The western European hedgehog *Erinaceus europaeus* L. 1758 on San Pietro Island (southern Sardinia, Italy) and an updated review of its presence on the Italian small islands

Corrado Battisti

Abstract - The current presence and local distribution of the western European hedgehog *Erinaceus europaeus* L. 1758, on San Pietro Island (Southern Sardinia, Italy) are here discussed for the period 2013-2021 with a short review of the species' occurrence on the small Italian islands. The species was found in the central-eastern sector of the island, which is characterised by a high urban and infrastructural density and an agricultural mosaic, both suitable ecological conditions favouring its presence. Most of the direct data were obtained from road kills. Despite the elusive behaviour of the species and the consequent possible underestimation, it can be assumed that the species shows a low density. In this respect, it might be interesting to investigate whether local limiting factors, either anthropogenic or natural might act on the hedgehog population. At a larger scale, the updated review of the small Italian islands shows the presence of the species on 13 islands, of which probably only Elba, Asinara and San Pietro (all >50 km^2) support established populations. Further research is needed to study anthropogenic origin, history of introduction, genetics, density, and medium-long-term viability of these small populations in each insular context.

Key words: eradication, introduction, road kills, small island, viability.

Riassunto - Il riccio europeo occidentale *Erinaceus europaeus* L. 1758, sull'isola di San Pietro (Sardegna meridionale, Italia): distribuzione locale e revisione aggiornata della sua presenza nelle piccole isole italiane.

Una indagine sulla presenza del Riccio europeo occidentale su un'isola circumsarda (San Pietro), condotta dal 2013 al 2021, ha evidenziato una distribuzione limitata al settore centro-orientale, caratterizzato sia da una più alta densità urbana e infrastrutturale, sia dalla presenza di mosaici agricoli, condizioni ecologiche sinantropiche che possono favorire la presenza di questa specie. La maggior parte dei dati originali è stata ottenuta da investimenti con autoveicoli. Benché la specie mostri un comportamento elusivo e i dati potrebbero essere sottostimati, si può ipotizzare una bassa densità di popolazione sull'isola. A tal proposito, potrebbe essere interessante verificare se ciò possa essere fatto risalire a fattori locali limitanti, sia antropici sia naturali. Su scala nazionale, la revisione della letteratura evidenzia la presenza su 13 piccole isole italiane, con presenza di popolazioni stabili probabilmente solo su Elba, Asinara e San Pietro (tutte con superficie > 50 km^2). Ulteriori ricerche sono necessarie per studiare l'origine, la storia dell'introduzione, la genetica, la densità e la vitalità a medio-lungo termine di queste popolazioni in ciascun contesto insulare.

Parole chiave: eradicazione, introduzione, piccole isole, *road kill*, vitalità.

'Torre Flavia' LTER (Long Term Ecological Research) Station, Protected Area Service, Città Metropolitana di Roma, Via G. Ribotta 41, 00144 Roma, Italia.
E-mail: c.battisti@cittametropolitanaroma.it

Received for publication: 15 November 2021
Accepted for publication: 8 March 2022
Online publication: 20 October 2022

INTRODUCTION

The western European hedgehog *Erinaceus europaeus* L. 1758 (Mammalia: Erinaceomorpha) is a common generalist species, widely distributed in mainland Italy, in Sicily, in Sardinia and in some small islands (Amori, 1993; Angelici *et al.,* 2009; Reggiani & Filippucci, 2008; Loy *et al.*, 2019; Tab. 1). In Sardinia, this mammal has been introduced in the middle and late neolithic (4th Millennium B.C.; Cetti, 1774; Cei, 1941; Sanges & Alcover, 1980; Vigne 1992; Masseti, 1993; Wilkens, 2003; Baldino *et al.*, 2008). However, although the hedgehog has been studied in Sardinia (e.g., roadkills: De Montis *et al.*, 2017; parasites: Scala & Garippa, 1996, Poglayen *et al.* 2003; Fois *et al.*, 2006; see also Regione Sardegna, 2017), data on its presence and local distribution on the circum-Sardinian islands, where this insectivore has been introduced, are still lacking (Angelici *et al.,* 2009; Masseti, 2019).

In this paper, I reported some direct and indirect records of presence and data on the local distribution of the western European hedgehog on the Island of San Pietro, a circum-Sardinian medium-sized island (Sulcis archipelago).

The western European hedgehog has also been recorded on several other small islands along peninsular Italy and on neighbouring large islands (Sicily and Sardinia: e.g. Angelici *et al*., 2009). In this regard, given the interest in the presence and introduction history of this erinaceomorph in these contexts, I carried out an up-to-date review of scientific and grey literature on its presence on Italian small islands, also providing preliminary considerations on its status (occurrences of only occasionally introduced individuals vs. hypothetical stable populations).

Tab. 1 - Author's direct observations (1-6) and indirect records (7-12) of western European Hedgehog on San Pietro Island (2013-2021 period). For the indirect records (7-12), the reported coordinates are approximate. / Osservazioni dirette dell'autore (1-6) e segnalazioni indirette (7-12) di riccio europeo occidentale sull'Isola di San Pietro (periodo 2013-2021). Per le segnalazioni indirette (7-12), le coordinate riportate sono approssimative.

N	Year	Site and geographical coordinates	Notes (nr. ind., type of record, observer)
1	2015	Macchione (39°07'58"N, 8°18'00"E)	1 ind, roadkill (C. Battisti, pers. obs.)
2	2019	Girin (39°06'51"N, 8°18'25"E)	1 ind., roadkill (C. Battisti, pers. obs.)
3	2019	Valacca (39°07'25"N, 8°17'29"E)	2 ind. (P. Battisti, G. Masnata, pers. obs.)
4	2019 (8 August)	Macchione (39°07'54"N, 8°18'00"E)	1 ind., roadkill (C. Battisti, pers. obs.)
5	2019 (13 August)	Gioia, Sebino (39°08'42"N, 8°16'26"E)	1 ind., roadkill (C. Battisti, pers. obs.)
6	2021	La Punta, Memmerosso (39°10'13"N, 8°18'02"E)	1 ind., roadkill (M. Gallarati, pers. obs.)
7	Post 2000	Giunco (39°07'32"N, 8°18'30"E)	Adult and juveniles (M. Masnata, pers. obs.)
8	Post 2010	Valacca (39°07'24"N, 8°17'28"E), provincial road	Ind. near a fountain (P. Battisti and G. Masnata, pers. obs.)
9	Post 2000	Bacciu (39°07'38"N, 8°17'40"E)	Recorded by a dog in a private garden (M. Masnata, pers. obs.)
10	Post 2000	Girin (39°06'54"N, 8°18'25"E)	M. Masnata, pers. obs.
11	Post 2010	Punta del Morto, Carloforte (39°09'01"N, 8°18'37"E)	2 ind. (M. Masnata, pers. obs.)
12	2017 (7 October)	Valacca (39°07'17''N, 8°17'19''E), provincial road	1 ind., roadkill (Julien Vittier, pers. obs. reported on Ornitho.it)

STUDY AREA

San Pietro island

San Pietro Island (39°08'N; 8°18'E) is situated 11 km off the South-Western coast of Sardinia, opposite the Sulcis Peninsula. With a surface area of 51 km^2, San Pietro Island is the sixth largest island in Italy (Fig. 1). The island is of volcanic origin (Cioni & Funedda, 2015; Gioncada *et al.,* 2019). Because of its high eco-biogeographic interest and the concern for its conservation (e.g., Arrigoni & Bocchieri, 1996; Bocchieri, 2001), San Pietro Island is listed as a Special Area of Conservation (code ITB040027 - SIC Isola di San Pietro; 92/43/EU Directive; Regione Sardegna, 2013).

The island is characterized mainly by a Mediterranean scrub (maquis with *Erica arborea* L., *Pistacia lentiscus* L., *Genista ephedroides* DC., *Juniperus turbinata* Guss. and *Arbutus unedo* L.). Mediterranean scrub is alternated with Mediterranean open prairies and anthropogenic pinewood patches (*Pinus pinaster* Aiton, *P. pinea* L., *P. halepensis* Mill.; further details in Regione Sardegna, 2015), these last widely diffused in the western sector.

After a long period in which the island was uninhabited, starting from 1738 the island was colonized by a human population of Ligurian origin that came from Tunisia (Vona *et al.*, 1996). In recent decades, the island's landscape has been progressively anthropized, with an increase in rural urbanisation, mainly in the eastern sector. In fact, the population is mostly concentrated in Carloforte (about 6,000 inhabitants), the only town on the island (Pellerano & Rivano, 1997; Pellerano, 2001). Climate is typically Mediterranean. A number of zoological studies have been carried out in this island in the last decades (see Baccetti *et al*., 1989; Baccetti, 1996; for homeothermic vertebrates: bats: Zava *et al.,* 1995; birds: e.g., Schenk & Torre, 1988; Baccetti *et al*., 1991; Rosén *et al.*, 1999; Battisti, 2018; Battisti & Zullo, 2019; Battisti & Fanelli, 2021).

Italian small islands

Along the coasts of the Italian peninsula and large islands (Sicily and Sardinia) there are many small islands, sometimes grouped in archipelagos, ranging from 224 km^2 (Elba) to less than 1 km^2. For this review, I included most of the Italian small islands, considering "small island" those "with limited surface and lack of environmental diversity" (La Greca & Sacchi, 1957). Small islands show different geological origin (sedimentary, metamorphic, volcanic effusive, volcanic intrusive). Most of the islands surveyed are situated relatively close to the mainland (excluding Pelagie Islands, located >70 km offshore). Human population in small islands ranges from 0 to >50,000 inhabitants (Ischia; for a review of their characteristics see Pretto *et al.,* 2012).

METHODS

San Pietro Island

In the 2013-2021 period, during holiday trips carried out in the summer season (July or August; approximately 20 days/year), I walked many pedestrian paths and

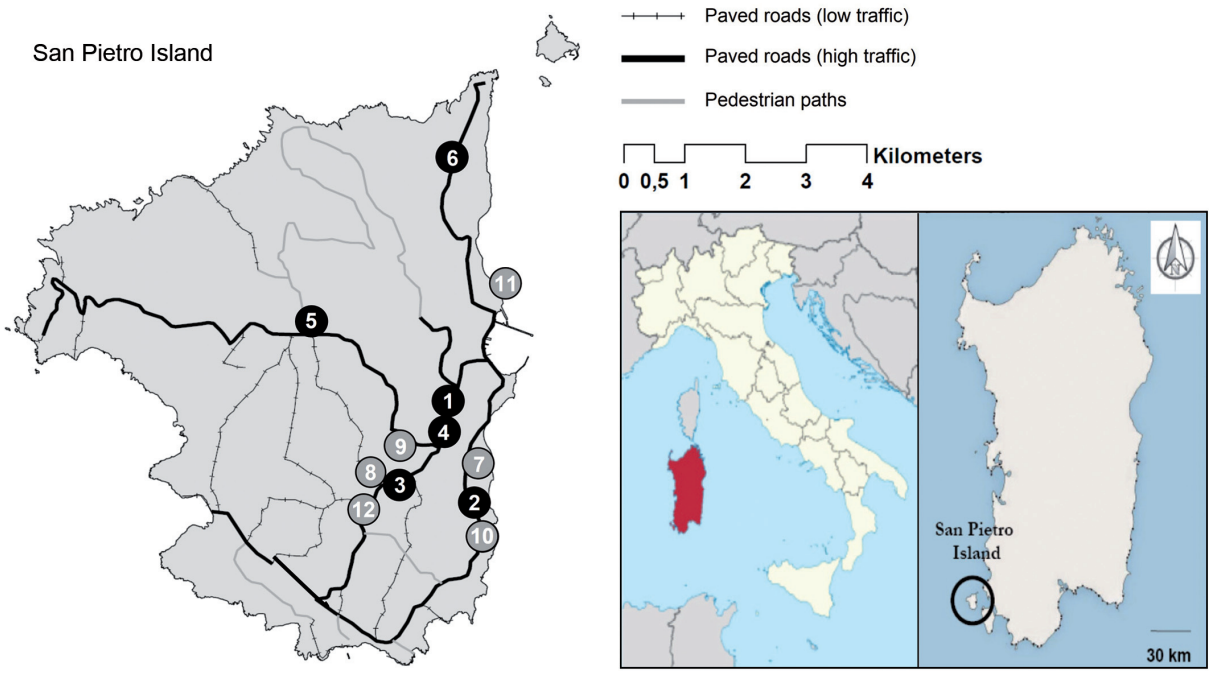

Fig. 1 - The study area (San Pietro Island, Sulcis archipelago; South Sardinia) with the evidence of presence of western European hedgehog. Black circles: direct observations; grey circles: indirect data. See Table 1 for details and numbers. / L'area di studio (Isola di San Pietro, arcipelago del Sulcis; Sardegna meridionale) con i siti di presenza del riccio europeo occidentale. Cerchi neri: osservazione dirette; cerchi grigi: dati indiretti. Vedere Tabella 1 per dettagli e numerazione.

paved roads (speed: 1.5 km/hour), covering all the main habitat types of the island (2013-2016: on an occasional basis; 2017-2021: >50 km/year and about 20 days/years of direct sampling; total: approximately >150 days of sampling effort). Interviews with local inhabitants were also conducted in an informal fashion. The collected data were all geo-referenced (latitude and longitude by Google Earth software ±10 m) and divided into direct (original) observations (living individuals and road-kills) and indirect records (obtained by interviewing local inhabitants or by web platforms: naturamediterraneo.com; ornitho.it; therio.it; iNaturalist.org), although with a lower degree of reliability.

Italian small islands

In order to carry out a brief review of the presence of the western European hedgehog on the Italian small islands, I considered only small continental islands (see Watson, 2009; Ali, 2018; i.e. islands that had a connection to the mainland and/or to the larger islands or located <100 km away, such as the circum-peninsular, circum-Sardinian and circum-Sicilian islands). I excluded from the study those islands located in inland water basins (e.g., the Polvese Island, Lake Trasimeno, central Italy, where this species is present: Burzigotti & Capuano citated in Gaggi & Paci, 2014). To carry out the review, I considered all (at the best of my knowledge) scientific papers, grey literature and web platforms (naturamediterraneo.com; ornitho.it; therio.it; iNaturalist.org), obtaining updated information about the status of the species and on the viability of its populations on the small islands in the short and medium term (Tab. 2).

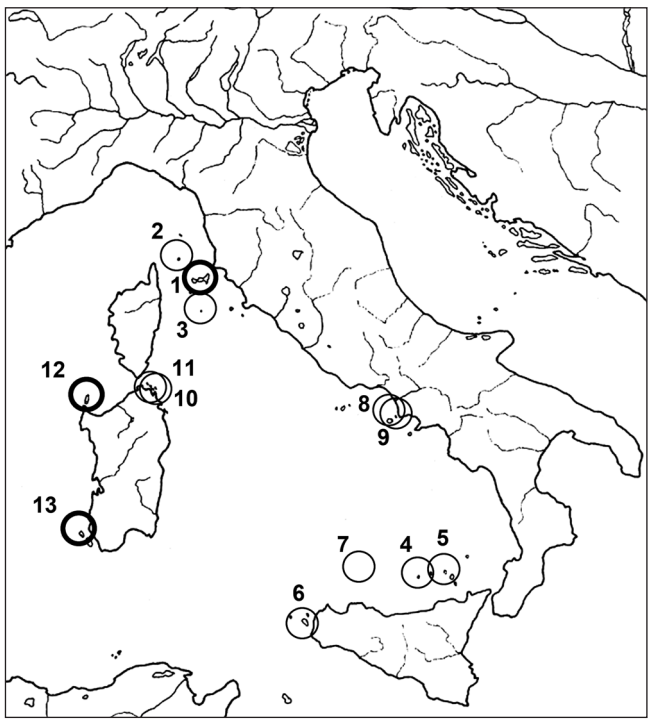

Fig. 2 - The small Italian islands with evidence of western European hedgehog presence. Thick-bordered circles: probable occurrence of stable populations; thin-bordered circles: only occasional presence of individuals (low probability of short-term persistence). See Tab. 2 for details. / Evidenze di presenza di riccio europeo occidentale nelle piccole isole italiane. Cerchi con bordo spesso: probabile presenza di popolazioni stabili; cerchi con bordo sottile: probabile presenza di singoli individui (bassa probabilità di persistenza a breve termine). Vedasi Tab. 2 per dettagli. 1) Elba; 2) Capraia; 3) Pianosa; 4) Alicudi; 5) Salina; 6) Favignana; 7) Ustica; 8) Procida; 9) Vivara; 10) Capraia; 11) La Maddalena; 12) Asinara; 13) San Pietro.

Tab. 2 - The western European hedgehog on the Italian small islands. Bibliographic and web-based evidence of presence for each small island, notes about the occurrence of stable populations (p) or of occasional individuals (i) have been reported. (*) Vivara is connected to Procida by a bridge. / Il riccio europeo occidentale nelle piccole isole italiane. Per ciascuna piccola isola, sono riportati sia i riferimenti bibliografici (e sitografici) che segnalano la specie, sia gli indizi della probabile presenza di popolazioni stabili (p) o della presenza occasionale di individui (i). (*) Vivara è collegata a Procida da un ponte.

Island name (area)	**References**	**Notes**	**Probable stable population (p), occasional individuals (i)**
Elba (224 km^2)	Thiebaud De Berneaud, 1808; Damiani, 1923; Vesmanis & Hutterer 1980; De Marinis *et al.*, 1996; Amori & Masseti, 1996 (see also Amori, 1993; Sarà, 1998; Scaravelli, 1999; Spagnesi & De Marinis, 2002; Spagnesi *et al.*, 2004; Ruffo & Stoch, 2005; Arpa Sicilia, 2008; Angelici *et al.*, 2009; Ente Parco Nazionale dell'Arcipelago Toscano, 2016).	Documented presence for the last 200 years (Thiebaud De Berneaud, 1808); can be considered as native (see Iannucci *et al.*, 2009); 1 ind. roadkilled in Capoliveri (1993) (De Marinis *et al.*, 1996).	p
Capraia (19.3 km^2)	Angelici *et al.,* 2009, and references therein.	2 ind. observed (summer 1992; F.M. Angelici pers. obs.) Species not included in the National Park plan (Ente Parco Nazionale Arcipelago Toscano, 2016). Not reported in Sarà (1998).	i
Pianosa (10.2 km^2)	Agnelli, 1998; Ruffo & Stoch, 2005; Iannucci *et al.*, 2019 (see also Reggiani & Filippucci, 2008; Tomassone *et al.*, 2013; Ente Parco Nazionale dell'Arcipelago Toscano, 2016).	Population of Pianosa has an extremely low genetic diversity and a profile very similar to that of Elba (originated from a pool of individuals, perhaps also only a single pregnant female, moved by human from Elba in recent times; absent before 1950s Baccetti & Gotti, 2016; Iannucci *et al.*, 2019). Not reported in Sarà (1998).	i (p?)
Alicudi (5.2 km^2)	Cristaldi *et al.*, 1987; Lo Cascio & Navarra, 2003 (see also Amori, 1993; Sarà, 1998; Scaravelli, 1999; Spagnesi & De Marinis, 2002; Spagnesi *et al.*, 2004; Arpa Sicilia, 2008; Angelici *et al.*, 2009).	Introduced in the second half of the 20th century (beginning of the 1980s; Cristaldi *et al.*, 1987), 1 ind. observed in loc. Filo dell'Arpa (photo available; Lo Cascio & Navarra, 2003; see also Arpa Sicilia, 2008).	i
Salina (26.1 km^2)	Lo Cascio & Navarra, 2003.	1 ind. in a private garden in first 2000s (Lo Cascio & Navarra, 2003).	i
Favignana (19.8 km^2)	Sarà, 1998 (see also Arpa Sicilia, 2008; Reggiani & Filippucci, 2008; Angelici *et al.* 2009).	Occasional presence with a specimen found dead (roadkill) in 1989 (Sarà, 1998). Recently introduced (Arpa Sicilia, 2008).	i
Ustica (8.7 km^2)	Sarà, 1998 (see also Reggiani & Filippucci, 2008; Angelici *et al.* 2009).	1 ind. observed for a few months (1994) in a cropland (Sarà, 1998).	i
Procida (4.1 km^2)	Nappi & Masseti, 2005 (and references therein); Nappi *et al.*, 2007 (see also Reggiani & Filippucci, 2008; Angelici *et al.* 2009; www.isoledellacampania.eu/procida-1.html).	Established in the last years (Nappi & Masseti, 2005).	i
Vivara (0.4 km^2)(*)	M. Rodriguez (pers. obs.) cit. in Nappi *et al.*, 2007 (see also Angelici *et al.* 2009).	Reported for the second half of 90s. Data are not sufficient to confirm the existence of a stable population (Nappi *et al.*, 2007). Not reported in Sarà (1998).	i
Caprera (16 km^2)	Torre & Maiabailliu, 1993; Cossu *et al.*, 1994 (see also Angelici *et al.* 2009; Presutti, 2018; Masseti, 2019).	Recently introduced in Caprera (Cossu *et al.*, 1994).	i
La Maddalena (20 km^2)	Angelici *et al.,* 2009, and references therein.		i?
Asinara (52 km^2)	Torre & Maiabailliu, 1993; Cossu *et al.*, 1994; Amori & Masseti, 1996 (see also Sarà, 1998; Spagnesi & De Marinis, 2002; Spagnesi *et al.*, 2004; Ruffo & Stoch, 2005; Arpa Sicilia, 2008; Reggiani & Filippucci, 2008; Angelici *et al.* 2009; Masseti, 2019).	Recently introduced (Cossu *et al.*, 1994).	p?
San Pietro (51 km^2)	Zava *et al.*, 1995 (see also Ruffo & Stoch, 2005; Reggiani & Filippucci, 2008; Masseti, 2019). This study.	Recorded in 1989 (Zava *et al.*, 1995).	p?

RESULTS AND DISCUSSION

San Pietro Island

During the study period, I obtained 15 records (7 direct observations, and 6 indirect records of 8 individuals) from 12 sites (Fig. 1, Tab. 1), mainly located in the central-eastern sector of the island, characterized by a higher urban and infrastructural density and agricultural mosaics (see Battisti, 2018; Battisti & Zullo, 2019; Battisti *et al.,* 2021), suitable ecological conditions that can favour the presence of this species (Reggiani & Filippucci, 2008). The lack of observations in the western sector may also be linked to the widespread presence of monospecific *Pinus pinaster* forests, which typically have poor undergrowth and therefore represent habitats of low ecological suitability for this species (Reggiani & Filippucci, 2008).

Most of the direct data (6 out of 7 records; 85.7%) were obtained from roadkills (this species is highly sensitive to this anthropogenic impact: Rondinini & Doncaster, 2002; Battisti *et al.*, 2012; Wright *et al.*, 2020; see, for Sardinia: Amori *et al.,* 2014; De Montis *et al.*, 2017). However, despite considerable research effort, I have recorded low numbers of both road kills (even with the relatively high volume of vehicles during the summer period), and indirect detections of live animals, when compared to continental contexts (e.g., Reggiani & Filippucci, 2008). Although the species shows an elusive behaviour (Bearman-Brown *et al.*, 2020) and the data could be affected by underestimation, it can be hypothesized a sporadic presence on the island, with low densities. In this regard, it could be interesting to verify the role of indirect anthropogenic factors (e.g. road kill: Locatelli & Paolucci, 1998; Amori *et al.,* 2014; feral dogs: Reggiani & Filippucci, 2008) or natural processes, controlling this local population as, for example, the occasional predation by migrant and sedentary raptors, such as the barn owl *Tyto alba* (Mazzotti & Bortolotti, 1999) and common buzzard *Buteo buteo* (Swann & Etheridge, 1995, Sidorovich *et al*., 2016), all locally present (Meschini & Frugis, 1993; Battisti, 2018; M. Masnata, pers. comm.). However, this is only hypothetical, since these two birds occur on the island with few individuals and their predation on hedgehog is unlikely. Also, the scarcity of both the hedgehog's preferred food items (e.g. earthworms and land snails: Reggiani & Filippucci, 2008) and of reliable water sources in this insular ecosystem might represent further local limiting factors.

About the origin of this insular population, there are anecdotical data on a probable recent introduction (presumably in the second half of the 20th century: M. Masnata, pers. comm.) from the neighbouring Sardinian mainland (this species may be easily introduced also involuntarily: see Nappi *et al*., 2020). In this regard, further research is necessary.

The hedgehog has no conservation problems (Gippoliti & Amori, 2004; Bertolino *et al.,* 2015; para-autochthonous species: Senato della Repubblica, 2016), and does not represent a factor of local impact on species of conservation concern, especially if considering its low density on San Pietro Island. However, in other environmental contexts (for example, in wetland and coastal sites) evidence is shown of an impact of this mammal preying on clutches of waders and seabirds (see Utley *et al.,* 1989; Monteiro *et al.,* 1996; Jackson & Green, 2000). San Pietro is a site of high importance for waders, seabirds and other migratory and nesting species (Important Bird Area IT191; BirdLife International, 2001): in this regard, if further data will evidence circumstances of predation, an eradication project (e.g. by translocation) could be foreseeable, as suggested by Baccetti & Gotti (2016) and Iannucci *et al.* (2019) for Pianosa Island (see also Warwick *et al.*, 2006; Capizzi, 2020).

Italian small islands

At national scale, the updated bibliographic and web-based review suggests a presence of the species on at least 13 small Italian islands (Tab. 2), with an updated confirmed absence in Ponziane (Latium; Capizzi *et al.*, 2012), Ischia and Capri (Nappi *et al.* 2007), Tremiti (Ministero dell'Ambiente, 2021), Egadi (Felten & Storch, 1970; Zava & Lo Valvo, 1990; Ozella *et al.*, 2016) and Pelagie Islands (Arpa Sicilia, 2008; see also Amori, 1993; Angelici *et al.*, 2009). Although we do not have data available about local density, probably this mammal occurs with stable populations only on Elba Island (historical records reported by Thiebaud De Berneaud, 1808), and perhaps on San Pietro and Asinara, all islands with an area >50 km^2, which may allow its persistence in the short and medium term (see Sarà, 1998). The occasional reports obtained for the other islands are probably to be referred to single or to very few specimens introduced by humans, also voluntarily (the species is locally kept as pet or consumed for food: see Cornalia, 1870; Reggiani & Filippucci, 2008), therefore with a low probability of long-term persistence. In this sense, an in-depth and updated analysis of the local status and of the recent human-driven introduction/colonization history, possible local extinctions, genetics, and peculiar behaviours (e.g. absence of hibernation as found in southern populations: Aloise *et al.*, 2003) for the individual demographic units in the small islands could be of interest, contributing to the disciplinary arena of anthropogenic historical biogeography (e.g. see Balletto, 1996; Sarà, 1998; Mazza *et al.*, 2013; Amori *et al.*, 2015).

Acknowledgments

Luciano Durante, Mario and Gabriele Masnata, Monica Gallarati, Pierpaolo Battisti and Mrs. Granara provided indirect information about the presence of this species on the island. Giovanni Amori, Francesco M. Angelici, Massimo Brunelli, Spartaco Gippoliti, Armando Nappi and Julien Vittier provided further data and suggestions. Alessandro Zocchi reviewed the English style and language. Francesco Zullo drew up Figure 1. Marzio Zapparoli provided the draft of Figure 2. The Editor (Giorgio Chiozzi), Michela Mura and two anonymous reviewers provided further useful comments and suggestions.

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