralls, 1976; Ralls and Harvey, 1985). Moreover, the body size of mammals is determined during the growth period (Yom-Tov et al., 2007b; Yom-Tov and Geffen, 2011) and depends on multiple factors, including the gestation length, reproductive rate, home range size, habitat productivity, metabolism, feeding niche or population densities (Thom et al., 2004; Webster et al., 2004; Lomolino and Perault, 2007). In Egyptian mongoose, Palomares (1993) demonstrated that body mass of males in Doñana (Spain) was the unique factor that explained the variation of its reproductive behavior, whereas home-range size was correlated with weight, negatively for females but positively for males, suggesting that different processes affect the relationship between size and home range area between genders: larger females tend to better defend resource areas, maintaining themselves in reduced areas, while larger males, being territorial, will have further access to females (Palomares, 1994). Because home range size, reproductive tactics and metabolism can also be influenced by factors with a clear geographic component, sexual size dimorphism is expected to vary across regions with different environmental conditions (Ralls and Harvey, 1985; Wigginton and Dobson, 1999).

In this context, the present work aims to provide new insights into the geographic variations of Egyptian mongoose biometrics, building on a robust and large-scale sampling approach that expands biometrics data largely beyond the temporal and spatial scales of the studies reported so far.

In particular, by covering all environments of the contemporaneous distributional range of the species in Europe (Barros and Fonseca, 2011; Barros et al., 2015), we aimed to describe and analyze how regional environmental features differences can shape age- and gender- related biometrics. We assume that the conditions from north of the Tagus River are distinctly less favorable to the ecology of the Egyptian mongoose compared to those of the south, since human pressure and habitat fragmentation are much higher in the north, while average temperatures, food availability and refuge seem more favorable in the south (see CIGeoE; INE, 2016; Instituto da Conservação da Natureza e das Florestas, unpublished data). Since body size behaves as a barometer, rising and falling as the different forces exert their pressure (Yom-Tov and Geffen, 2011), geographic differences are expected to have influence on body size, presumably originating smaller individuals in the north and larger in the south.

## 2. Material and methods

### 2.1. Sampling procedures

Sampling of free-ranging Egyptian mongooses was conducted between January 2008 and December 2014. All specimens were obtained from hunting activities and accidental road kills, in compliance with legal requirements and with permits from the competent authorities. Carcasses were labeled with the date and place of collection and stored at  $-20^{\circ}\text{C}$  until the day of measurement and sample collection. Thawed carcasses were sexed, weighted, and measured. Measurements collected were snout-tail length (STL), tail length (TL, terminal hairs not included), head and body length (HBL), right hind leg length (RHLL), right hind foot length (RHFL), shoulder height (SH), neck perimeter (NP) and head width (HW), following the standard mammal measurement meth-

ods (eg. Palomares and Delibes, 1992; Castells and Mayo, 1993; Rosalino et al., 2005). In order to describe and compare different body weights and size parameters of males and females, within and across each age stage, the age of each specimen was determined by analysis of its dentition, following head removal and enzymatic cleaning for twelve hours using Neutrase 0.8L (provided by Univar, Maia, Portugal). 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. Skulls with completely developed definitive dentition were assigned to the adult class (Palomares and Delibes, 1992). For this purpose, all four canine teeth were checked to ascertain that all the definitive teeth were completely closed at their base (personal observations made by the same biologist to reduce operator variation). Skulls with 40 definitive teeth (Ben-Yaacov and Yom-Tov, 1983), but with some still growing, were assigned to the sub-adult age class (Palomares and Delibes, 1992). Active tooth growth was determined based on large insertion spaces and at least one canine tooth presenting an open hole at its base (personal observation), meaning that the apical root foramen was still open (Grue and Jensen, 1979). Animals whose skulls presented all 40 teeth, but including at least one milk tooth, were assigned to the juvenile type II class (Palomares and Delibes, 1992). Finally, animals without molars and presenting only 32 teeth were assigned to the juvenile type I age class (Ben-Yaacov and Yom-Tov, 1983). No animals under the age of 2.5 months (cubs) were sampled, likely because mongooses do not emerge from their burrows before that period (Ben-Yaacov and Yom-Tov, 1983).

### 2.2. Study area

Wild Egyptian mongoose specimens were collected from 13 of 17 districts of continental Portugal where the species is distributed. The study area encompasses both the Atlantic and Mediterranean biogeographical regions (Costa et al., 1998; Rivas-Martínez et al., 2004). Depending on the origin of the harvest, each sample was assigned to a particular region, north or south of the Tagus River, which may be considered a geographical barrier for the species, bearing in mind that, until the 90s (of the XX century), the distribution of the Egyptian mongoose was more concentrated in the south of the Tagus River (Borrallho et al., 1996; Barros and Fonseca, 2011). Regarding land cover and habitat characteristics of each region, flora found in the north is mainly characterized by monoculture of *Eucalyptus* sp., which replaced a large part of the areas occupied by *Pinus pinaster*, *Quercus robur*, *Salix* sp. or *Alnus glutinosa* (Alves et al., 2009). In the south, the prevailing flora consists of *Quercus suber*, with well-populated *Olea europaea* and *Quercus ilex* areas (Alves et al., 2009). In contrast with the south, the north is also characterized by higher human density, more kilometers of road, much more fragmented habitats and also more altered by human action, greater number of ridges with higher altitude, more rocky areas, denser hydrographic network, lower temperatures, higher rainfall (see CIGeoE, 2016; INE, 2016) and lower densities of prey target species as rabbits, rodents, red-legged partridges or reptiles (Instituto da Conservação da Natureza e das Florestas, unpublished data; Loureiro et al., 2008).

To complement study area information and to give insights into the biogeographic differences that each population faces in the north and south of Tagus River, we provide bioclimatic and environmental data as supplementary figures (Figs. B.S1–B.S4) [number of hectares of each habitat type (urban, rice fields, agroforestry, shrubs, inland water bodies, vineyards and orchards, coniferous, broadleaved and mix forests and agriculture areas) were retrieved from Corine Land Cover (2006) with spatial resolution of 250m. Mean altimetry value (data SRTM, NASA, resolution

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