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Update of the Egyptian mongoose (*Herpestes ichneumon*) distribution in Spain

Actualización de la distribución del meloncillo (*Herpestes ichneumon*) en España

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Abstract

The Egyptian mongoose *Herpestes ichneumon* (Linnaeus, 1758) is the only species of family Herpestidae that occurs naturally in Europe. It was restricted to SW Iberian Peninsula from where it seems to be expanding in the last decades. However, information on mongoose distribution and recent trends in some areas, such as central Spain (e.g. Castilla - La Mancha region), is scarce. With the aim of updating the distribution of the species in Spain, and particularly in this central area, we 1) performed a systematic questionnaire survey to environmental rangers, 2) collected citations from experts, and 3) carried out specific field surveys in some particular areas. Overall, 1,305 citations of the Egyptian mongoose were collected, resulting in 193 new 10x10 km UTM grids with mongoose occurrence in Spain; this extended the Egyptian mongoose distribution to 28.34 % of the Iberian 10x10 km UTM grids. Our results show that the Egyptian mongoose occurs in most of Extremadura, western Castilla - La Mancha and central-western Andalucía, with some isolated records in northern areas of Spain. This suggests that the range of this mongoose may be expanding in Spain, although other possible explanations for the new records, such as the lack of previous systematic studies on the species in the allegedly expanding area, could not be fully discarded.
Keywords: expertise knowledge, Herpestidae, questionnaire surveys, range expansion, wildlife monitoring.

Resumen

El meloncillo *Herpestes ichneumon* (Linnaeus, 1758) es la única especie de la familia Herpestidae que está presente de manera natural en Europa. Esta especie estaba previamente restringida al suroeste de la Península Ibérica desde donde parece que podría haberse ido expandiendo en las últimas décadas. Sin embargo, la información sobre la distribución de esta mangosta y su tendencia poblacional reciente en

algunas áreas del país es escasa, como es el caso del centro de España (por ejemplo, en la Comunidad de Castilla - La Mancha). Con el objetivo de actualizar la distribución del meloncillo en España, particularmente en el área central, 1) realizamos un muestreo sistemático a través de cuestionarios a Agentes Medioambientales, 2) recopilamos citas a través de expertos, y 3) utilizamos diferentes métodos de muestreo en algunas áreas específicas. En total, se recopilaron 1.305 citas de meloncillo, lo que dio como resultado 193 nuevas cuadrículas UTM 10x10 con presencia de meloncillo en España; esto extiende la distribución del meloncillo al 28,34 % de las cuadrículas UTM 10x10 km de la Península Ibérica. Nuestros resultados muestran que el meloncillo está presente en la mayor parte de Extremadura, oeste de Castilla - La Mancha y centro-oeste de Andalucía, con algunas citas aisladas en áreas del norte de España. Estos resultados sugieren una posible expansión de este carnívoro en España, aunque no se podrían descartar por completo otras posibles explicaciones de estos nuevos registros como la ausencia de estudios sistemáticos previos sobre el meloncillo en el área de supuesta expansión.
Palabras clave: conocimiento de expertos, cuestionarios, expansión, Herpestidae, monitorización de fauna silvestre.

Introduction

Distribution atlases represent species occurrence on a regular spatial grid, providing a rough estimate of areas of occupancy of each species within a specific territory (e.g. Palomo *et al*. 2007, Gaston & Fuller 2009). However, distribution maps of some species often become out-of-date because species distribution changes over time but the publication of updated versions of the atlas does not match the range shift velocity. The geographic distribution area of a mammal species is often difficult to estimate due to dynamic processes, since the species distribution experiences spatial contractions and expansions along the time, which are the result of responses to biologic, ecologic and biogeographic factors (Grinnell 1917, Maciel-Mata *et al*. 2015). Besides, mammalian carnivore species usually have an elusive behaviour that hinders their observation (Harrington *et al*. 2010, Oliveira *et al*. 2010) and lack of studies and inefficient survey methods may be also factors that cause inaccuracy of mammal distribution maps as those shown in the atlases.

A good example of this problem is the distribution map of the Egyptian mongoose (*Herpestes ichneumon;* mongoose hereafter), the only species of the family Herpestidae that occurs naturally in Europe (Gaubert *et al*. 2011), available in the Spanish Atlas of the Terrestrial Mammals (Palomo *et al.* 2007). This species was apparently widespread in the Iberian Peninsula in the XIXth century, but it declined in the first half of XXth century becoming restricted to the southwestern Iberian quarter (Balmori & Carbonell 2012). Afterwards, its distribution expanded again northwards and eastwards of the Iberian Peninsula (Balmori & Carbonell 2012). However, it is likely that these observed patterns of apparent changes in mongoose distribution are influenced, at least partially, by the scarcity of systematic studies on the species.

According to the most recent Spanish and Portuguese atlases of mammals, the Egyptian mongoose is mainly distributed in the southwest of Spain (Palomares 2007) and occupies nearly all continental Portugal (Bencatel *et al*. 2019). Remarkably, several local and regional studies conducted in the last few decades reported new occurrences outside the distribution shown in the Spanish atlas (e.g. Ramos *et al*. 2009, Talegón & Parody 2009, Balmori & Carbonell 2012, González-Broco *et al*. 2016, Martínez-Jauregui *et al*. 2017, Alarcos 2018, Linares *et al.* 2020, Palomares & Román 2020). Such occurrences were mainly located in the boundaries of the south and north-western regions of the mongoose distribution in Spain. There is an evident lack of information about mongoose occurrence in central Spain, which is mainly occupied by the autonomous community of Castilla - La Mancha (CLM hereafter), where hunters' complaints about the impact of this species on game species have increased in the last decade. In addition, the lack of systematic studies does not allow knowing whether the species is present in other potentially expanding Spanish areas. To update the mongoose distribution in Spain, and particularly in CLM, we conducted a comprehensive survey based on 1) a questionnaire survey to environmental rangers, 2) collection of citations from experts, and 3) specific field surveys. Following this approach, we were able not only to estimate the distribution of the species in CLM but also to gather a few additional occurrences in other regions throughout Spain (see methods for more details).

Methods

Different methodologies were used to obtain new information about the mongoose distribution in Spain, being some of these approaches particularly focused on CLM (see below).

Questionnaire survey to environmental rangers

To gather information on mongoose presence in CLM, we conducted an on-line survey in February-March 2019 on the web platform www.tickstat.com. We focused on official environmental rangers (rangers hereafter, n= 467) because they develop most of their duties (e.g. surveillance of forestry, hunting, fires, water pollution and wildlife monitoring) in the field and therefore are often familiar with local wildlife. In fact, it has been recently demonstrated in southern Spain that rangers may provide reliable information on mongoose occurrence (Linares *et al.* 2020). In addition, rangers are distributed throughout all the municipalities of CLM (i.e. at least one ranger surveys each municipality, though each ranger usually guards several municipalities), which means that our survey covered all the CLM territory.

At the time the survey was carried out, CSIC (*Consejo Superior de Investigaciones Científicas;* Spanish Research Council) projects entailing this type of studies were not yet required to undergo formal evaluation by an ethics committee. Nevertheless, our study adhered to the basic ethical principles for conducting research that involves human subjects. In particular, the participants were informed about the safeguard of the privacy, confidentiality, and anonymity of all the information they provided, according to Spanish law of data protection and its adaptations to European Union regulations on data privacy.

Several pre-tests of the questionnaire were performed to avoid problems with the understanding and fulfilled of the questionnaire. These included a pilot survey with 17 rangers and preliminary meetings with the provincial coordinators to obtain their feedback about the questionnaire. The final version of the questionnaire was distributed among rangers via email by rangers' provincial coordinators. In the questionnaire we asked rangers about their working area (i.e. the municipalities where they work), how many years they have been working in these areas, the proportion of their daily work devoted to field work and their level of implication in wildlife monitoring. In addition, rangers were also asked if they had seen mongooses in their working municipalities and when those observations occurred within some pre-defined periods (2018, 2017, 2016, 2010-2015, 2000-2009 and before 2000). For most recent observations (i.e. 2018) we inquired about the kind of observation, including alive, dead or live-trapped animals or individuals photographed by camera-traps. We decided to request this additional information only about most recent observations because of the potential difficulty to remember details of older observations. After that, we also asked about potential observations of the target species outside their working area in Spain in 2018 and before 2018. In this case, rangers had to mark the observation points in a map of the Iberian Peninsula.

In summary, we obtained data from 308 rangers of CLM, whose cumulative working areas corresponded to most of the territory of CLM (90.6% of municipalities), at two spatial scales: 1) municipalities from CLM in which the rangers developed their work (in those cases the exact coordinates of the observations were unknown); and 2) points outside the rangers' working areas.

Collection of citations from experts

We contacted different experts (scientists or technicians chosen due to their expected knowledge on the species) and asked them for undoubted records of the species across Spain. These records included mongooses killed in road accidents, recorded by camera-traps or captured, in addition to direct observations or reports of mongoose signs like scats or footprints. For example, technicians of the World Wide Fund for Nature (WWF) and Iberlince LIFE project provided data from roadkills and camera-trapping, whereas environmental technicians of the CLM regional government provided data from roadkills and direct observations. Employees of wildlife rehabilitation centres of CLM shared information on the origin of mongooses received in their centres. We also recorded information of mongooses road-killed collected by the "Sociedad de Historia Natural de Ciudad Real" through the app 'Atropellos', which is a citizen-science platform that stores data of car accidents involving mammal species throughout the Iberian Peninsula (https://www.shncr.es/app-atropellos/).

Some additional information was also provided by local conservationist groups, such as "Colectivo Azálvaro" (https://www.colectivoazalvaro.com/) and "Asociación ACENVA" (https://acenva.blogspot.com/) in the region of Castilla y León.

Another study, carried out by some of the authors of this paper (OL, MS, MMJ), collected opportunistically mongoose observations during field surveys aimed at estimating carnivore relative abundance in Andalucía. These surveys consisted of transects on vehicle and were performed between 2010-2016 by technicians from the environmental administration of Andalucía in both private and public properties, hence this information was available at a different spatial scale (game estate). These data could be transformed to municipality scale according to the geographic location of each transect, but the exact locations of those observations were unknown.

We also compiled mongoose occurrences reported in scientific papers that were not recorded in the last published Spanish Atlas of Terrestrial Mammals (e.g. Ramos *et al*. 2009, Talegón & Parody 2009, González-Broco *et al*. 2016, Martínez-Jauregui *et al*. 2017, Alarcos 2018, Linares *et al.* 2020, Palomares & Román 2020). This information was available at the 10x10 km grid scale.

Field surveys

We conducted field work in a few areas within CLM (18 municipalities) that were favourable for the mongoose according to favourability models (Díaz-Ruiz *et al.* 2019) but where the species had not been previously recorded. In those municipalities, we employed three different methods to detect the mongoose: transects on foot searching for mongoose signs, camera-traps and hair-traps, which provide occurrence data at the point scale (Descalzo *et al.* 2021a). The reliability of these methods was previously tested in locations with confirmed occurrence of the species (Descalzo *et al.* 2021a). Transects on foot consisted on walking along edges of dense vegetation searching for mongoose scats and footprints (Descalzo *et al.* 2021b). The scats were inspected in the lab, being assigned to the mongoose only when its hairs were detected (Descalzo *et al.* 2021a). Baited hair-traps consisted on two inverted U-shaped corrugated iron rods, deployed with the upper side at the height of mongoose shoulders with adhesive tape around each side and upper part of the arc (Fernández *et al.* 2015, González-Broco *et al*. 2017). These traps were placed in walked narrow pathways, with chicken bait between the arcs. Camera-traps were deployed also with chicken bait at 1.5-2 m from the camera within a little wire cage (Ferreras *et al.* 2018). Camera-traps and hair-traps were visited weekly during a month to replace baits, SD cards and batteries in the case of camera-traps, and the adhesive tape for hair-traps. In all study areas we carried out at least 1 km transect on foot, deploying a camera-trap and a hair-trap per transect when conditions were suitable. Transects on foot were walked only once. For further details about the field survey methods see Descalzo *et al.* (2021a).

In addition, one of the authors of this research article (IS) conducted a sign survey (i.e. searching for footprints and scats) to estimate the range of the Egyptian mongoose over large agricultural areas in the province of Toledo from April 2019 to October 2020. He stratified 21 10x10 km UTM grids by habitat and surveyed 1-2,5 km transects (10 km in each 10x10 km UTM grid) on foot along paths in riparian forest and scrubland. He also surveyed stream and river crossings for 15-20 minutes (track stations; Long et al. 2008). The observer's skill and experience in animal tracking, and also the sampling effort (transect length ≥ 1000 m), assured a high detection probability (Jeffress et al. 2011). Moreover, he placed non-baited camera traps next to animal trails for 10 days where no tracking substrate, such as mud or sand, was available. Roadkill and sightings were also recorded as opportunistic data.

Data processing

The information on mongoose presence was obtained at different spatial scales (point, game estate, 10x10 km UTM grid and municipality), depending on the method. When possible, we converted this information to the 10x10 km grids employed in both Iberian atlases of terrestrial mammals, Spanish and Portuguese (Palomo *et al.* 2007, Bencatel *et al*. 2019). For those observations we had the exact coordinates, data were assigned to the 10x10 km grids in which those points were located using QGis software (QGis 2.18.17 Las Palmas). This was also possible with those municipalities and game estates that were fully contained within a single 10x10 km grid. When the municipality or game estate covered more than one 10x10 km grid, this information was shown at the municipality scale. In order to

obtain a whole picture of the Iberian distribution of the mongoose, we also presented data from Portugal using only those confirmed presences in the Portuguese Atlas of Mammals (Bencatel *et al.* 2019); records within the "credible" and "possible" categories were not included in our maps to avoid using a different criterion than in Spain. All collected data were represented in distribution maps using QGis software.

Results

Overall, 1,305 records were obtained at the point scale, including, among others, 379 reported in the questionnaire survey to rangers (i.e. observations out of rangers' working area), 70 roadkill records from the app 'Atropellos', 92 direct observations from experts, and 211 records collected during our field surveys (See a full list of records in Appendix). Furthermore, mongoose was detected in 149 municipalities in CLM, according to rangers' questionnaires, and 54 municipalities in Andalucía, according to field surveys performed by technicians in game estates.

Considering all the records reported in this study and the previously published distribution (both in the Atlases and later publications), the Egyptian mongoose occurs in 1,794 10x10 km UTM grids in the Iberian Peninsula (1,133 grids in Spain and 661 grids in Portugal, Fig. 1), representing 28.34 % of the grids in the peninsular territory.

This is shown in a map of the updated distribution of mongoose in the Iberian Peninsula at the 10x10 km grid scale (Fig. 1). Importantly, this study detected the mongoose in 193 new 10x10 km grids in Spain (Fig. 1) through the different methods described above (Table 1; Appendix). Most of these new grids (167) were located in CLM, and particularly in the western part of this region (Toledo and Ciudad Real provinces); the mongoose

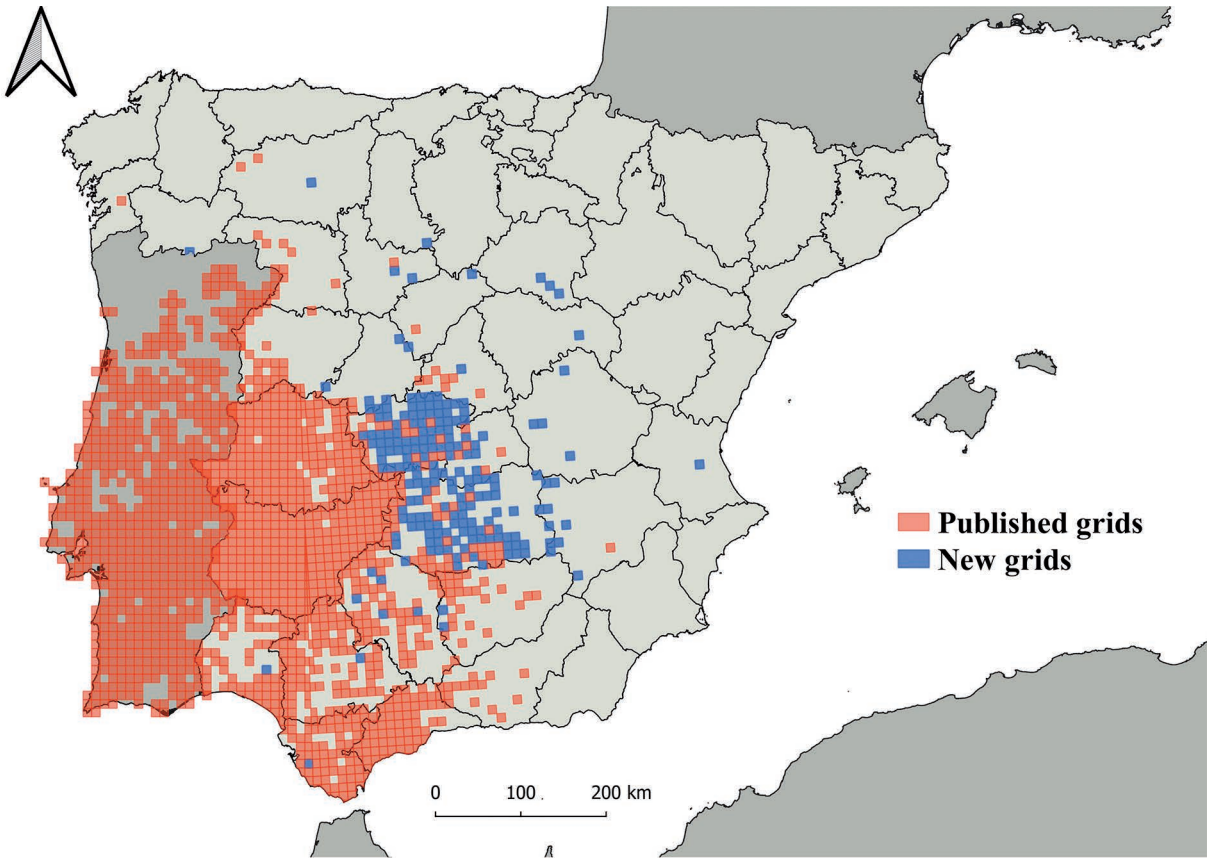

Figure 1. Map of the updated distribution of the Egyptian mongoose in the Iberian Peninsula at the 10x10 km UTM grid scale. New grids provided by the present study are represented in blue. Red colour represents grids where the Egyptian mongoose had been recorded in publications until 2020 (both atlases - Palomo *et al.* 2007; Bencatel *et al.* 2019 - and later publications - Ramos *et al.* 2009, Talegón & Parody 2009, González-Broco *et al.* 2016, Martínez-Jauregui *et al.* 2017, Alarcos 2018, Palomares & Román 2020).

Table 1. Records of Egyptian mongoose collected in this study and the new 10x10 km UTM grids in which the species was detected. The information is shown according to the spatial scales and methodologies employed in this study.

1. POINT SCALE			
Kind of data	Source	Records (n)	New grids
Questionnaire	Rangers	379	111
	Total	379	111
Direct observations	Rangers	5	5
	Experts	92	37
	Own records	1	0
	Total	98	42
Roadkills	Rangers	1	1
	Experts	190	56
	Own records	4	1
	Total	195	58
Signs	Rangers	1	0
	Experts	100	15
	Own records	173	15
	Total	274	30
Camera-trapping	Rangers	16	0
	Experts	269	43
	Own records	38	8
	Total	323	51
Captures	Experts	3	2
	Total	3	2
Killed by Iberian lynx	Experts	1	0
	Own records	1	1
	Total	2	1
Poisoning	Experts	1	1

2. MUNICIPALITY SCALE			
Kind of data	Source	Records number	New grids
Questionnaire survey	Rangers	417	3
Direct observations	Experts	1	1

3. GAME ESTATE SCALE			
Kind of data	Source	Records number	New grids
Transects on vehicle	Rangers	12	2

was also detected in some isolated grids in the east of CLM. Eleven new grids were recorded in Andalucía (provinces of Córdoba, Huelva, Jaén and Sevilla), 12 in Castilla y León (provinces of Ávila, León, Palencia, Segovia, Soria and Valladolid), and in just one new grid in Madrid, Galicia (Orense province) and Comunidad Valenciana (Valencia province). Finally, we also provide a map of the distribution of the mongoose at the municipal scale (Fig. 2) which we believe that complements the information shown in Figure 1.

Discussion

Our results show a rather continuous distribution of the Egyptian mongoose in southwestern and central Spain, occupying all Extremadura, west of CLM and central-western Andalucía, with some isolated locations in central and northern areas of Spain (Figs. 1 and 2). Most of the new grids reported in this study are located within CLM, which is not surprising since our study was mostly focused on this region. Bearing this in mind, it is important to notice that our study may have overlooked the occurrence of mongoose in other Spanish regions, and therefore we encourage to conduct further investigations on mongoose occurrence in potentially expanding areas.

According to our results, the Egyptian mongoose currently occurs in at least 28.34 % of the 10x10 km grids in the Iberian Peninsula, which represents a slight increase in the estimated range compared with previous assessments: i.e. according to Palomares & Román (2020) and the atlases of mammals of Spain and Portugal (Palomares 2007, Bencatel *et al.* 2019) the mongoose occurred in 25.28% and 20.97% of the grids, respectively. This means that the current mongoose range according to our study is 35% larger than that shown in the last published atlases (Palomares 2007, Bencatel *et al.* 2019).

Previous studies pointing at new occurrences of the mongoose in areas where it had not been recorded in the recent past suggest that the species could be actually spreading (Palomares 2007, Ramos *et al.*

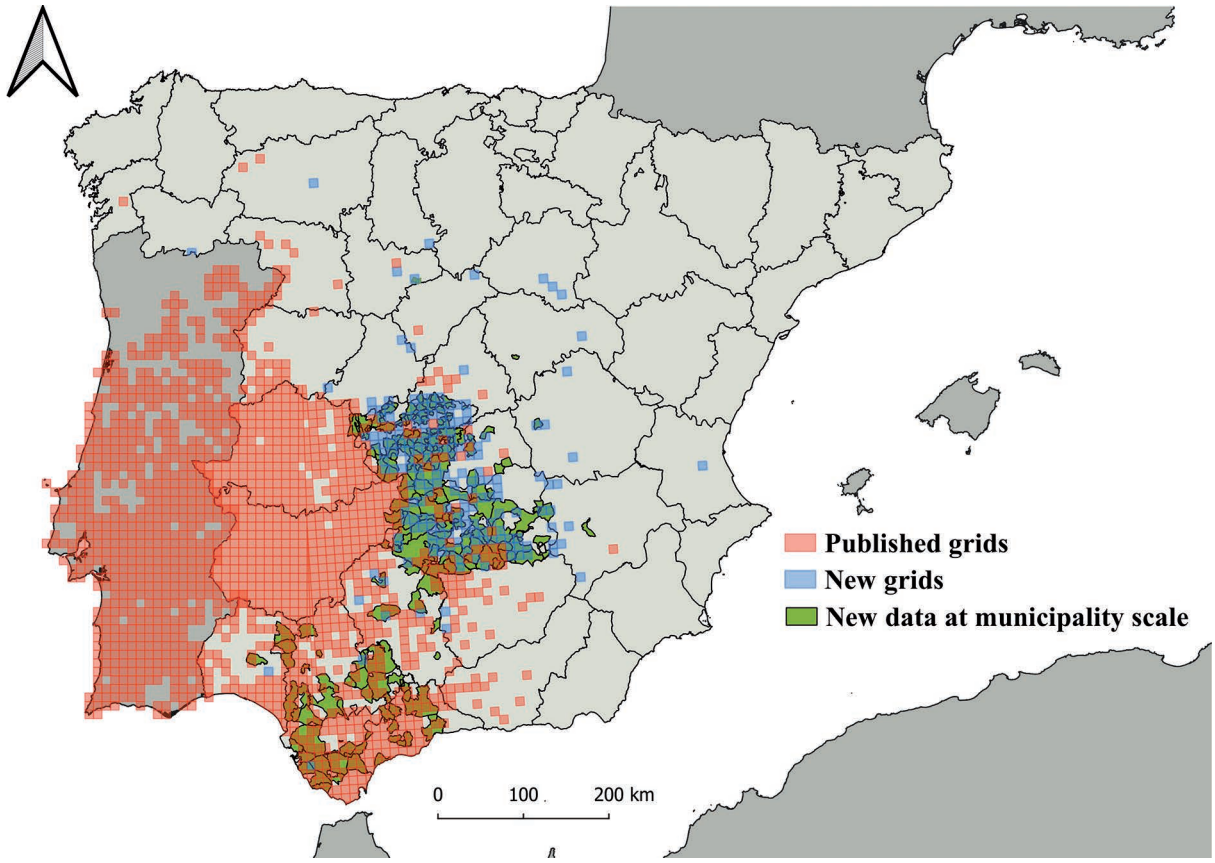

Figure 2. Updated distribution of the Egyptian mongoose in the Iberian Peninsula with mongoose detections at the municipality scale highlighted in green. Red colour represents 10x10 km UTM grids in which mongooses had been recorded before our study (i.e. until 2020), and grids with new records at the grid scale reported in this study are shown in blue.

2009, Talegón & Parody 2009, González-Broco *et al*. 2016, Martínez-Jauregui *et al*. 2017, Alarcos 2018, Palomares & Román 2020). Our study agrees with this possibility, since we found evidence of mongoose presence in a nearly continuous area of western CLM where the species had been previously recorded only occasionally (Palomo *et al.* 2007). Nevertheless, other possible explanations to this, such as the lack of previous systematic studies in this region and the scarcity of local informants, should not be totally discarded. The information gathered in this study would represent a still photo of the current mongoose distribution, and therefore further analyses are needed to provide a definitive answer to the question of the recent expansion of the species in central Iberia. In this sense, the assessment of mongoose observations that rangers assigned to different temporal periods in the questionnaires (information not considered in this study) will be very useful.

Our study reveals that combining different survey methods may provide valuable information on mammal species distribution at large geographical scales. Nevertheless, the reliability of data sources should be always taken into account. For example, the low experience of a particular informant in recognizing the target species could result in false negatives or positives (Clare *et al.* 2019). In this study we have considered only information provided by experienced informants such as rangers, researchers and technicians. Additional caution must be taken in the case of records based on signs (scats and footprints) due to the risk of misidentification (Monterroso *et al.* 2013). However, when carried out by experienced observers, sign surveys are a valuable technique for carnivore distribution monitoring at large temporal and spatial scales (Silveira *et al.* 2003, Barea-Azcón *et al.* 2007). In the present study, this type of records represents a small proportion of new grids, and in nearly all the cases mongoose identification was confirmed by the authors either analysing in the lab the hairs detected in the scats or checking pictures of the footprints. We have also included records from roadkills, which are supported by the evidence of the dead specimen.

This study also points at questionnaire surveys to rangers as a powerful tool to collect information on mammal occurrence for studies conducted at a regional scale (see also Linares *et al.* 2020). Therefore, we suggest that this type of approaches could be useful to survey the status of the mongoose on other regions as well as that of other species of mammals in the Iberian Peninsula.

In conclusion, we have revisited and updated the distribution of the Egyptian mongoose in Spain by using different information sources. Although our findings suggest that the range of this mongoose may be expanding in Spain (eastwards and northwards), other possible explanations for the new records, such as the lack of previous systematic studies on the species in the allegedly expanding area, could not be fully discarded. Future detailed studies on the dates of the records presented here will serve to assess quantitatively this expansion and throw light on its causes.

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