LIFE ON ISLANDS

BIODIVERSITY IN SICILY AND SURROUNDING ISLANDS

Studies dedicated to Bruno Massa

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Tommaso La Mantia, Emilio Badalamenti, Attilio Carapezza,
Pietro Lo Cascio & Angelo Troia (Editors)

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On the front cover a Sicilian rock partridge, *Alectoris graeca whitakeri* Schiebel, 1934 and an Egyptian locust, *Anacridium aegyptium* (Linnaeus, 1764); on the back cover a summer image of Linosa Island (photos T. Puma).

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"COLD-BLOODED" TRAVELLERS AROUND SICILY: HOW INTRODUCTIONS AND EXTINCTIONS HAVE SHAPED THE RECENT HERPETOFAUNA OF CIRCUM-SICILIAN AND MALTESE ISLANDS

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Summary: Circum-Sicilian and Maltese herpetofauna includes 22 species occurring with steady populations, and some of them (*Pelophylax bedriagae*, *Trachemys scripta*, *Chamaeleo chamaeleon*, *Hemorrhois algirus* and perhaps *Telescopus fallax*) were introduced during the last two centuries, while for other 7 at least one introduction within the study islands was documented during the same span of time; furthermore, temporary occurrences were also detected for other 16 species (3 amphibians and 13 reptiles), some of which (*Hyla* sp., *Graptemys pseudogeographica*, *Centrochelys sulcata*, *Pantherophis guttatus* and *Lampropeltis getula*) have not been previously recorded for these islands. Accidental or intentional introductions have gradually increased in recent decades and have a significant influence in shaping these herpetofunal assemblages. On the contrary, extinction seems to be less frequent and involved especially amphibians. The updated faunal inventory for 65 islands includes several new records and the results of the first herpetological investigations on the islets Faraglione di terra di Cala Fico, Colombaia, Vittoria Garcia (circum-Sicilian), Pigeon Rock and Cheirolopus Rock (Maltese).

Key Words: amphibians, reptiles, Sicily, Malta, introductions, extinctions, alien species, new records.

Riassunto: *Viaggiatori a "sangue freddo" attorno alla Sicilia: come introduzioni ed estinzioni hanno modellato l'attuale erpetofauna delle isole circum-siciliane e maltesi* - L'attuale erpetofauna delle isole circum-siciliane e maltesi comprende 22 specie (3 anfibi e 19 rettili) presenti con popolazioni stabili; tra queste, *Pelophylax bedriagae*, *Trachemys scripta*, *Chamaeleo chamaeleon*, *Hemorrhois algirus* e, forse, *Telescopus fallax* sono state introdotte durante gli ultimi due secoli, mentre nello stesso arco temporale altre 7 sono state "protagoniste" di almeno un caso di introduzione nell'ambito di queste isole. Casi di introduzione e presenze temporanee riguardano inoltre 16 specie (3 anfibi e 13 rettili), tra le quali *Hyla* sp., *Graptemys pseudogeographica*, *Centrochelys sulcata*, *Pantherophis guttatus* e *Lampropeltis getula* non erano mai state segnalate in precedenza per i territori studiati. Le introduzioni, sia accidentali sia intenzionali, hanno registrato un progressivo incremento durante gli ultimi decenni e possono avere riflessi significativi sulla struttura e sulla composizione dei popolamenti erpetologici circum-siciliani e maltesi, dove invece le estinzioni sembrano essersi verificate con minore frequenza e avere coinvolto soprattutto popolazioni di anfibi. L'elenco faunistico aggiornato per 65 isole comprende numerose nuove segnalazioni e i risultati delle prime prospezioni erpetologiche sugli isolotti circumsiciliani Faraglione di terra di Cala Fico, Colombaia e Vittoria Garcia e su quelli maltesi di Pigeon Rock e Cheirolopus Rock.

Parole chiave: anfibi, rettili, Sicilia, Malta, introduzioni, estinzioni, specie aliene, nuove segnalazioni.

INTRODUCTION

The (accidental or intentional) introduction of amphibians and reptiles on islands is widely documented by the scientific literature, also in consideration of the negative consequences that it may determine in terms of survival for autochthonous species (Lever 2003; Cole *et al.* 2005; Kraus 2009; Silva-Rocha *et al.* 2018, 2019). Within the Mediterranean context, marked by a thousand-year history of interactions between man and the environment (Blondel *et al.* 2010), the distinction between the latter and the allochthone can however be difficult. Some authors (e.g. Manchester & Bullock 2000) have indicated the Neolithic as a temporal reference to establish a boundary between native and alien species, but Böhme (2000) has highlighted the arbitrariness of this distinction, emphasizing the ethical implications of an excessively rigid interpretation in the perspective of any management and conservation of fauna.

Also extinction is a frequent event within the islands' herpetofauna (see Case *et al.* 1992), although its occurrence seems less significant in the Mediterranean context (Corti *et al.* 1999; Foufopoulos *et al.* 2011). Its main causes, often interconnected, may be represented by i) apparently natural processes, such as reduction of viable space, low population densities, or high level of ecological specialization (Foufopoulos & Ives 1999), ii) competition with alien species or introduction of predators (Capula *et al.* 2002; Pinya & Carretero 2011), and iii) anthropogenic disturbance and/or environmental degradation

(Corti *et al.* 1999; Ficetola & Padoa Schioppa 2008; Foufopoulos *et al.* 2011).

Introductions and extinctions have therefore a prominent and often complementary role in shaping the islands' herpetofauna and, if supported by detailed information, may offer an interesting key to understand its dynamics and actual composition.

The herpetofauna of the islands surrounding Sicily (circum-Sicilian and Maltese islands) was deeply investigated, especially during the last half century: Lanfranco (1955), Bruno (1970), Lanza (1973), Massa & Di Palma (1988), Corti *et al.* (1998, 2006), Savona Ventura (2001) and Baldacchino & Schembri (2002) provided and updated the faunal lists, while further records concerning single or more islands have added by many authors (Savona Ventura 1983a, 1983b; Schembri & Schembri 1984; Borg & Schembri 1991; Capula 1994a; Lo Valvo 1998; Lo Valvo & Massa 1999; Sultana & Borg 2000; Lo Valvo & Nicolini 2001; Panuccio 2003; Sciberras & Schembri 2004, 2006a, 2006b; Lo Cascio *et al.* 2005a; Lillo 2006; Sciberras 2007; Harris *et al.* 2009; Ficetola *et al.* 2012; Pasta *et al.* 2014; Speybroeck 2014; Sciberras & Sciberras 2014; Lo Cascio & Grita 2016; Vella *et al.* 2020).

Excluding doubtful or erroneous records, as well as those concerning species recently detected but not surely established (see below), these islands currently host three species of amphibians and nineteen of reptiles; this number, equal to about 70% of the species occurring at regional level (including the Maltese Archipelago) (see Lo Cascio & Turrisi 2008; Insacco *et al.* 2015), sounds as remarkable if consider the relatively small spatial extent of the study islands, that overall is less than 7% of the Sicily surface. Furthermore, circum-Sicilian and Maltese islands harbor two narrow endemics and some species exclusively represented here at regional scale.

A general overview on the introduced species has been done for Sicily (Lillo & Vaccaro 2008; see also Faraone *et al.* 2019) and the Maltese islands (Lanfranco 1964; Schembri & Lanfranco 1996), while no similar reviews concern specifically the extinctions at regional level, for which there are however several single cases illustrated in literature (see references given below).

The aim of the present paper is to provide the first comprehensive and updated inventory of the introduction and extinction events that have occurred in the circum-Sicilian and Maltese islands during the past two centuries, a time span for which reliable data and information are available, and to analyze the influence determined in the current composition of the local herpetofauna. The faunal knowledge has also been implemented by new records collected by the authors and their collaborators over the past few years.

MATERIAL AND METHODS

Faunal data

Data have been gathered both from literature and from field surveys, and listed in the herpetofaunal inventory, that is arranged in four parts.

The first includes all the palaeontological records concerning the occurrence of amphibians and reptiles in the study islands since Pleistocene.

The second part of the herpetofaunal inventory includes the species actually confirmed for the study area, whose distribution within the circum-Sicilian and Maltese islands is given in Table 2; for each species have been provided i) the geographical distribution, that unless otherwise indicated was taken from Speybroeck *et al.* (2016) and Amphibian Species of the World 6.0 database (www.research.amnh.org/vz/herpetology/amphibia) for the amphibians and from Sindaco & Jeremčenko (2008), Sindaco *et al.* (2013) and The Reptile Database (www.reptile-database/org) for the reptiles, ii) the references concerning the life-history of circum-Sicilian and Maltese populations, iii) a review of unconfirmed, erroneous or doubtful records, iv) a review of the cases of introduction and extinction documented from 19th century up to now, and v) the new records.

In the third part are grouped only the (few) species not occurring in the study area (and therefore excluded from the previous list) for which were however erroneously recorded in literature.

Finally, the fourth part of the inventory concerns other cases of species introduced and/or extinct in the study islands, including those established with short-lived populations or the exotics that have been introduced but seem unable to become established.

Unless otherwise specified, the data listed in the new records have been obtained during the investigations carried out by the authors.

Geographical setting

The study area is located between 38°49’02” and 35°29’28” of latitude North, and 11°55’35” and 15°18’02” of longitude East of Greenwich. It includes 65 islands, 50 of them administratively belonging to Sicily (33 satellites and 17 coastal), while 15 are part of the Republic of Malta (Repubblika ta' Malta).

In Table 1, islands are grouped as follows: Aeolian, Ustica, Aegadian, Stagnone, Pantelleria, Pelagian, Ciclopi, other coastal islands, Maltese; within each group, they are listed in decreasing order of size, while the right columns provide the relative geographical (location, surface, elevation) and faunal data (number of confirmed species).

ISLAND	A	B	C	D
Lipari	382920N 145600E	37.297	602	5
Salina	383355N 145005E	26.380	962	5
Vulcano	382335N 145820E	20.870	499	5
Stromboli	384725N 151255E	12.193	924	5
Filicudi	383420N 143330E	9.496	773	4
Alicudi	383235N 142105E	5.101	676	4
Panarea	383805N 150400E	3.348	421	4
Basiluzzo	383947N 150650E	0.281	165	4
Lisca Bianca	383821N 150650E	0.031	32	3
Dattilo	383821N 150550E	0.028	103	3
Strombolicchio	384902N 151506E	0.007	49	2
Bottaro	383815N 150638E	0.007	23	3
Scoglio Faraglione	383445N 144802E	0.005	33	2
Spinazzola	383953N 150629E	0.005	78	1
Pietra Quaglietto	382359N 145618E	0.005	34	1
La Nave	383848N 150350E	0.003	39	1
Faraglione di terra di Cala Fico (Faraglione Grande di Cala Fico)	382846N 145356E	0.003	32	1
La Canna	383456N 143116E	0.003	70	1
Faraglione di fuori di Cala Fico (Faraglione Piccolo di Cala Fico)	382847N 145354E	0.001	31	1
Ustica	384220N 131035E	8.339	239	5
Favignana	375530N 121915E	19.851	302	7
Marettimo	375815N 120335E	12.263	686	6
Levanzo	375950N 122010E	5.654	277	6
Formica	375920N 122530E	0.047	5	1
Preveto	375452N 121807E	0.043	8	2
Maraone	375923N 122449E	0.031	5	1
Faraglione di Levanzo	375911N 121942E	0.009	20	1
Cala Rotonda	375525N 121648E	0.004	4	1
Isola Lunga**	375307N 122628E	5.447	3	6
San Pantaleo (Mozia)	375202N 122807E	0.435	5	5
Santa Maria	375255N 122731E	0.131	3	6
La Scuola	375145N 122724E	0.008	3	3
Pantelleria	364705N 120000E	82.928	836	6
Lampedusa	353045N 123500E	20.197	133	7
Linosa	355200N 125205E	5.430	195	6
Conigli*	353036N 123330E	0.044	26	3

Lampione	353316N 121959E	0.021	36	2
Lachea	373341N 150958E	0.019	27	3
Scoglio della Madonnina (Faraglione Grande dei Ciclopi)	373334N 150955E	0.004	70	3
Capo Passero	364110N 150855E	0.365	21	4
Isola delle Femmine	381236N 131408E	0.156	36	5
Vendicari	364729N 150618E	0.044	3	3
Correnti*	363840N 150440E	0.023	9	2
Colombaia	380040N 122937E	0.021	5	2
Ognina	365845N 151549E	0.018	2	1
Isola Bella*	375101N 151802E	0.009	33	3
Rocca di San Nicola	370644N 135123E	0.007	12	2
Grande di Marzamemi*	364405N 150715E	0.007	3	1
Piccola di Marzamemi	364417N 150708E	0.004	2	1
Vittoria Garcia	371409N 151215E	0.003	2	1
Malta	355260N 142555E	245.856	253	12
Gozo (Għawdex)	360233N 141533E	67.148	191	9
Comino (Kemmuna)	360039N 142010E	2.832	80	8
Manoel (Il-Gzira ta'Manoel)*	355413N 143007E	0.326	26	9
Selmunett (Il-Gzejjer ta'San Pawl)	355755N 142403E	0.101	25	0
Cominotto (Kemmunett)	360049N 141913E	0.099	30	6
Filfla	354714N 142435E	0.061	30	3
Qawra Point (Ta'Fra Ben)*	355735N 142543E	0.020	8	6
Fungus Rock (Gebla tal General)	360248N 141120E	0.007	60	3
Large Blue Lagoon Rock (Il-Hagra ta'Bejn il-Kmiemen il-Kbira)	360039N 141931E	0.007	20	2
Halfa Rock (Gebla tal Ħalfa)	360145N 141952E	0.004	15	3
Tac Cawl (Gebla taċ-Ċawl)*	360133N 141858E	0.002	18	3
Small Blue Lagoon Rock (Il-Hagra ta'Bejn il-Kmiemen il-Zghira)	360040N 141925E	0.001	18	1
Pigeon Rock (Gebla ta'Taht il-Mazz)	360031N 141945E	0.0001	20	1
Cheirolophus Rock (Hagra tas-Sajjetta)	354848N 142942E	0.0001	12	1

Table 1. Geographical and faunal data for the study are: A) location (longitude W Greenwich and latitude), B) surface (in km^2), C) maximum elevation (in m a.s.l.), D) N species actually confirmed. Symbols: *periodically/permanently connected to the mainland/nearby island, **2.58 km^2 of the surface consist of salt pans.

The island size ranges from 245 (Malta) to 0.0001 km^2 (Pigeon and Cheirolopus Rocks); only 10 islands (Malta, Pantelleria, Gozo, Lipari, Salina, Vulcano, Lampedusa, Favignana, Stromboli and Marettimo) have a surface greater than 10 km^2, while 46 are islets with an area less than 1 km^2.

The Aeolian Archipelago, Ustica, Pantelleria and Linosa have volcanic origin and their emersion occurred generally during the last 500,000 years, although some of them (Stromboli, Alicudi, Basiluzzo) are younger than 100,000 years old, while other have been involved in catastrophic eruptive events during the last 50,000 years (Stromboli, Vulcano, Pantelleria). Mostly formed by limestone, the Maltese, the Aegadian except Marettimo and Lampedusa with Lampione islet were connected to the main island/mainland (Sicily or, in the case of Pelagian, N Africa) during the Last Glacial Maximum (20,000 years ago). A presumably more recent separation, whose age is related to the local bathymetry and the distance from the coast, occurred also between Sicily and the islets grouped in table 1 as Stagnone, Ciclopi and other coastal, as well as between the main islands of the Aeolian, Aegadian, Pelagian and Maltese archipelagoes and their tiny satellites. Moreover, some islets have been artificially connected to the mainland (Correnti, Grande di Marzamemi, Manoel), or are periodically/permanently linked to the nearby island by sandy/rocky isthmus (Conigli, Isola Bella, Qawra Point, Tac Cawl); the same occurred in past for San Pantaleo, Capo Passero and, probably, Rocca di San Nicola, while Isola Lunga is composed by three islets artificially connected together in the 18th century for the creation of salt pans, that actually are extended on about the 50% of its surface.

The landscape is extremely heterogeneous: the top of Salina, Stromboli and Pantelleria is nearly to 1,000 m a.s.l., but most part of the study islands do not exceed 100 m a.s.l.; hence, it is not a surprise that they result characterized by a remarkable variety in terms of plant assemblages. The top of the largest volcanic islands (Aeolian, Pantelleria) should potentially be occupied by evergreen acidophilic formations generally referring to *Quercion ilicis* and typical of a mesomediterranean climate, but in reality it is covered by a wide range of degradation phases. Aegadian, Pelagian, Maltese islands and the lower belt of Pantelleria are characterized by peculiar formations referred to *Periplocion angustifoliae* and dominated by summer-deciduous shrubs. In the lower part of the other islands (from the sea level up to about 500 m a.s.l.), the plant communities consist mainly in evergreen sclerophyllous pre-forest formations ascribed to the Oleo-Ceratonion siliquae or in Mediterraean pine formations, such as *Pinus pinaster* ssp. *hamiltonii* (Ten.) Huguet in Pantelleria and *Pinus halepensis* Mill. in Marettimo. This picture is however actually quite unrealistic, as most part of circum-Sicilian and Maltese islands have been subject to a strong and ancient anthropization, and some of them (Vulcano, Ustica, Lampedusa, Linosa) underwent dramatic transformations during the last two centuries; scattered aspects of pre-forest and forest vegetation still occur on Salina, Marettimo and Pantelleria, while the remaining islands are mainly characterized by a discontinuous mosaic of maquis, garrigue and perennial or annual grasslands. As many of them were intensely cultivated until 1950s and then abandoned, a significant portion of their surface is now interested by a progressive succession processes, often occurring on terraced slopes, where different pseudo-climax stages expands their range within abandoned vineyards, caper and olive groves and annual crops. On the tiny islets, the low spaces availability and the sea closeness are the main constrains for composition and structure of the local plant assemblages: most of these communities are strongly influenced by salt spraying and the eventual presence of seagull colonies, that induce the formation of salty and hypernitrophilous soils.

As above mentioned, the long-term history of human occupation on these islands (almost all the larger have been colonized since Neolithic, while for Favignana and Levanzo the human presence is documented since Upper Palaeolithic) determined generally a quite strong level of anthropization, recently increased after the affirmation of an economy mainly based on tourism and the consequent urbanization. Even many small islets, including those actually uninhabited, have undergone a more or less intense anthropization: San Pantaleo was entirely occupied by the Phoenician town of Motya between the 7th and the 4th century BC; Formica, La Scuola, Colombaia, Rocca di San Nicola, Vittoria Garcia, the two islets of Marzamemi and Isola Bella are largely covered by extensive fortifications or other buildings, while the whole area of Manoel is entirely urbanized; ancient towers or other archaeological remains on Basiluzzo, Lisca Bianca, Lachea, Capo Passero, Isola delle Femmine, Ognina and even on the remote Lampione attest a past human presence (or at least a seasonal use); the top of Strombolicchio was demolished at the end of the 19th century to build a lighthouse, while Filfla was used for target practice by the Royal Navy until the 1970s; Selmunett and Cominotto were cultivated until 20th century, and Fungus Rock (Fig. 1) was exploited in past for the occurrence of *Cynomorium coccineum* L., a plant appreciated for medical properties, until 18th century when its cliffs were artificially scraped to make the islet only accessible from the nearby Gozo via funicular.

Figure 1. Fungus Rock (or Gebla tal General), near Gozo (photo P. Lo Cascio).

Among the islands that are currently inhabited, Malta stands out for being the most densely populated, with more than 450,000 units and a density of about 1,800 inhabitants/km^2, followed by Gozo (32,700 units and 488 inh./km^2); the anthropogenic pressure related to these outstanding numbers results extremely high if compared with the circum-Sicilian framework, where only on 5 islands (Lipari, Lampedusa, Favignana, Ustica and Panarea) the population density ranges between 300 and 150 inh./km^2, while the others do not exceed 100 inh./km^2. Furthermore, Malta has about 2.5 million visitors per year, a value that alone exceeds the entire number of annual visitors registered for the circum-Sicilian islands; among these latter, the Aeolian archipelago represents the most important touristic destination, with about 500,000 visitors/year and a peak of visitors in the summer.

Nature 2000 network includes 85% of the circum-Sicilian islands, covering about 60% of their whole surface with a total number of 23 Site of Community Importance (SCI) and 6 Special Protection Areas (SPA); in the Maltese Archipelago it is extended on 13% of the islands' surface, with the highest number of sites on Malta (17 SCI and 7 SPA) and Gozo (7 SCI and 4 SPA), while others are recognized for Comino and surrounding islets (SCI/SPA MT0000017), Selmunett (SCI MT0000 022), Fungus Rock (SCI MT0000019 and SPA MT00 00030), and Filfla (SCI/SPA MT0000016). Out of Nature 2000 boundaries, Halfa Rock and Tac Cawl are however sites of national importance (respectively MT1000007 and MT1000006), while several coastal islets (Ognina, Colombaia, Rocca di San Nicola, the two islets of Marzamemi and Vittoria Garcia) and Scoglio Faraglione are not subject to any environmental regulation: especially in the latter case, that conflicts with the great biological importance of the site, inhabited by some species listed in the annexes of 43/92 and 147/09 EU Directives and by one of the last populations of the threatened endemic Aeolian wall lizard. Along with those above mentioned, Lipari, Vulcano, the Aegadian Archipelago, Capo Passero and Correnti, despite hosting Nature 2000 sites, are not yet designated as protected areas; all the other circum-Sicilian are instead partially or totally recognized as Nature Reserves (with access interdictions for several Aeolian islets, Lampione, Vendicari and the Ciclopi), and Pantelleria is a National Park since 2016. The same concerns Selmunett, Filfla and Fungus Rock, also declared Nature Reserves with access restrictions for the latter two.

Acronyms and abbreviations

The following acronyms and abbreviations have been used in the text: AS, Arnold Sciberras; BP, before present; MHS, Maltese Herpetological Society; MNHNP, National Museum of Natural History of Paris; MZUF, Zoological Section "La Specola", Natural History Museum of Florence University; PLC, Pietro Lo Cascio.

HERPETOFAUNAL INVENTORY

The actual distribution of the herpetofauna in the study area is shown in Table 2.

Discoglossus pictus
Malta, Gozo, Comino.

Bufotes boulengeri
ssp. *siculus*: Ustica, Favignana; ssp. *boulengeri*: Lampedusa.

Pelophylax bedriagae
Malta, Gozo.

Testudo hermanni
Lipari, Salina, Vulcano, Pantelleria, ?Lampedusa, Linosa.

Trachemys scripta **ssp.** ***scripta/elegans***
Malta, Gozo.

Chamaeleo chamaeleon
Malta, Gozo, Comino, Manoel, Qawra Point, Fungus Rock.

Hemidactylus turcicus
Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi, Panarea, Basiluzzo, Lisca Bianca, Dattilo, Bottaro, Pietra Quaglietto, Ustica, Favignana, Marettimo, Levanzo, Isola Lunga, San Pantaleo, Santa Maria, Pantelleria, Lampedusa, Linosa, Lachea, Scoglio Madonnina, Capo Passero, Isola delle Femmine, Vendicari, Isola Bella, Rocca di San Nicola, Malta, Gozo, Comino, Manoel, Cominotto, Filfla, Qawra Point, Fungus Rock, Large Blue Lagoon Rock, Halfa Rock, Tac Cawl.

Tarentola fascicularis
Lampedusa, Conigli.

Tarentola mauritanica
Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi, Panarea, Basiluzzo, Lisca Bianca, Dattilo, Strombolicchio, Bottaro, Scoglio Faraglione, Ustica, Favignana, Marettimo, Levanzo, Preveto, Isola Lunga, San Pantaleo, Santa Maria, La Scuola, Pantelleria, Linosa, Lachea, Scoglio Madonnina, Capo Passero, Isola delle Femmine, Vendicari, Correnti, Colombaia, Isola Bella, Vittoria Garcia, Malta, Gozo, Comino, Manoel, Cominotto, Filfla, Qawra Point, Halfa Rock, Tac Cawl.

Podarcis filfolensis
Linosa, Lampione, Malta, Gozo, Comino, Manoel, Filfla, Fungus Rock, Cominotto, Qawra Point, Large Blue Lagoon Rock, Halfa Rock, Tac Cawl, Small Blue Lagoon Rock, Pigeon Rock, Cheirolophus Rock.

Podarcis raffonei
Strombolicchio (ssp. *raffonei*), Scoglio Faraglione, La Canna (ssp. *alvearioi*).

Podarcis siculus
Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi, Panarea, Basiluzzo, Lisca Bianca, Dattilo, Bottaro, Spinazzola, La Nave, Faraglione di terra Cala Fico, Faraglione di fuori Cala Fico, Ustica, Favignana, Marettimo, Levanzo, Formica, Preveto, Maraone, Faraglione di Levanzo, Cala Rotonda, Isola Lunga, San Pantaleo, Santa Maria, Pantelleria, Lampedusa, Lachea, Scoglio Madonnina, Capo Passero, Isola delle Femmine, Vendicari, Correnti, Colombaia, Ognina, Isola Bella, Rocca di San Nicola, Grande di Marzamemi, Piccola di Marzamemi.

Podarcis waglerianus
Favignana, Marettimo, Levanzo, Isola Lunga, Santa Maria, La Scuola.

Psammodromus algirus
Conigli.

Chalcides ocellatus
Stromboli, ?Ustica, Favignana, Marettimo, Levanzo, Isola Lunga, San Pantaleo, Santa Maria, La Scuola, Pantelleria, Lampedusa, Linosa, Lampione, Conigli, Capo Passero, Isola delle Femmine, Malta, Gozo, Comino, Manoel, Cominotto, Qawra Point.

Hemorrhois algirus
Malta, Manoel.

Hemorrhois hippocrepis
Pantelleria.

Hierophis carbonarius
Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi, Panarea, Basiluzzo, Ustica, Favignana, Marettimo, Levanzo, Isola Lunga, San Pantaleo, Santa Maria, Isola delle Femmine, Malta, Gozo, Comino, Manoel.

Macroprotodon cucullatus
Lampedusa.

Telescopus fallax
Malta, Manoel.

Zamenis situla
Malta, Gozo, Comino, Manoel, Cominotto, Qawra Point.

Malpolon insignitus
Lampedusa.

Table 2. Actual distribution of the herpetofauna in the study area.

1. A glance to the past: palaeontological records for the study islands

Knowledge on the palaeo-herpetofauna of the circum-Sicilian islands is far from be considered exhaustive and generally based on few findings. Fossil remains of *Testudo* cf. *hermanni* Gmelin, 1789 from Lipari have been initially dated to about 120,000-104,000 years BP (Bonfiglio & Latino 1988) while more recent dating for the same pyroclastic deposits suggests an age of 40,000 years (Lo Cascio 2015); in both cases, the occurrence of the species is assessed before the human arrival on this island. The only reptile found at Grotta del Genovese on Levanzo has been dated to Mesolithic and identified as *Emys orbicularis* (Linnaeus, 1758) by Burgio *et al.* (2005), but most likely belongs to the Sicilian endemic *E. trinacris* Fritz, Fattizzo, Guicking, Tripepi, Pennisi, Lenk, Joger & Wink, 2005. From Lampedusa are known Pleistocene remains of Anura and unidentified snakes (Burgio *et al.* 1997), whose origin is therefore uncertain. However, their association with endemic mammals which are very close to the North-African fauna suggests that these species may have colonized Lampedusa during the land-bridge connections of this island with the Tunisia shore that existed until 18,000 years BP.

By contrast, Malta has a relatively rich Pleistocene herpetofauna, studied since 19th century from remains found in several cave systems and limestone deposits, that includes three amphibian and three reptile species. Only one of them, *Discoglossus pictus* Otth, 1837, is still living in the archipelago, and its occurrence at Mnajdra cave (Bate 1935) agrees with biomolecular data (Stöck *et al.* 2016) which suggest that this species has colonized Sicily and Maltese Islands from North Africa around 240,000 years BP. Other remains from Għar Dalam cave have been referred to "*Bufo viridis*" [perhaps *Bufotes boulengeri* ssp. *siculus* (Stöck et al., 2008)] and *Bufo bufo* (Linnaeus, 1758) (Bate 1935; Savona Ventura 1984; Hunt & Schembri 1999), both now absent from the Maltese Islands. Also *Emys* cf. *orbicularis* found at Għar Dalam and Zebbug sites (Adams 1877; Despott 1923) does not belong to the current local fauna. Giant tortoises found at Zebbug and Kordin (Fig. 2) were initially described as three different species (Adams 1877; Tagliaferro 1914) but successively grouped under

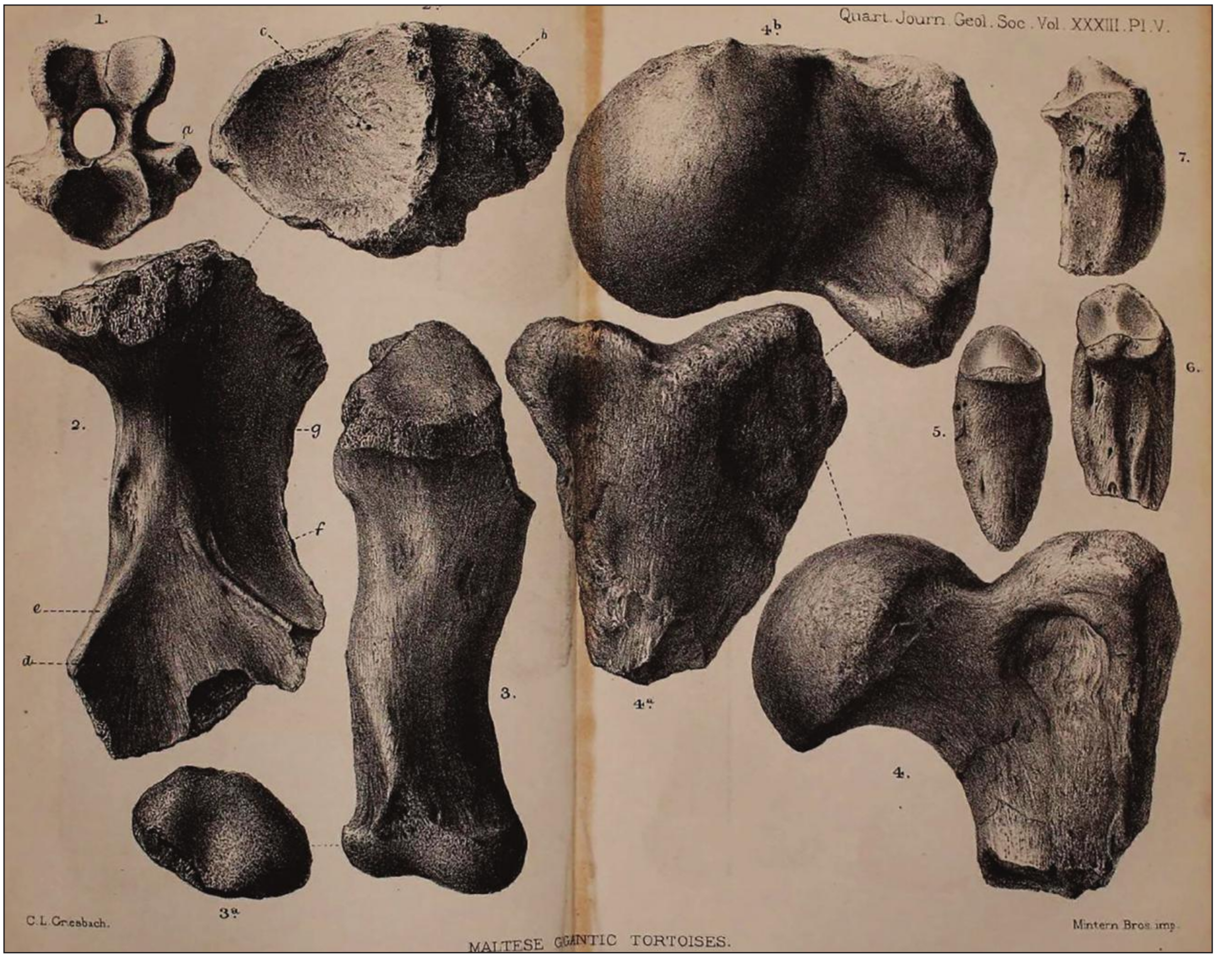

Figure 2. Remains of *Geochelone robusta* from Malta caves; original table published by Adams (1877).

the name *Geochelone robusta* (Adams, 1877). This species, interpreted as palaeo-tropical relict that persisted until recent times due to the favorable local climate conditions (Thake 2002) and become extinct after the human arrival on the island, has been recently placed in the genus *Centrochelys* Gray, 1872, but more likely it belongs to the genus *Titanochelon* Pérez-García & Vlachos, 2014 (see Rhodin *et al.* 2015). *Timon siculimelitensis* has been described by Böhme & Zammit-Maempel (1982) as *Lacerta* from various sites of Malta and is known also from Pleistocene remains found in Sicily; however, Tschopp *et al.* (2018) suspect that under this name could be hidden more species. Finally, fossil remains found in the same layers of the first Neolithic human settlements belong to *Testudo* cf. *graeca* Linnaeus, 1758 (Despott 1918), currently absent from the Maltese Archipelago, and *Chalcides ocellatus* (Forskål, 1775) (Storch 1970; Savona Ventura & Mifsud 1998).

2. Species confirmed for the study area

Discoglossus pictus Otth, 1837 (Discoglossidae) - Painted frog

Distribution. Distributed in NW Africa and Sicily, D. pictus occurs in the Maltese Islands but despite its wide diffusion in Sicily (Lo Valvo *et al.* 2017) is absent from the circum-Sicilian ones. The species is monotypic, since the subspecies recognized in past are now not considered valid due to the scarce genetic divergence (*auritus*) or, conversely, have been raised to specific rank (*scovazzii*) (Zangari *et al.* 2006).

Life-history in the study area. Phenotypic characters: Lanza (1983); larval morphometrics, reproductive biology and feeding behaviour: Sammut & Schembri (1991); predation: Pieris (1964), Lanfranco (1969), Sciberras & Schembri (2006b); cannibalism on tadpoles: Lanfranco (1955), Savona Ventura (1979); other generic information: Schembri (1983).

Figure 3. *Discoglossus pictus* from Malta, September 2017 (photo P. Lo Cascio).

Unconfirmed/erroneous records. An old record reported for Lampedusa by Giglioli (1884) is certainly due to a *lapsus calami*, because the specimens from this island, kept in the MZUF collection, have been properly identified by the same author as *Bufo variabilis* (= *Bufotes boulengeri*) (see Lanza & Bruzzone 1961a).

Doubtful records. Lanza (1973) has referred the record of *D. pictus* for Ustica given by Palcich (1957) to a wrong indication of the provenance of the examined specimens, but it should be noted that this information was received from third parties and not directly from the author; on the contrary, Palcich (1957) seems to have a precise knowledge of the context, as revealed by the fact that he has also excluded the occurrence of true frogs and other amphibians from the pools where this species was found. The unique amphibian that currently inhabits Ustica, *Bufotes boulengeri*, was recorded for the first time only a decade later (Bruno 1970) and its occurrence is certainly due to an human-mediated introduction. In our opinion, the possibility that *D. pictus* for a certain period was effectively present in the same site and successively replaced by the green toads cannot be categorically excluded.

Introductions/extinctions. This species has been (likely intentionally) introduced on Comino at least since 2002 and seems to be acclimatized in the artificial ponds that represent the only suitable habitats on this islet; tadpoles were still observed in 2018 (AS unpubl. data).

Bufotes boulengeri (Lataste, 1879) (Bufonidae) - African green toad

Distribution. The range of *B. boulengeri* covers a wide area from W-Sahara to Egypt and, perhaps, the western coast of the Arabian Peninsula. Sicily and circum-Sicilian islands (except Lampedusa, where occurs the nominal form) are inhabited by the subspecies *siculus* (Stöck *et al.*, 2008), originally described as distinct species (Stöck *et al.* 2008); according to Nicolas *et al.* (2018) and Dufresnes *et al.* (2019), the genetic distance among these taxa is however not sufficient for their distinction at specific rank.

Life-history in the study area. Morphometrics: Lanza & Bruzzone (1961a), Lo Valvo *et al.* (2017); breeding phenology and spatial use (Ustica): Sicilia *et al.* (2006), Lillo *et al.* (2008); general information on the status of the species (Ustica): Panuccio (2003), Lillo (2005).

Unconfirmed/erroneous records. As *Bufo variabilis*, this species was erroneously recorded for Linosa by Trabucco (1899) (see Lanza & Bruzzone 1961a). For Malta, erroneous records (in this case referred to *Bufo viridis*) are given by Bowles (1988), successively refuted by Borg & Schembri (1991), and once more by the distribution map of "Atlas of Amphibians and Reptiles in Europe" ("after 1970": see Roth 1997).

Introductions/extinctions. Some individuals, identified as *Bufo viridis* by Lillo (2006), have been found in Contrada Rekale at Pantelleria in October 2005; anyway, further investigations did not allow to confirm the occurrence of the species (Lillo 2006), that is definitively excluded by Lo Valvo *et al.* (2017). Most likely it was a case of accidental and human-mediated introduction, probably occurred in recent times, while remains uncertain whether these animals belonged to the north-African or the Sicilian subspecies of *B. boulengeri*.

Bruno (1970) has recorded *Bufo viridis* (probably *Bufotes boulenger*i ssp. *siculus*) for Marettimo and Isola Grande, the main islet of Stagnone archipelago; however, the absence of further observations (see Lanza 1973; Corti *et al.* 1998; Lo Valvo & Massa 1999) suggests that these populations may have become extinct during the 1970s, despite the occurrence of suitable habitats on both islands.

The presence of green toads in the thermal springs of Lipari was recorded in late 19th century (Giglioli 1880; Boulenger 1898; see also Douglas 1930) and the last sightings date back to the 1980s (M. Capula, pers. comm.); contrariwise, some specimens collected on Salina in 1967 and now kept in the MZUF collections (Bruno 1970; Corti *et al.* 1998) represent the only finding of the species from this island; finally, Bruno (1970) has reported that green toads have intentionally introduced by locals in late 1960s on Vulcano, but there are nor evidences nor further observations that support this record, except for Bologna & Giacoma (2006) who have uncritically recorded the occurrence of *Bufo viridis* in all these islands. At least for Lipari and Salina, the cause of the extinction of these populations is still unclear, because especially in the first island there are still suitable habitats not particularly subject to anthropogenic pressure or disturbance. Furthermore, the status of conservation of the only Aeolian specimens preserved in museum collections (those from Salina) is not compatible with any genetic analysis in order to clarify if them should be referred to *Bufotes boulengeri* or the morphologically similar *B. balearicus* (Boettger, 1880), a not unlikely possibility in light of the geographical proximity between the archipelago and north-eastern Sicily, where this latter species occurs.

Pelophylax bedriagae complex (Camerano, 1882) (Ranidae) - Levantine frog

Distribution. The range of *P. bedriagae* extends from the Nile Delta in Egypt to NE Greece and SE Bulgaria, through the Near East (up to W Iran) and the western part of Anatolia (Speybroeck *et al.* 2016; Lukanow *et al.* 2018); however, Akin *et*

Figure 4. Reproductive site of *Bufotes boulengeri* at Taccio Vecchio, Lampedusa (photo P. Lo Cascio).

al. (2010) recognized this species as a complex of several evolutionary distinct taxa not yet described, and the original range of the "true" *P. bedriagae* should be western Turkey, and some insular populations in the Aegean previously identified as this species are indeed now referred to other taxa (Lymberakis *et al.* 2017). *Pelophylax bedriagae* is a recent acquisition for the Maltese Islands (see below); apart from some introduced populations in Europe (Belgium, Switzerland), its occurrence as alien is also known for Cyprus and Sardinia (Plötner *et al.* 2015; Bellati *et al.* 2019).

Life-history in the study area. Population consistence, phenology, trophic behaviour: Sciberras & Schembri (2006a, 2006b), Sciberras (2008); the same authors provided an evaluation of the potential impact of the species on native fauna.

Introductions. *Pelophylax bedriagae* was detected for the first time in Ta' Sarraflu pond at Gozo in 2000 (Sciberras & Schembri 2004, 2006b), and successively found in other wetlands of the same island (Wied il-Lunzjata, Ghajn il-Papri, Mgarr ix-Xini and Nadur), as well as at Mellieha Bay in Malta (Sciberras & Schembri 2006a). This species was most likely introduced in late 1990s and its expansion within the archipelago seems be due to anthropic translocations.

Testudo hermanni Gmelin, 1789 (Testudinidae) - Hermann's tortoise

Distribution. The Hermann's tortoise is distributed in S Europe and occurs with the nominal form in the western part of its range, including Sicily and circum-Sicilian islands, while Balkans and Greece harbor the subspecies *boettgeri* Mojsisovics, 1889. According to Corti *et al.* (2014), at regional level the species shows a constant decline, and in many cases is difficult to assess if the individuals found in natural habitats have wild or semi-domestic origin; only for Lipari the autochthony is supported by palaeontological data (see above).

Figure 5. The herpetologist Claudia Corti sampling a tissue piece from a captive autochthonous *Testudo hermanni* for molecular analysis, Lampedusa, June 2005 (photo P. Lo Cascio).

Life-history in the study area. No data available.

Introductions/extinctions. *Testudo hermanni* has been observed during 1980s in less anthropized areas of Salina (Navarra 1990) and more recently on Vulcano (Lo Cascio & Navarra 2003; July 2018, PLC unpubl. data); these observations are certainly to be referred to semi-domestic (or recently released) individuals, because the species has never been previously recorded for these islands, both extensively investigated by herpetologists.

From the results of several surveys carried out by one of us (PLC) since 2005, as well as from information gathered by residents (see Corti *et al.* 2006), this species in Lampedusa seems to be now represented only by captive individuals of local origin (Fig. 5); if still survives, the autochthonous population seems therefore to be really critical and close to its extinction in nature.

The decline of the species is probably part of a relatively recent general trend; still during the 19th century, in fact, several naturalists reported that the tortoises were quite common on the island (Gussone 1839; Calcara 1847; Sommier 1908).

The custom of collecting and breeding tortoises from the local populations seems rather common also in the islands of Pantelleria and Linosa, as reported by Lo Valvo (1998) and recently observed by T. La Mantia (pers. comm.).

Trachemys scripta (Thunberg in Schoeppf, 1792) (Emydidae) - Red-eared slider

Distribution. *Trachemys scripta* ssp. *elegans* (Wied-Neuwied, 1838), originally from S USA and N Mexico, has been introduced worldwide as pet and has recently recorded for the Maltese Islands (Ficetola *et al.* 2012; Speybroeck 2014), also with small feral populations; some of them occurring on Gozo could be hybridized with ssp. *scripta*, originally from SE USA (AS unpubl. data).

Life-history in the study area. No data available.

Introductions. The introduction was likely originated by individuals released in public gardens of few localities of Malta (e.g. Siġġiewi, Attard) and the first nest has been found in the Chadwick Lakes in June 2004 (AS unpubl. data). Although initially considered as alien with little potential of spreading by local authorities (see https://rm.coe.int/invasive-alien-species- in-malta/16807303b0, last access February 2020), an eradication program for the species is now being planned. This species seems able to expand gradually also in natural contexts (Ficetola *et al.* 2012), where it represents a threat for the invertebrates (Sciberras 2008a), but also for the native herpetofauna.

Chamaeleo chamaeleon (Linnaeus, 1758) (Chamaeleonidae) - Mediterranean chameleon

Distribution. This species occurs in N Africa, Middle East, SW Arabia and S Turkey, Cyprus, southern Greece, Crete and other Aegean Islands, Maltese Islands, S Italian Peninsula and S Iberian Peninsula. All the European populations are originated from historical or recent introductions; those occurring in the Maltese Islands belong to a group of eastern Mediterranean haplotypes (Dimaki *et al.* 2008).

Life-history in the study area. Genetics: Dimaki *et al.* (2008); population consistence (Gozo): Chini (2009, estimating 400-1000 individuals); trophic ecology: Luiselli & Rugiero (1996); information on habitat use: Bruekers (2003). More recent surveys carried out by MHS allow to estimate about 5000 individuals on Gozo and 300 on Comino (AS unpubl. data), while no data are still available for Malta.

Introductions/extinctions. The introduction of *C. chamaeleon* in Malta probably date back to middle 19th century (Sciberras 2007a); still rare and localized to the St. Julian's Garden until the time of Gulia (1914), the species is now widespread and common in the main islands and even in several islets of the archipelago. In contrast with this trend, the (small) population of Cominotto, probably introduced around mid-1990s (Sciberras 2007a), seems now extinct (AS unpubl. data).

New records. Manoel, Qawra Point.

Figure 6. *Chamaeleo chamaeleon* from Malta (photo B. Bok).

Hemidactylus turcicus (Linnaeus, 1758) (Gekkonidae) - Turkish gecko

Distribution. The geographical range of *H. turcicus* is extended to the Mediterranean area and Middle East, reaching the southern and eastern boundaries, respectively, in Somalia and India; introduced populations are recorded for some localities of N and C America and the Canary Islands. It is relatively common in the study area.

Life-history in the study area. Genetics (Lampedusa): Rato dos Santos (2012); morphometrics (Lampedusa): Lanza & Bruzzone (1961b).

Extinctions. The only case of extinction known for the study area concerns Selmunett, where the species has not been found since 2015 (AS unpubl. data).

Figure 7. Large Blue Lagoon Rock (or Il-Hagra ta'Bejn il-Kmiemen il-Kbira), near Comino (photo P. Lo Cascio).

New records. Santa Maria, Isola delle Femmine (V. Di Dio, pers. comm.), Rocca di San Nicola, Manoel, Cominotto, Qawra Point, Large Blue Lagoon Rock, Halfa Rock, Tac Cawl.

Tarentola fascicularis (Daudin, 1802) (Phyllodactylidae) - Wolfgang's wall gecko

Distribution. Previously considered a subspecies of the Moorish gecko, *T. fascicularis* has been raised at species rank and contextually stated as polytypic by Joger & Bshaenia (2010); however, according to Rato *et al.* (2012), this taxon should be considered as a "species complex" that includes yet undescribed species. Its distribution is extended from S Tunisia to Egypt and NW Sinai (Sarra *et al.* 2013; Werner 2016; Bauer *et al.* 2017), with an introduced population on Zakynthos (Ionian Islands) (Joger 2004).

The occurrence of this species on Lampedusa and Isola dei Conigli was detected by Harris *et al.* (2009; see also Aprea *et al.* 2011) who found two distinct genetic lineages, one closely related to W Lybian populations and another (only from Conigli) with N African affinities that however remain to be clarified. Furthermore, Rato *et al.* (2012) placed the Lampedusa and Conigli samples within a clade that includes also W Lybian and Lybian/Egypt border area populations.

Life-history in the study area. Genetics: Harris *et al.* (2009), Rato *et al.* (2012); morphometrics: Lanza & Bruzzone (1961b), Lo Cascio & Corti (2008); population density, habitat use, trophic and thermal ecology: Lo Cascio *et al.* (2005b), Lo Cascio & Corti (2008); hemoparasites: Ricci (1999).

Introductions/extinctions. The presence of two different genetic lineages within the small populations of Lampedusa and Conigli (Harris *et al.* 2009) suggests that these islands experienced multiple colonization events, probably related to recent introductions from N Africa, but their timing is still unclear.

Tarentola mauritanica (Linnaeus, 1758) (Phyllodactylidae) - Moorish gecko

Distribution. This polytypic species is widespread in the S Europe and NW Africa (with two subspecies recognized in Morocco) and occurring with introduced populations in N and S America.

Life-history in the study area. Ectoparasites (Malta): Bertrand *et al.* (2012).

Introductions/extinctions. Similarly to *H. turcicus*, also *T. mauritanica* seems now extinct from Selmunett, where the last sighting date back to 2014 (AS unpubl. data).

New records. La Scuola, Isola delle Femmine (V. Di Dio, pers. comm.), Colombaia, Vittoria Garcia, Manoel, Qawra Point, Halfa Rock, Tac Cawl.

Podarcis filfolensis (Bedriaga, 1876) (Lacertidae) - Maltese wall lizard

Distribution. *Podarcis filfolensis* occurs exclusively in Maltese and Pelagie archipelagoes with the nominal subspecies from Filfla Islet, the subspecies *generalensis* (Gulia, 1914) from Fungus Rock, kieselbachi (Fejérváry, 1924) from Selmunett, *laurentiimuelleri* (Fejérváry, 1924) from Pelagie, and *maltensis* Mertens, 1921 from the main islands of the Maltese group. Their taxonomic validity is however debated and most likely doubt, as suggested by the results of recent studies (Rodríguez *et al.* 2014; Salvi *et al.* 2014) that shown the existence of two main phylogroups

Figure 8. Detail of the head of *Tarentola fascicularis* from Lampedusa (photo P. Lo Cascio).

Figure 9. Male of *Podarcis filfolensis* from Lampione (photo P. Lo Cascio).

within the species populations, one (Maltese lineage) occurring on Malta and the nearby Filfla and one (Gozitan lineage) that includes those inhabiting Gozo, Comino and surrounding islets, two satellites of Malta (Selmunett and Qawra Point), and the Pelagie; the arrival of the species in these latter islands may be due to an historical introduction, while the divergence between these lineage is dated back to Middle Pleistocene.

Life-history in the study area. Genetics (Linosa): Scalera *et al.* (2004); (whole populations): Capula (1994b), Rodríguez *et al.* (2014), Salvi *et al.* (2014); morphometrics and phenotypes: Lanza & Bruzzone (1961b), Savona Ventura (1983a, 2001), Bischoff (1986), Scalera *et al.* (2004), Lo Cascio *et al.* (2006), Faraone (2011); density and population consistence (Linosa): Di Palma (1991), Scalera *et al.* (2004); (islets): Lanfranco in Honegger (1981); Lo Cascio *et al.* (2006), Sciberras & Schembri (2008); reproductive biology: Moravec (1993); post-natal ontogeny related to phenotypic diversity: Piras *et al.* (2011); trophic ecology (Linosa): Sorci (1990), Bombi *et al.* (2005); (Lampedusa): Lo Cascio & Corti (2008); (Lampione): Lo Cascio *et al.* (2006), Carretero *et al.* (2010); dietary shifts or adaptations: Fici & Lo Valvo (2004), Sciberras (2007b, 2009), Lo Cascio & Pasta (2012), Sciberras & Sciberras (2014), Lewis *et al.* (2015); thermal ecology (Lampedusa): Lo Cascio & Corti (2008); (Lampione): Lo Cascio (2010a); predation: Fornasari & Zava (2001), Sciberras (2007a, 2007b), Borg & Sultana (2010), Sciberras *et al.* (2012), Sciberras & Sciberras (2014); defense behaviour: Sciberras (2014); endo- and ectoparasites: Roca *et al.* (2006), Stekolnikov *et al.* (2014). Furthermore, some contributions deal with monitoring methods (Corti & Lo Cascio 2016) and conservation problems (Sciberras & Lalov 2007; Sciberras & Schembri 2008), a priority topic considering that this endemic lizard currently appear to be in decline not only on some small islets (see below) but also on Malta, where it seems lacking from wide portions of the island probably due to competition processes and/or environmental degradation.

Figure 10. Male of *Podarcis filfolensis* from the extinct population of Selmunett (photo A. Sciberras).

Introductions/extinctions. As above already mentioned, the origin of Pelagian populations is due to historical introduction of lizards belonging to the Gozitan lineage (Rodríguez *et al.* 2014; Salvi *et al.* 2014). However, these colonization events are certainly not recent.

Between 2001 and 2002, instead, some individuals of *P. filfolensis* from Linosa have been intentionally released by locals in a private backyard of Lampedusa village (Lo Cascio *et al.* 2005). An expected expansion of this small population (30-40 individuals estimated by Lo Cascio & Corti 2008) into neighbouring areas has been probably hampered by the occurrence of the congeneric *P. siculus*, already established in the village since late 1990s (see below). On the contrary, for unknown reasons the Maltese wall lizard should no longer be present (Lo Valvo *et al.* 2018).

Podarcis filfolensis occurred on Selmunett (Fig. 10) with an high population density until the 1990s (Moravec 1993); since this time a constant decline was observed, until it became extinct in 2005 (Sciberras & Schembri 2008). The cause is supposed to be the predation by rats, that seem to have concurrently increased on this islet due to the availability of organic refuse left by summer visitors. It should be noted that the same involved all the four reptile species living on Selmunett (apart from the lizard, two geckos and one snake: see Sciberras & Sciberras 2014; AS unpubl. data).

On Malta, this species currently has not been detected from the north west coast of the island to about two kilometers inland, although it was observed still abundant in past (Sciberras 2008b). The contraction of its range could be due to competition with other species (e.g. the invasive Mediterranean chameleon) and deserves attention.

New records. Pigeon Rock, Cheirolophus Rock.

Podarcis raffonei (Mertens, 1952) (Lacertidae) - Aeolian wall lizard

Distribution. *Podarcis raffonei* shows a relict distribution within the Aeolian Archipelago, with three populations inhabiting tiny islets and a fourth that in recent times has (most likely) become extinct from one main island; of the four infraspecific taxa originally described, only two are currently considered valid, namely the nominal form that inhabits Strombolicchio and the subspecies *alvearioi* (Mertens, 1955) from Scoglio Faraglione and La Canna (Capula 2006). Concerning the species name, Michels & Bauer (2004) have argued that it should be declined in feminine (*raffoneae*), but according to the opinions recently expressed by Arribas (2017) we prefer to maintain here the original form.

Life-history in the study area. Genetics: Capula (1994a, 2006), Bruschi *et al.* (2005); morphometrics and phenotypes: Mertens (1952, 1955), Di Palma (1980), Lo Cascio (2006), Capula *et al.* (2009); population density, consistence and structure: Capula & Luiselli (1997), Capula & Lo Cascio (2006), Lo Cascio (2006), Lo Cascio *et al.* (2014a), Ficetola *et al.* (2018); trophic ecology and dietary adaptations: Luiselli *et al.* (2004), Lo Cascio (2006), Lo Cascio & Capula (2011), Delaugerre *et al.* (2012), Lo Cascio *et al.* (2014a); thermal ecology: Lo Cascio (2006), Capula *et al.* (2014); defense behaviour: Pérez-Mellado *et al.* (1997); spatial use and predation: Lo Cascio (2006); parasites: Roca *et al.* (2006). Standard monitoring methods for have been recently proposed by Lo Cascio & Ficetola (2016), while some contributions claimed attention on the urgency of effective measures of conservation (Capula *et al.* 2002; Lo Cascio 2006; Lo Cascio 2010b; Gippoliti *et al.* 2017).

Unconfirmed or erroneous records. The occurrence of this species on the Gran Cratere of Vulcano was recorded in a recent paper (D'Amico *et al.* 2018) on the basis of individuals seen by two German amateur herpetologists. However, one of us (PLC) carried out long-term surveys in the same area, finding only individuals of *P. siculus*, that sometime show melanic dorsal patterns and may have been misidentified with the other species. On this island the endemic *P. raffonei* has undergone a drastic contraction of its range during the last decades and its last population was detected on the small peninsula of Capo Grosso (Lo Cascio 2010b), but also there it seems now probably extinct or on the brink of extinction (see below).

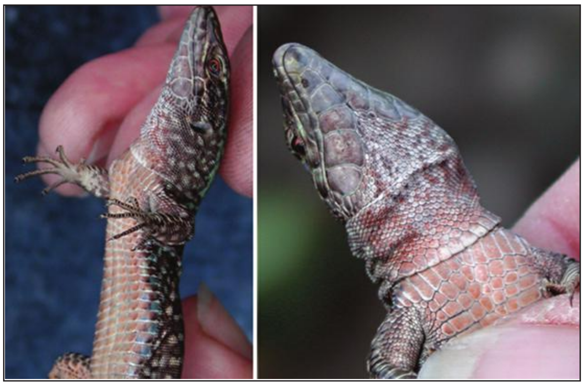

Figure 11. Probable hybrid between *Podarcis siculus* and *P. raffonei*, Alicudi, April 2002 (photo P. Lo Cascio).

Extinctions. As previously mentioned, *P. raffonei* has now most likely disappeared from Vulcano, where the last population survived on the distal area of Capo Grosso peninsula (Lo Cascio 2010b) until that came into contact with *P. siculus*. From linear transects and visual encounter surveys performed in spring 2017, Ficetola *et al.* (2018) have estimated the size of this population as about 1050 individuals with an average density of 0.35 individuals/m^2; however, it is really not clear how much of this sample was composed by pure or hybridized *P. raffonei*. Further surveys carried out two years later in the same site (spring 2019, PLC unpubl. data) have indeed allow to detect only specimens belonging to *P. siculus* and/or probable hybrids between the two species, hence if we assume that data provided by Ficetola *et al.* (2018) are reliable, the decline of the native species was surprisingly fast. Unfortunately, this epilogue seems consistent with the scenario outlined since *P. raffonei* was recognized as biological species (Capula 1994a), that is its extinction from all or most of the main Aeolian islands, probably due to competitive exclusion processes with *P. siculus* (Capula 1992; Capula *et al.* 2002). It is strongly suggested by i) the finding of hybrids F1 *siculus* x *raffonei* in Vulcano and probable hybrids in Alicudi (Capula 1993; Lo Cascio 2017) (Fig. 11), ii) a case of genetic introgression found in the *P. siculus* population of Lipari (Capula 1993) and iii) the current distribution of the *P. raffonei*, restricted to three islets where isolation acts as barrier against the contact between these species.

Podarcis siculus (Rafinesque-Schmaltz, 1810) (Lacertidae) - Italian wall lizard

Distribution. The geographical range of *P. siculus* is limited to the Italian Peninsula (including the main islands) and the E Adriatic coast, but the species has been introduced in several localities of S Europe, N Africa, Turkey and United States. It is widespread in the circum-Sicilian islands, where occurs on 40 out of 49 islands with some melanic or hyperchromatic populations that have been referred to distinct subspecies: *ciclopicus* (Taddei, 1949) from Lachea and Scoglio della Madonnina, *liscabiancae* (Mertens, 1952) from Lisca Bianca, *medemi* (Mertens, 1942) from Isola Bella, *strombolensis* (Taddei, 1949) from Stromboli, Panarea and Basiluzzo, and *trischittai* (Mertens, 1952) from Bottaro. Although the large number of "island races" described for this species have been, often dogmatically, considered as not valid and therefore synonymized (see Razzetti *et al.* 2006), the recent case of the western Pontine Islands - where the subspecies *latastei* has been raised at species rank (see Senczuk *et al.* 2019b) - suggests that these populations could deserve more attention, as well as the whole infraspecific taxonomy of *P. siculus*. Furthermore, Lo Valvo *et al.* (2004) and Faraone (2011) found in some populations slight but intriguing examples of "insular syndrome", such as tendency to dwarfism (Pantelleria and Isola delle Femmine) and reduction of limb length (Isola Bella).

Life-history in the study area. Genetics (Marettimo and Pantelleria): Capula (1993, 1994c); (Ustica): Fulgione *et al.* (2008); (several populations): Maggio *et al.* (2005), Senczuk *et al.* (2017); morphometrics and phenotypes: Mertens (1942, 1952, 1955), Lo Valvo *et al.* (2004), Fulgione *et al.* (2008), Capula *et al.* (2009), Faraone (2011); population density and consistence (Isola Bella): Lo Valvo *et al.* (2004); (Lachea): Siracusa *et al.* (2012); defense behaviour (some Aeolian Islands): Pérez-Mellado *et al.* (1997); parasites: Stekolnikov *et al.* (2014).

Unconfirmed/erroneous records. A record for Pietra Quaglietto given by Bruno (1970) has not been confirmed successively in literature (Lanza 1973; Corti *et al.* 1998, 2006), as well as from surveys carried out during the last two decades (PLC unpubl. data). Its possible occurrence on a "conservative" context such as an islet, not subject to anthropogenic disturbance and with suitable conditions to support a viable population, and moreover located near Vulcano, where this species seems to have expanded its range in recent decades, appears rather unlikely even from a biogeographical point of view, leading to exclude the hypothesis of a local extinction.

Introductions/extinctions. The Italian wall lizard has been often considered as invasive species (see Lever 2003), due to the large number of localities out of its originally range where it is established and in general to its tendency to expand through anthropogenic transportations. Low levels of genetic diversity found in some circum-Sicilian islands (Capula 1994c) strongly support also the hypothesis of recent introductions; recent analysis of the haplogroups of Aegadian and Aeolian populations have shown a monophyletic and a polyphyletic origin respectively, although strangely no haplotypes are shared between the Aeolian archipelago and Sicily (Senczuk *et al.* 2017).

The case of Aeolian Archipelago, where the endemic *P. raffonei* has undergone to a drastic contraction of its range due to the competition with *P. siculus*, has the implicit assumption that this latter colonized these islands, and especially Vulcano, only after the arrival of the other lizard and perhaps in historical times. Although human settlement and exploitation may have played a significant role in the expansion of *P. siculus* in some islets (for instance, those around Panarea, see Lo Cascio & Corti 2006), there are no certain evidences that the whole archipelago was invaded in very recent times, as argued by D'Amico *et al.* (2018) for Vulcano. Can not to be excluded indeed that in some contexts (e.g. the main islands) a prolonged syntopy between the two species have occurred, up to the arise of further factors (e.g. a massive anthropization) that changed a former equilibrium and caused the extinction of *P. raffonei*. It seems also suggested by the polyphyletic origin of the Aeolian haplotypes (Senczuk *et al.* 2017), that indicates for these islands multiple and probably ancient colonization events. In this perspective, *P. siculus* cannot be included among the "recent" introductions considered in the present paper.

Similar considerations may be extended also to the populations of Marettimo and Pantelleria. It should be noted that the first specimens of *P. siculus* collected by pioneering zoological explorations on these islands dated back to 1890 and 1875 respectively (see Taddei 1949; Corti *et al.* 1998), and no annotations and/or observations refer to the possible rarity of this lizard, hence is presumable that at this time it was already common and widespread. Furthermore, at least for Marettimo, comparing the recent observations (PLC unpubl. data) and the situation of about 70 years ago described by Klemmer (1956), the space repartition between *P. siculus* and *P. waglerianus* seems relatively stable through the time.

On the contrary, *P. siculus* was accidentally introduced on Lampedusa since late 1990s, probably during the implantation of ornamental trees (Lo Valvo & Nicolini 2001), and now a small population is established in the village, where occurs in some gardens and in the archaeological ruins of the village with an estimated density of 3.3-4 individuals/100 m^2 and an occupied surface of about 2.5 ha (Lo Cascio & Corti 2008). It is noteworthy that more than 20 years after its arrival on the island, the species has not expanded outside the urban areas and has not colonized natural environments.

A well-known case of extinction is that of Lisca Nera (not listed in Table 1, geographical coordinates: 383805N, 150624E), a satellite islet of Panarea now almost entirely destroyed by the erosion: the occurrence of a population of *P. siculus* was discovered by Giglioli (1878) and its disappearance placed between late 19th century and 1950s, explained with the surface reduction underwent by the islet (Mertens 1955; Lanza & Corti 1996). New hypothesis suggest however that its extinction could have occurred within a shorter span of time, due to a demographic decline paradoxically accelerated by the sample of specimens (Lo Cascio *et al.* 2014b).

New records. Faraglione di terra di Cala Fico, Colombaia (B. Massa, pers. comm. and authors' field survey).

Podarcis waglerianus Gistel, 1868 (Lacertidae) - Sicilian wall lizard

Distribution. *Podarcis waglerianus* is exclusively distributed in Sicily and some circum-Sicilian islands. Currently it is considered as monotypic, because the subspecies *marettimensis* (Klemmer, 1956) from Marettimo (Fig. 12) is not supported by a sufficient degree of genetic differentiation from the nominal one (Capula & Lo Cascio 2011); although not forming a distinct mtDNA clade, Mizan (2015) and Senczuk *et al.* (2019a) found however that the Aegadian populations are characterized by an unique haplotype and especially Marettimo constitutes a subgroup rather distinct from the others; in the same island Capula (1993) found also hybrids F1 *siculus* x *waglerianus*. Concerning the morphological traits, Faraone *et al.* (2010) found that a certain degree of distinctiveness characterized La Scuola population.

Life-history in the study area. Genetics: Capula (1993), Mizan (2015), Senczuk *et al.* (2019a); morphometrics and phenotypes: Faraone *et al.* (2010), Faraone (2011), Mizan (2015); trophic ecology (La Scuola): Lo Cascio & Pasta (2006).

Unconfirmed/erroneous records. *Podarcis waglerianus* was recorded for Maraone by Lo Valvo (1998), where further investigations have confirmed exclusively the occurrence of *P. siculus* (Maggio *et al.* 2005; Faraone 2011; Capula & Lo Cascio 2011).

It was also recorded for San Pantaleo by Lo Valvo & Massa (1999; see also Corti *et al.* 2006), but its occurrence has not been successively detected (Faraone *et al.* 2010; Faraone 2011; PLC unpubl. data from surveys carried out in 2017 and 2019); more than an extinction case, difficult to explain considering the environmental and faunal homogeneity between this and the other Stagnone islands, it was very likely an erroneous report.

Psammodromus algirus (Linnaeus, 1758) (Lacertidae) - Algerian Psammodromus

Distribution. *Psammodromus algirus* has a W Mediterranean distribution and is a polytypic species, with some subspecies described for the N African part of its range. Conigli Islet (Fig. 13) harbors the only Italian population, whose occurrence has been recorded for the first time by Zavattari (1954).

Life-history in the study area. Genetics: Carretero *et al.* (2009); morphometrics: Lanza & Bruzzone (1961b), Lo Cascio & Corti (2008); trophic ecology: Di Palma (1984), Sorci (1990), Lo Cascio & Corti (2008); activity patterns, habitat and spatial use, thermal ecology, predation pressure: Lo Cascio & Corti (2008). The islet population has been estimated as about 2000 individuals by Di Palma (1984) and only 600-1200 individuals by Lo Cascio & Corti (2008).

Introductions/extinctions. The occurrence of *P. algirus* on Isola dei Conigli (Zavattari 1954), has long represented a biogeographical enigma, due to the absence of this lizard from the nearby Lampedusa; phylogeographic affinities of this population with a Moroccan clade instead of those found in closer areas (for instance, Tunisia) sug-

Figure 12. Male of *Podarcis waglerianus* from Marettimo (photo P. Lo Cascio).

Figure 13. Isola dei Conigli, near Lampedusa (photo P. Lo Cascio).

gest, however, that its origin is due to a probably recent and human-mediated colonization, rather than a land crossing from N Africa during Pleistocene (Carretero *et al.* 2009). This does not exclude of course the possibility that the species inhabited also the main island, where the predation by saurophagous snakes and the environmental alterations occurred at mid-19th century could have led to its extinction, as hypothesized by Padoa Schioppa & Massa (2001).

Chalcides ocellatus (Forskål, 1775) (Scincidae) - Ocellated skink

DISTRIBUTION. This species is widely distributed through N and E Africa, Near and Middle East (until to SW Pakistan) and in some areas of S Europe (main Italian islands, Greece and some Aegean islands, Cyprus and Turkey) and was considered polytypic, with the following subspecies recognized in (or described for) the study area: *linosae* E.G. Boulenger, 1920 from Linosa, *tiligugu* (Gmelin, 1789) in the circum-Sicilian (except Pelagie) and Maltese Islands, and *zavattarii* Lanza, 1954 from Lampedusa and Conigli. According to Kornilios *et al.* (2010), these taxa represent however most likely ecomorphs and are not genetically distinct, thus here *C. ocellatus* is considered as a monotypic species.

LIFE-HISTORY IN THE STUDY AREA. Genetics: Carranza *et al.* (2008), Kornilios *et al.* (2010), Stöck *et al.* (2016); morphometrics and phenotypes: Lanza & Bruzzone (1961a), Savona Ventura (1983b), Lo Cascio & Corti (2008); trophic ecology: Lo Cascio & Corti (2008), Lo Cascio *et al.* (2008), Carretero *et al.* (2010); other data on feeding behaviour: Sciberras (2007a, 2008, 2009); thermal ecology: Lo Cascio & Corti (2008), Lo Cascio (2010b); spatial use, predation pressure, population density and consistence (Conigli and Lampedusa): Lo Cascio & Corti (2008); parasites: Roca *et al.* (2006). Unconfirmed/erroneous records

A record for Formica given by Corti *et al.* (1998) is due to a *lapsus calami* and has not been successively confirmed by Corti *et al.* (2006).

INTRODUCTIONS. Circum-Sicilian (Pelagie and Pantelleria) and Maltese populations, together with those from Sicily, Tunisia and Sardinia, fall into a well-defined clade (Kornilios *et al.* 2010), and the very low genetic divergence values found between them suggest a (recent?) human-mediated introduction in these islands or, at least, a Middle-Pleistocene colonization event (Stöck *et al.* 2016). Similar cases of anthropogenic origin for some populations due to species traslocations are known for other areas of the western Mediterranean (Bisbal-Chinesta *et al.* 2020).

Chalcides ocellatus has been recently found on Ustica and Stromboli; in both islands its occurrence seems due to accidental introductions. However, on Ustica just one individual was detected (Panuccio 2003) and no further data suggested a successful colonization, while on Stromboli a small population observed for the first time four years ago (Lo Cascio & Grita 2016) seems now established in the sandy coastal area of Punta Lena (PLC unpubl. data).

NEW RECORDS. Manoel, Qawra Point.

Hemorrhois algirus (Jan, 1863) (Colubridae) - Algerian whip snake

DISTRIBUTION. This N African polytypic species occurs in the eastern sector of its range (including Malta, see below) with the nominal form, while the western part is inhabited by the subspecies *intermedius* Werner, 1929.

LIFE-HISTORY IN THE STUDY AREA. Morphometrics: Bons (1962), Schätti (1986); distribution in Malta: Lang (1993).

INTRODUCTIONS. According to Borg (1939), this species have been introduced with shipments of firewood during the first World War, while Lanfranco (1955) believes that its colonization was around 1927, when the first individuals were found at Foss tal-Bucci and Marsa.

NEW RECORDS. Manoel.

Hemorrhois hippocrepis (Linnaeus, 1758) (Colubridae) - Horseshoe whip snake

DISTRIBUTION. *Hemorrhois hippocrepis* is a W Mediterranean species (originally from Maghreb) that in the study area occurs only on Pantelleria; this population has been referred to the subspecies *nigrescens* (Cattaneo 1985) on the basis of its melanic pattern, its size larger than in conti-

Figure 14. *Hemorrhois algirus* from Malta (photo B. Bok).

nental conspecifics and other meristic characters; however, Corti *et al.* (2000) found no significant difference within the populations from this island, Tunisia and Sardinia, hence the validity of this taxon needs to be confirmed.

Life-history in the study area. Morphometrics and phenotypes: Cattaneo (1985, 2001, 2015), Corti *et al.* (2000); reproductive biology: Cattaneo (2001); trophic ecology and population density: Capula *et al.* (1997), Cattaneo (2015).

Unconfirmed/erroneous records. Bons (1962) reported this species for Malta on the basis of specimens kept in the MNHNP collections and emphasized its unusual sympatry with *H. algirus*, but Lanza (1973) has successively clarified as this record was due to an erroneous indication of locality or a misidentification.

Introductions. It is presumable that *H. hippocrepis* was introduced on Pantelleria, but its arrival shouldn't be recent: the oldest museum specimens, kept in the MZUF collection, date back to 1882 (Corti *et al.* 1998) and were collected more or less at the same time of the first record of the species given by Doderlein (1881).

Hierophis carbonarius (Bonaparte, 1833) (Colubridae) - Western whip snake

Distribution. Recently raised at species rank by Mezzasalma *et al.* (2015), *H. carbonarius* is distributed in the Italian Peninsula and Sicily and is relatively widespread in the study area, occurring both on circum-Sicilian (see Avella *et al.* 2017) and Maltese islands (Cattaneo 2015).

Life-history in the study area. Genetics (Aeolian and Aegadian): Avella *et al.* (2017); morphometrics and phenotypes (Malta): Cattaneo (2015); trophic ecology and habitat use (Malta): Cattaneo (2015); (Ustica): Filippi *et al.* (2003).

Introductions/extinctions. *Hierophis carbonarius* was detected between 1984 and 1986 in the surroundings of the harbour of Linosa (SHI 1996; Lo Valvo 1998), where probably a single or few individuals have been accidentally introduced; after the last sighting no other data confirmed however the occurrence of the species on this island (F. Lo Valvo, pers. comm. and authors' further surveys).

New records. Manoel.

Macroprotodon cucullatus (Geoffroy Saint-Hilaire, 1827) (Colubridae) - Algerian false smooth snake

Distribution. This species is distributed along a N Saharian belt from Morocco to NE Sinai and NW Israel. The only Italian population occurs on Lampedusa and its taxonomic status is still uncertain: it has been indeed referred to *M. mauritanicus* Guichenot, 1850 by Busack & McCoy (1990), then successively to *M. cucullatus* ssp. *textilis* (Duméril & Bibron, 1833) by Wade (2001), but according to the recent results of mtDNA analysis (Carranza *et al.* 2004) this subspecies would fall into different clades, so its phylogenetic relationships need to be clarified. Hence, in the present paper we prefer to consider the species as *M. cucullatus* sensu lato.

Life-history in the study area. Morphometrics: Lanza & Bruzzone (1961b), Corti & Luiselli (2001), Cattaneo (2015); activity patterns and trophic behaviour: Corti & Luiselli (2001), Lo Valvo & Longo (2001), Cattaneo (2015), Faraone *et al.* (2020).

Doubtful records. During a brief visit on Lampione in August 1882, companions of the Italian zoologist Enrico H. Giglioli have seen two snakes dubitatively referred to *Coronella cucullata* (= *Macroprotodon cucullatus*) (Giglioli 1884), but no further data confirmed the occurrence of the species on this islet. According to Lanza (1973), it is anyway hard to believe that a snake may have be confused with lizards or skinks, that are the only reptiles inhabiting Lampione. It is therefore possible that a (presumably small) snake population, whose true identity remains unclarified, could have disappeared from the islet between late 19th century and the zoological surveys carried out in the 1950s (see Lanza & Bruzzone 1961b).

Telescopus fallax (Fleischmann, 1831) (Colubridae) - Cat snake

Distribution. The range of *T. fallax* is extended to SE Europe (including Malta, where it has been surely introduced: see Lanfranco 1955), Anatolia and Near East; it is a polytypic species, with several subspecies described for some islands and/or continental areas in the eastern portion of its range, while the nominal form occurs in the study area.

Life-history in the study area. No data available.

Introductions. *Telescopus fallax* was recorded for the first time for Malta by Giglioli (1894); Borg (1939) assumed its occurrence as due to accidental introduction, similarly to *Hemorrhois algirus*; Lanfranco (1955) has given new records from Floriana; Schembri (1984) and Schembri & Lanfranco (1996) supposed that the species may be native, but it should be noted that i) *T. fallax* is absent from Sicily and North Africa, and ii) there are cases of its human-mediated introduction on other Mediterranean islands already reported in literature (see Warnecke 1988).

New records. Manoel.

Zamenis situla (Linnaeus, 1758) (Colubridae) - Leopard snake

Distribution. This monotypic species has a S European distribution extended to W Anatolia; within the study area it occurs only in the Maltese Islands.

Life-history in the study area. Morphometrics and phenotypes: Cattaneo (2015); the same author provides few information on preys and habitat of the species.

Extinctions. *Zamenis situla* seems now extinct from Selmunett, where the last sighting date back to 2007 (AS unpubl. data) (see also *H. turcicus*, *T. mauritanica* and *P. filfolensis* in the same islet).

New records. Cominotto, Qawra Point.

Figure 15. *Zamenis situla* from Malta (photo B. Bok).

Malpolon insignitus (Geoffroy Saint-Hilaire, 1827) (Psammophiidae) - Eastern Montpellier snake

Distribution. *Malpolon insignitus* is widely distributed in N Africa, Near and Middle East, Anatolia and SE Europe; in most part of its range, including Lampedusa (that harbors its only Italian population), this polytypic species occurs with the nominal form, while another subspecies is described for the Balkans.

Life-history in the study area. Morphometrics and phenotypes: Lanza & Bruzzone (1961b), Corti *et al.* (2001), Cattaneo (2015); activity, habitat use and trophic behaviour: Corti *et al.* (2001), Cattaneo (2015).

3. Species erroneously recorded

Pelophylax lessonae (Camerano, 1882) (Ranidae) - Pool frog

This species has been erroneously reported for Ustica and Lampedusa in the relative map by the first Italian atlas (SHI 1996), as already clarified by Corti *et al.* (1998).

Lacerta bilineata Daudin, 1802 (Lacertidae) - Western green lizard

The records of this species given by Boettger (1881) for Ustica and Marettimo have been already excluded in the previous literature (see Bruno 1970; Lanza 1973; Massa & Di Palma 1988; Corti *et al.* 1998).

4. Other cases of introductions/extinctions

Bufo bufo (Linnaeus, 1758) (Bufonidae) - Common toad

This species is widespread in Europe (except SW, Ireland and central Scandinavia), W Anatolia, N Kazakhstan and far into Russia. Cases of introduction of the common toad on Lipari, Ustica and Marettimo have been reported by Bruno (1970), who at the same time expresses however doubts about its actual naturalization. The occurrence of the species on these islands has been successively excluded by Lanza (1973) and Corti *et al.* (1998).

Unidentified Anura (Discoglossidae or Ranidae)

The identity of the "frogs" recorded for Lipari by Habsburg Lothringen (1894) and occurring until thirty years ago in the area of Marina Lunga (Fig. 16), a fertile plain with some artificial ponds and now densely urbanized, is destined to remain unknown. As reported by elderly residents, during the 1930s these animals were extremely common in this area and usually captured by locals to be sold as food to the political exiles confined in the island: this allows to exclude that they were green toads, the only amphibian known for Lipari, suggesting rather they were green frogs belonging to the genus *Pelophylax* or perhaps *Discoglossus pictus* (Lo Cascio 2014).

Figure 16. Marina Lunga (Lipari Island) in late 1950s; a population of unidentified frogs inhabited the artificial ponds of this area before its wide urbanization.

Hyla sp. (Hylidae)

A small population of *Hyla* sp. [probably *H. intermedia* Boulenger 1882, or *H. arborea* (Linnaeus, 1758)], clearly originated by human-mediated introduction, was present from 2013 to 2016 in Wied ta' San Martin near Mgarr in Malta, and has been (fully?) eradicated by MHS members; some individuals have been also found in Buskett (AS unpubl. data). After these sightings the species was no longer observed.

Graptemys pseudogeographica ssp. *kohni* (Baur, 1890) (Emydidae) - Mississipi map turtle

Originally from central-southern USA, according to Global Register of Introduced and Invasive Species (https://www.gbif.org/fr/species/6157050) this freshwater turtle has been introduced as exotic pet in Europe, South America and Japan. It is known also for some Mediterranean islands (e.g. Krk: see Schweiger 2015). In Europe the risk of establishment is generally considered low (Kopecký *et al.* 2013; Filz *et al.* 2017). In Italy its occurrence was detected since 1990s in natural and urban habitats (Di Santo *et al.* 2017; Ferri *et al.* in press), almost always associated with other alien turtles, but only recently the breeding has been confirmed (Ferri *et al.* 2020). *Graptemys pseudogeographica* ssp. *kohni* was observed for the first time in March 2002 at Il-Wied tal-Fiddien in Malta. Successively, 8 adults in 2007 and 16 juveniles in 2009 were found in the same locality; this latter observation suggests that breeding may have occurred. Thereafter every year one or two specimens are always captured from the same site by MHS members. Furthermore, 5 individuals were seen in 2014 at Għain il-Papri in Gozo; they have been regularly seen until 12 November 2019 (AS, unpubl. data). There are no previous records of the occurrence of this species in these islands, that provisionally is listed here waiting for further evidences of its probable establishment.

Testudo graeca Linnaeus, 1758 - Spur-thighed tortoise

Testudo marginata Schoepff, 1792 (Testudinidae) Marginated tortoise

The range of *T. graeca* includes SE Europe, Anatolia, Near and Middle East, and N Africa, while that of *T. marginata* is originally limited to Albania, Greece and some Aegean islands; since ancient times both have been however object of human trade and transport, as evidenced by the many localities where they are introduced (*T. marginata*: Sardinia and surrounding islands, Turkey; *T. graeca*: Balears, Sardinia, France). Gulia (1914) has reported the local use to introduce *T. marginata* and *T. graeca* (also under the synonym of *T. mauritanica*) in Malta from N Africa; according to this author, especially the latter was widely naturalized, enough to receive a Maltese name (fecruna ta' l-art). Also Lanfranco (1964) recorded a case of introduction of *T. graeca* on Gozo. The species has been found in the Neolithic layers of Għar Dalam cave on Malta and in Pergla cave on Gozo, associated to human remains (Despott 1918), and that therefore suggests a long history of probable introductions apparently not followed by naturalization: both species are indeed not confirmed for the Maltese fauna. Records of *T. graeca* given for Lampedusa by several naturalists and visitors of the 19th century have most likely to be referred to *T. hermann*i (see Lanza & Bruzzone 1961b; Masseti 2002); contrariwise, an enigmatic iconography of a "*Testudo Lampadosae sive Africana*" given by Cupani (1713: table 146) in the third volume of his "Panphyton Siculum", that according to Lo Valvo (1998) and Massa (2009) clearly resembles a specimen of *T. marginata*, suggests that this species could have occurred on this island at least until 18th century, surely due to an (ancient?) human-mediated introduction.

Centrochelys sulcata (Miller, 1779) (Testudinidae) - African spurred tortoise

Originally from C Africa, *C. sulcata* is widespread as exotic pet. In 2004 and 2015, some adults and juveniles have been found in a coastal area of Xagħra in Gozo (AS unpubl. data); these individuals could be illegally released or escaped from captivity. No further data allow to confirm the occurrence of this species in the island.

Agama agama (Linnaeus, 1758) (Agamidae) - African rainbow lizard

This species is widely distributed in C Africa and has been introduced in Madagascar, Comoro, Cape Verde and Madeira islands (Vasconcelos *et al.* 2009; Wagner *et al.* 2012); in late 1990s, for a short span of time, a population has also established in the harbour of Palermo (Lo Valvo 1998). At least one individual was found in the harbour of Marsa in 1979 (Schembri & Schembri 1984) and three were found in July 2008 near the freeport of Birżebbuġa by one of us (AS), probably accidentally introduced through cargo ships, but no other data confirm the occurrence of this species on Malta.

Mediodactylus kotschyi (Steindachner, 1870) (Gekkonidae) - Kotschy's gecko

This species, originally from SE Europe, Aegean area and Middle East, is known also for some localities out of its range where it was accidentally introduced (Farkas *et al.* 1999; Grillenzoni & Mazzotti 1999; Novarini 2012). It was recorded as introduced species on Malta by E.O. Wade (in Lever 2003) and by Invasive Species Compendium (https://www.cabi.org/isc/datasheet/115534, last access February 2020); furthermore, at least one specimen affected by *Sauroleishmania* from Malta was recorded by Telford (2009) without details about the host identification. Despite extensive investigations carried out by one of us (AS) during the last decade, no evidences allow to confirm the actual occurrence of the species. However, cannot be excluded that a casual population was established in the town for a short span of time, becoming extinct during the last years.

Unidentified Lacertidae

Lanfranco (1964) has reported the case of a British officer that during 1960s released individuals of "*eyed and green lizards*" (probably *Timon* sp. and *Lacerta bilineata*) on Gozo, none of them successively naturalized.

Pantherophis guttatus (Linnaeus, 1766) (Colubridae) - Corn snake

Originally from SE USA, the corn snake is one of the most popular pet species among collectionists and vivarium hobbyists; according to Global Invasive Species Database (http://www.iucngisd.org/gisd/species.php?sc= 1572, last access February 2020), the exotic pet trade seems to be the main pathway for its introduction, that has been recorded for West Indies, Brazil, South Africa, some European countries and Australia, although not always followed by establishment (Van Wilgen *et al.* 2008; Kraus 2009; Powell *et al.* 2011; Fonseca *et al.* 2014; Maričič & Koren 2014; García Diaz *et al.* 2017). This species has been observed since 1999 in Malta with individuals probably escaped or illegally released from captivity; some juveniles and hatchlings were also found between 2015 and 2019 in Wied il-Kbir and in the surroundings of Għar Ħanżir (AS unpubl. data). There are no previous records of the occurrence of this species in the island, that provisionally is listed here waiting for further evidences of its probable establishment.

Lampropeltis getula (Linnaeus, 1766) (Colubridae) - Chain kingsnake

This colubrid snake is originally from SE USA and also widespread as exotic pet, but is considered as less potentially invasive species in comparison to the corn snake and no naturalized populations are known out of its geographical range, while the congeneric *L. californiae* (Blainville, 1835), treated by some authors as subspecies of *L. getula*, has been introduced and is now established in Gran Canaria Island, where it represents a threat for the native fauna (Monzón-Argüello *et al.* 2015). During the last decade, some specimens of *L. getula* have been found all over Malta (AS unpubl. data).

Natrix natrix (Linnaeus, 1758) (Colubridae) - Grass snake

This polytypic species is widely distributed in Europe (from S Scandinavia to S Greece, S Italy and S France) except SW and Ireland, Asia (from Turkey to NW Mongolia) and NW Africa; the Sicilian populations have been referred to the ssp. *sicula* (Cuvier, 1829), that however is considered synonym of the nominal form (Thorpe 1975). Six individuals of *N. natrix* were found on Vulcano in 1955, where the species was accidentally introduced but not confirmed later (Bruno 1970, Lanza 1973). Schembri & Lanfranco (1996) have reported the case of introduction of individuals belonging to the ssp. *persa* (Pallas, 1814), distributed in the Balkans and in many Aegean islands, that were found at Floriana in Malta during the 1950s. Another specimen, not identified at subspecific rank, was found at Pembroke in Malta in June 2014 (AS unpubl. data).

Vipera aspis (Linnaeus, 1758) (Viperidae) - Asp viper

At least two individuals of *V. aspis* were introduced in the early 1990s in Vulcano (Corti *et al.* 1998); one of them is kept in the MZUF collections and belongs to the ssp. *francisciredi* Laurenti, 1768, distributed in the Italian Peninsula, from where should be have certainly origin this accidental introduction. Other two specimens, in this case belonging to ssp. *hugyi* Schinz, 1833 that occurs in S Italy and Sicily, were found in Dingli at Malta in June 2013 (AS unpubl. data). For both islands the occurrence of naturalized populations of this species is currently excluded.

Indotyphlops braminus (Daudin, 1803) (Typhlopidae) - Brahminy blindsnake

Recently found in Malta (Vella *et al.* 2020), this alien species is native to the Indo-Malayan region but now globally distributed; it has been recorded also for Sicily (Faraone *et al*. 2019). Further evidences of its probable establishment are needed.

DISCUSSION

In addition to the 22 species currently occurring with steady populations in the circum-Sicilian and Maltese islands, the third part of the inventory lists other 15 species (3 amphibians and 12 reptiles) for which a temporary presence or at least a finding has been documented for the study area. Four of them (*Hyla* sp., *Graptemys pseudogeographica* spp. *kohni*, *Centrochelys sulcata*, *Pantherophis guttatus* and *Lampropeltis getula*) are recorded for the first time for these islands.

Concerning the confirmed species, 4 out of 22 (*Pelophylax bedriagae*, *Trachemys scripta*, *Chamaeleo chamaeleon* and *Hemorrhois algirus*), equal to 18% of the current herpetofauna, were certainly introduced and have colonized the islands during the last two centuries; the same most likely regards a fifth species (*Telescopus fallax*) that some authors supposed however to be "native" (Schembri 1984; Schembri & Lanfranco 1996), although it is clearly outside its original range. Furthermore, for 7 of the remaining 17 confirmed species (equal to 41%) at least a case of introduction within the study area occurred during the last two centuries.

The species for which therefore have been documented introduction events in this span of time are 28 on the whole. It is a high value that, excluding from this counting the two species probably (*T. fallax*) or certainly (*C. chamaeleon*) introduced in the 19th century and considering only those arrived from the 20th century, would correspond to an average rate of 2.25 species every 10 years.

However, analyzing the chronology for single cases, a substantial increase emerges during the

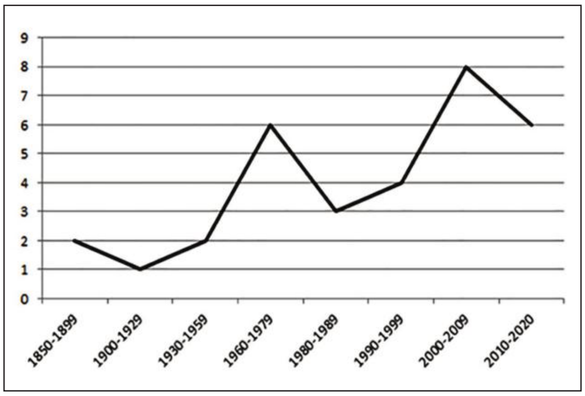

Figure 17. Chronology of the cases of introduction of amphibians and reptiles in the study area.

last decades, as shown by figure 17. This trend could be easily explained with the increase of ship traffics and human activities that during the last half century has characterized generally the Mediterranean islands, as well as with the rising number of vivarium hobbyists: among those newly introduced, at least five (*T. scripta*, *G. pseudogeographica*, *C. sulcata*, *P. guttatus* and *L. getula*) are clearly pet species more or less commonly reared by reptile-keepers. Similar trends are known also for the Pityusic and Balearic Islands, where nine introduced species have been detected only since 1990s (Pinya & Carretero 2011; Mateo 2015).

Although the circum-Sicilian are most part of the study islands, the larger amount of introductions affected the Maltese ones both in terms of number of involved species (69%) and of documented events (59%). A plausible reason can be searched in the strong degree of anthropization of Malta, that has almost half a million inhabitants and five times more visitors per year. It was generally observed that alien richness is related more to human population size and other anthropic factors than geographical variables, such as island area or distance from mainland (Roura-Pascual *et al.* 2016; Silva-Rocha *et al.* 2019), and that richest communities have more alien species (Yiming *et al.* 2006). Not by chance, Malta has the richer herpetofauna within the study area (see Table 1); furthermore, it should be noted that testing the relationships between number of introduced species and island surface by using ordinary least square regression, a highly significant correlation was found for the the Maltese islands (r = 0.955, P = 0.001) (see Fig. 18) while no correlation resulted for all the study islands (r = 0.457, P = 0.06).

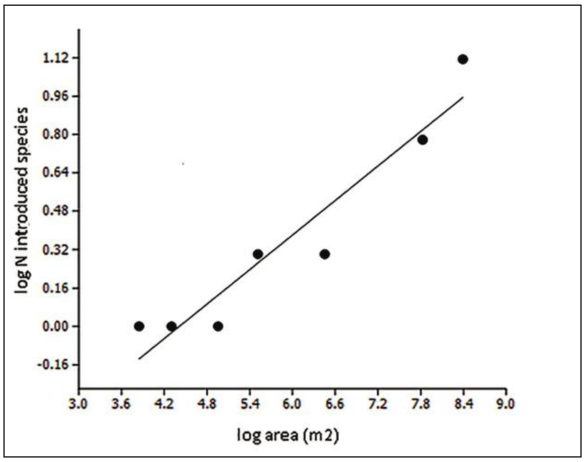

Figure 18. Relationships between number of introduced species and island surface in the Maltese Archipelago.

This picture seems also indirectly confirmed by the lacking of recent introductions in the uninhabited islets belonging to both groups, with the only exception of those colonized by *C. chamaeleon* most likely in recent times (see Sciberras 2007a).

Several different factors and life-history traits that may contribute to determine a successful introduction. For instance, it has been observed that early sexual maturity in *Trachemys scripta* seems to facilitate its establishment in southern European regions (Pérez-Santigosa *et al.* 2008); or the low metabolic rate and the capacity to spend long time without alimentation, typical of the snakes, can improve their success in colonization of overseas lands (Kraus 2009); or the occupation of empty functional niches, that could be the case of *C. chamaeleon* in Malta.

The events' chronology illustrated in figure 17 includes the arrival of the latter species on this island but not its (probably recent) gradual expansion on the nearby islands and islets, whose effective timing is unknown. However, the spreading out of *C. chamaeleon* in the Maltese archipelago must be regarded as a true biological invasion, that according to Simberloff *et al.* (2013) has three steps: introduction to a new environment, establishment and dispersal across the new area. Its occurrence poses a serious conservation problem because this species represents a threat for the native herpetofauna (Sciberras 2007a), especially for the endemic *Podarcis filfolensis* that shows an alarming decline in the natural contexts of Malta (Sciberras 2007b; AS and PLC unpubl. data). Despite the apparently unsuccessful colonization of Cominotto, *C. chamaeleon* seems able to occupy many different habitats and to survives even in small spaces characterized by rough morphology and scarce trophic resources, like the tiny and steep Fungus Rock. Its attitude as invasive species has few comparable examples among chameleons: the Madagascan *Furcifer pardalis* (Cuvier, 1829) has become invasive in Reunion Island, while the E African *Trioceros jacksonii* (Boulenger, 1896) introduced as pet is now widely established in many Hawaiian islands (Bourgat 1970; Rödder *et al.* 2011).

In this perspective, also the recent findings of *L. getula* and *P. guttatus* deserve attention in order to monitoring their eventual establishment; especially the latter, for which have been reported repeated observations during the last two decades, is known to have an high invasive potential, and both species could determine negative impacts on the local biodiversity (see Powell *et al.* 2011; Monzón-Argüello *et al.* 2015).

On the contrary, extinction seems to have happened less frequently within the study area at least in the past two centuries. All the cases have been recorded in the circum-Sicilian islands, with the only exception of Selmunett, where all the four occurring reptile species disappeared during the last two decades in the framework of a general, massive depletion of the faunal assemblage of this islet, probably related to the indirect anthropic disturbance (Sciberras & Schembri 2008).

Most of the extinct populations are amphibians: *Bufotes boulengeri* from Marettimo and Isola Lunga, *Bufotes* sp. from Lipari and Salina, and once more an unidentified frog from Lipari. Except for latter, disappeared after the massive urbanization that involved the small area with artificial ponds where its occurrence was observed until 1970s, the other above mentioned cases are hard to explain, and probably should be interpreted in the perspective of a general decline of amphibians (Beebee & Griffiths 2005; Collins & Crump 2009). However, the fact that viable populations of green toads still persist on islands with similar habitat (such as Ustica), or even characterized by more harsh conditions (Lampedusa) apparently does not support this hypothesis.

One lizard population (*Podarcis raffonei* from Vulcano) has recently become definitively extinct due to a strong competitive exclusion process largely documented in literature (Capula 1992, 2006; Lo Cascio 2010b).

Another lizard population (*P. siculus* from Lisca Nera) seem to have instead disappeared in late 19th century basically due to its small size, although a combining of factors may have accelerated its extinction (Lo Cascio *et al.* 2014b); anyhow, this epilogue would have been inevitable, as today the islet has been completely demolished by erosion.

Finally, the last case concerns *Testudo hermanni* from Lampedusa, that may be considered virtually extinct in nature, although autochthonous individuals still survive in captivity. This species seems to be extremely rare also in the other circum-Sicilian islands for which its presence has been confirmed since long time (Lipari, Pantelleria and Linosa), and even in Sicily (Corti *et al.* 2014).

The present paper has given us the opportunity to update the faunal list of the study area with new records for several species (*Chamaeleo chamaeleon*, *Hemidactylus turcicus*, *Tarentola mauritanica*, *Podarcis filfolensis*, *P. siculus*, *Chalcides ocellatus*, *Hemorrhois algirus*, *Hierophis carbonarius*, *Telescopus fallax* and *Zamenis situla*) (see Table 2). It should be pointed that these records does not belong to the previous categories, but are mostly new findings carried out during recent field investigations or, in the case of some islets not previously mentioned in literature (Faraglione di terra di Cala Fico, Colombaia, Vittoria Garcia, Pigeon Rock and Cheirolophus Rock), the results of their first herpetological exploration.

The current herpetofaunal richness seems in general mostly influenced by island size, and an highly significant correlation was found between log number of species and log island surface (r = 0.800, P = 0.0001; see Fig. 19).

However, amphibians occur only on 9% of the study islands. Apart from the already discussed extinction cases, their relative rarity especially within the circum-Sicilian ones is clearly due to the low availability of suitable habitats for their eco-physiological requirements (particularly in the large number of tiny islets) as well as to their lower dispersal capacity than reptiles.

Within the study area, instead, the most widespread species are *T. mauritanica* (42 islands), *P. siculus* (41) and *H. turcicus* (40); also *C. ocellatus* and *H. carbonarius* are relatively frequent, respectively, with 22 and 20 island records, while *P. filfolensis* is an endemic with a restricted range but within which it is however occurring on all the islands (16). Effectively, the more widely represented group would be that of the lizards belonging to the genus *Podarcis*, which occur in 94% of the study islands, with two species (*P. siculus* and *P. waglerianus*) syntopic on five islands (the main Aegadians and the Stagnone except San Pantaleo and La Scuola), and are lacking only on Lampedusa, Conigli and Vittoria Garcia (and Selmunett, due to a recent local extinction). Especially *P. siculus* is an opportunistic species characterized by broad ecological tolerance and high spreading ca-

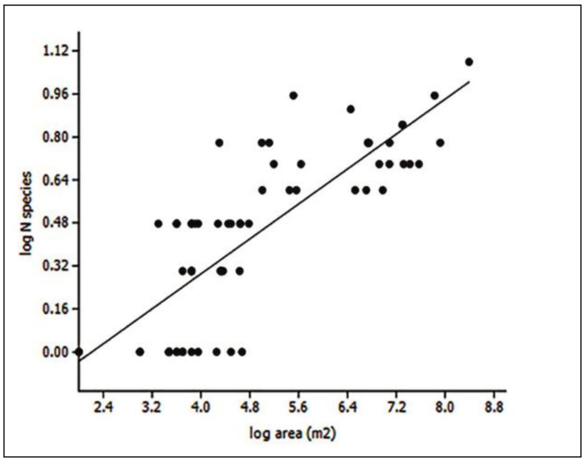

Figure 19. Relationships between number of species and island surface.

pacity, that explains its wide distribution in the circum-Sicilian islands and perhaps also the low rate of extinction (only an event documented until now for Lisca Nera).

This latter case stimulates intriguing questions about what is the minimum area that can support a vital population of lizards: Foufopoulos *et al.* (2011) have estimated about 0.005 km^2, but within the study area there are many examples of smaller islets (for instance, Tac Cawl, Small Blue Lagoon Rock, Pigeon Rock and Cheirolophus Rock in the Maltese Archipelago) inhabited by these animals, and the same has been observed in the Pityusic and Balears (Van Der Berg & Zawadzky 2010). Cheirolophus Rock, named also Il-Hagra tas-Sajjetta, is the smallest islet where was found a lizard population and constitutes a remarkable example in the framework of the Mediterranean micro-insular herpetofaunas: it lies 20 m off the southern coast of Malta, has a size of 10 x 17 m with a maximum elevation of 12 m a.s.l., and harbours also a very poor chasmo-halophile plant community that includes only six species (Sciberras & Sciberras 2010). Hence, the real surface occupied by lizards may be estimated in few square metres and as consequence the trophic resources are presumably scarce.

In conclusion, retracing the history of the last two centuries, it becomes evident that the introductions have gradually increased in recent decades and have a significant influence in shaping the recent herpetofunal assemblages of the circum-Sicilian and Maltese islands. Moreover, it is quite realistic that for many of these islands, especially the "oceanic" ones with volcanic origin, the current herpetofauna must be the result of several and sometimes multiple colonization processes, in which man also played a significant role through the accidental or intentional transport of species.

Going back in time, however, it is more difficult to reconstruct their exact chronology. Unfortunately, palaeontological and archeozoological data are still available for few taxa, while the results from molecular investigations allow to understand the evolutionary history of some species (as in the case of *Podarcis* lizards) and to clarify their eventual provenance (e.g. for *Tarentola* spp. and *Psammodromus algirus*), but seem to be less reliable in reconstructing the times of colonizations.

It is well known that alien amphibians and reptiles represent generally a threat for the local biodiversity and several human-related factors, combined with some life-history traits (diet, reproductive modality, etc.), contribute to the success of their invasion and persistence in Mediterranean islands; however, in the study area the 58.5% of the arrivals was not followed by an establishment, that suggests as a fair resilience characterizes the circum-Sicilian and Maltese environments.

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