

ReptIslands: Mediterranean islands and the distribution of their reptile fauna

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Abstract

Aim: Analyses of biogeographical patterns and macroecology of islands require large datasets reporting the occurrence of species. The Mediterranean region is a biodiversity hotspot, which hosts a large number of reptile species and has been the focus of many studies. Nevertheless, comprehensive inventories describing the features and biodiversity of these environments are lacking. We gathered a dataset summarizing data on reptile distribution on islands of the Mediterranean basin and Macaronesia, also including detailed information on the geographical features.

Location: Islands from the Mediterranean Basin, the Atlantic Ocean within the Mediterranean biogeographical region, and Macaronesia (Canary and Savage Islands, Azores, Madeira and Cape Verde).

Time period: Present.

Taxon: Reptiles (squamates and turtles).

Methods: Initially, we developed a geographical database describing islands of the study region, then gathered information on reptile occurrences from 757 bibliographical sources, including atlases, published papers and the grey literature. Through a critical review of these sources, we also obtained information on the status of populations (native, island endemic or non-native) and on the reliability of occurrence data.

Results: We obtained basic geographical information from 1875 islands covering the whole study region and with a very broad range of geographical features. We gathered >4150 records of reptile occurrence on islands, referring to 198 taxonomic units (species or species complexes); information on population status was available for 84.9% of records. Data are provided as comma-delimited text files.

Main conclusions: The database provides a key resource for biogeographical analyses and can also serve as a backbone for conservation studies. The availability of a large database on island features can also be useful for biogeographers working on other taxonomic groups. Nevertheless, more data are required for some geographical areas, in order to ascertain the status (e.g., native vs. non-native) of many populations and to understand the interplay between natural and human-driven processes.

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KEYWORDS

endemism, geckos, island biogeography, island features, lizards, Mediterranean basin, reptiles, snakes, species distribution, turtles

1 | INTRODUCTION

The analysis of biodiversity on islands has been a central topic of biogeography for decades. Early works on island biogeography focused on how key geographical features of islands (e.g., area and isolation) determine species richness through a dynamic equilibrium between species colonization, extinction and speciation (McArthur & Wilson, 1967; Whittaker & Fernández-Palacios, 2007). More recent works have added complexity to biogeographical analyses, stressing that isolation is a complex of factors that influence insular biodiversity (Itescu et al., 2020; Weigelt & Kreft, 2013) and that many factors beyond geographical features influence species distribution on islands, such as habitat heterogeneity, human influence and climate (Capinha et al., 2020; Helmus et al., 2014; Losos & Ricklefs, 2010; Santos et al., 2016; Whittaker & Fernández-Palacios, 2007).

The analysis of biogeographical patterns requires sound distribution and geographical data. However, the availability and quality of biodiversity data are highly uneven, because more accurate information on species distribution exists especially for accessible areas and in regions with intense scientific research (Ficetola, Cagnetta, et al., 2014; Ficetola, Rondinini, et al., 2014; Guedes Thaís et al., 2017; Meiri et al., 2018; Nelson et al., 1990; Yang et al., 2014). The Mediterranean Basin is a vast biodiversity hotspot that includes the region of Mediterranean Sea and the nearby Macaronesia (Myers et al., 2000), lies between Europe, Africa and Asia, and has been the focus of several biodiversity inventories since the 19th century. Therefore, Mediterranean islands have been investigated carefully in biogeographical studies and are probably among the islands with the best biodiversity inventories. The Mediterranean Basin includes thousands of islands and islets spreading across 76° of longitude and 30° of latitude, with a huge variation of geographical, climatic and ecological features (Arnold, 2008; Blondel & Aronson, 1999). It is therefore an ideal region in which to understand how the interplay between these factors determines species distribution. Studies on the biogeography of Mediterranean islands cover a wide range of taxa, including birds, beetles, snails and plants (e.g., Chiarucci et al., 2017; Escoriza, 2021; Fattorini et al., 2017; Ficetola & Padoa-Schioppa, 2009; Foufopoulos & Mayer, 2007; Heiser et al., 2014). However, studies on the biogeography of the Mediterranean Basin have often focused on specific archipelagos and on subsets of this region, probably because of a lack of overall data summarizing species distribution and island features across the whole Mediterranean.

Reptiles are among the most abundant vertebrates on islands, and even tiny islets can host large reptile populations (Novosolov et al., 2016; Santini et al., 2018), with some threatened endemic

species living on very small islands or archipelagos (Escoriza, 2021; Ficetola et al., 2018; Pinya & Carretero, 2011; Spatz et al., 2017). As a consequence, reptiles are a major focus of island biogeography research evaluating both the role of natural processes and the impact of human activities. Here, we provide an extensive dataset summarizing the distribution of reptiles in the islands of the Mediterranean Basin (i.e., the Mediterranean Sea and adjacent regions, including Macaronesia; Figure 1), obtained by collating literature records spanning the last 130 years. The biota of the Mediterranean basin has been heavily shaped by human activities, with multiple ancient and recent introductions of alien reptiles (Silva-Rocha et al., 2019); therefore, we also report available information on the species status. Finally, we report basic geographical features of each island (location, area and elevation) that can be extremely useful for biogeographical analyses, whatever the study taxon.

2 | METHODS

2.1 | Island features

We focused on islands of the Mediterranean Basin biodiversity hotspot (Myers et al., 2000), which includes the Mediterranean Sea and Macaronesia (following Carracedo & Troll, 2021, Macaronesia includes the Canary and Savage Islands, Azores, Madeira and Cape Verde; Figure 1). We also included a few Portuguese islands within the Atlantic Ocean but belonging to the Mediterranean region according to Cervellini et al. (2020) (e.g., Pesequeiro, Berlenga and nearby islets). We adopted the database from Arnold (2008) as a backbone for the features of Mediterranean islands. This provides basic geographical information (mostly surface area and low-resolution geographical coordinates) for >1000 islands and islets of the Mediterranean basin; for a subset of islands, additional information (e.g., elevation) was available. If surface area was not available from the database of Arnold (2008), we obtained it from online sources or by digitizing island surface using QGIS v.3.10 (www.qgis.org) on the basis of satellite images. Information on maximum elevation was obtained from topographic maps or, if not available, from the digital elevation model (DEM) data by NASA's Shuttle Radar Topography Mission (<https://gisgeography.com/srtm-shuttle-radar-topography-mission/>). The nomenclature of small islands is extremely unstable, and the same islet can receive multiple, sometimes very different names; therefore, we also included alternative names when available. In a few cases, we found reptile records for islets that could not be identified unambiguously, because their names did not match geographical sources and the related publications lacked

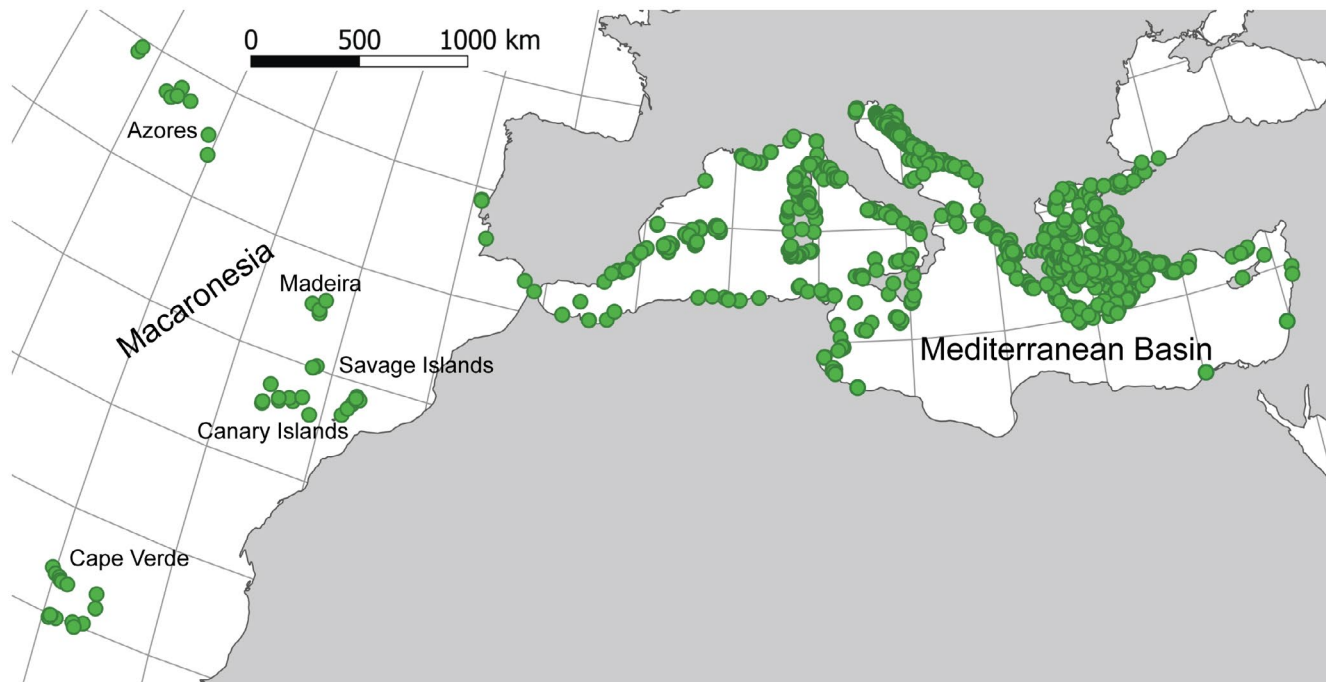


FIGURE 1 Study area and distribution of islands in the database. The map is an ETRS89 Lambert azimuthal equal-area projection

geographical coordinates. In these cases, we preferred not to exclude the records; we tentatively report the records and the island names without assigning specific coordinates, and we have indicated the original references to allow the reader to obtain all the available information.

2.2 | Reptile distribution

Information on reptile distribution on Mediterranean Islands was compiled starting from herpetological atlases published for several countries and regions of the study region (e.g., Baier et al., 2009; Delaugerre & Cheylan, 1992; Malkmus, 2004; Pleguezuelos et al., 2002; Sindaco et al., 2006; Sultana & Falzon, 2002). Some of these atlases include specific sections on island diversity that have been compiled after long-term survey programmes and provide reports on the communities of reptiles for a number of islands. This information was complemented with data taken from peer-reviewed papers, the grey literature, publications summarizing the grey literature and direct surveys by the authors (Sindaco & Jeremčenko, 2008; Sindaco et al., 2013 and references cited in the database). Overall, we considered 757 bibliographical sources.

Assessing the status of island populations is particularly complex. Some islets are only surveyed occasionally, hence it is unclear whether old records or sporadic observations represent extant populations. In our database, we thus explicitly provide information on the degree of uncertainty of observations, on

the basis of the available references. Furthermore, many reptile species have been transported by humans for ≥ 3000 years; therefore, for many records, it is not known whether the species is native or non-native (Silva-Rocha et al., 2019). We used information from the literature to evaluate the alien/native status of species on each island. The status was considered certainly native if this could be ascertained on the basis of genetic or fossil lines of evidence, or if the species was locally endemic. A species was considered non-native if there was clear evidence from genetic studies performed on that island or from historical/direct records (e.g., reporting the introduction date). It must be noted that there are also cases where genetic data were inconclusive. For instance, the low genetic diversity of the Moorish gecko, *Tarentola mauritanica*, and of the house gecko, *Hemidactylus turcicus*, has been interpreted as evidence of widespread human introduction (Carranza & Arnold, 2006; Harris et al., 2004), but it can also be explained by natural evolutionary processes, such as selective sweeps (Rato et al., 2010, 2011). In such conflicting cases, the status of the population was considered uncertain. In many cases, the status of the species was assigned based on authors' expertise, hypotheses or on biogeographical criteria; in such circumstances, we coded the species as probably non-native/probably native. See Silva-Rocha et al. (2019) for additional details and examples. Nomenclature followed the Reptile Database v. 2020_12 (<http://www.reptile-database.org/data/>; accessed 1 December 2021), updated with recent phylogenetic data on *Anatololacerta* (Karakasi et al., 2021) and with the addition of *Podarcis galerae*, recently recognized as a full species (Bassitta et al., 2020).

2.3 | Data verification

Data were entered directly from the literature into the digital file, and values were double-checked carefully by the authors. After the complete data entry, we performed three rounds of verifications, in which the co-authors rechecked the data against the literature. In the final round of verification, the error rate was 0.9%.

3 | DATA STRUCTURE

3.1 | Data table

We provide a total of three data files. The first file contains the list of islands, their geographical coordinates and basic geographical information (Table 1). The second file reports the reptile records, along with information on the status of the populations, the references and some notes for the most controversial cases (Table 1). The third file contains the complete list of references

used to develop the database. We distinguish between main references (the most comprehensive/recent references that summarize the situation across islands) and additional references (which include old or difficult-to-access references that are confirmed or discussed by more recent studies).

3.2 | Format type and data availability

Each data file is in ASCII text, comma delimited, not compressed. Data are available at figshare at the following Digital Object Identifier: <https://doi.org/10.6084/m9.figshare.14346416.v1>

3.3 | Header information

The header information in all files is self-explanatory. The naming conventions of each column and their description are given in Table 1.

TABLE 1 Features of islands and information on species records available from the database

Field name	Description/potential values	Note
File: Island_features.csv		
Name		
Alternative name		If available, we tried to report alternative names of islands/alternative spellings to allow easier island identification
Latitude/longitude	Coordinates of the centroid (decimal degrees, WGS84)	Available for 98.1% of islands ^a
Country		
Archipelago		
Area	Surface area (in square kilometres)	Available for 98.2% of islands
Altitude	Maximum elevation	Available for 75.5% of islands
File: reptile_records.csv		
Species name	Species name according to the Reptile Database	In some cases, taxonomical uncertainties or nomenclatural issues exist, particularly when recent nomenclatural changes have occurred or when closely related species cannot be identified easily through morphology. All these cases are highlighted in the database as: <ul style="list-style-type: none"> • sp.: unidentified species within genus; • s.l.: <i>sensu lato</i>, referring to a species complex • c.f.: species identification is uncertain in the absence of more accurate (e.g., genetic) data • sp. nova: probably distinct but still undescribed species Nomenclatural uncertainty exists for 2.5% of records
Type of record	Direct observation by the authors in the references/reported (e.g., in review papers)	
Occurrence	Present/extinct/dubious/possibly wrong	
Status	Native/probably native/island endemic/non-native/probably non-native	No data for 15% of cases
MainReferences	The most comprehensive/recent references that summarize the situation across islands	
AdditionalReferences	include additional, old or difficult-to-access references that are confirmed or discussed by more recent papers	

^aIn a very few cases (35 islets), it was impossible to identify the location of the islet unambiguously, because of discordance between maps or because of a lack of details in the references.

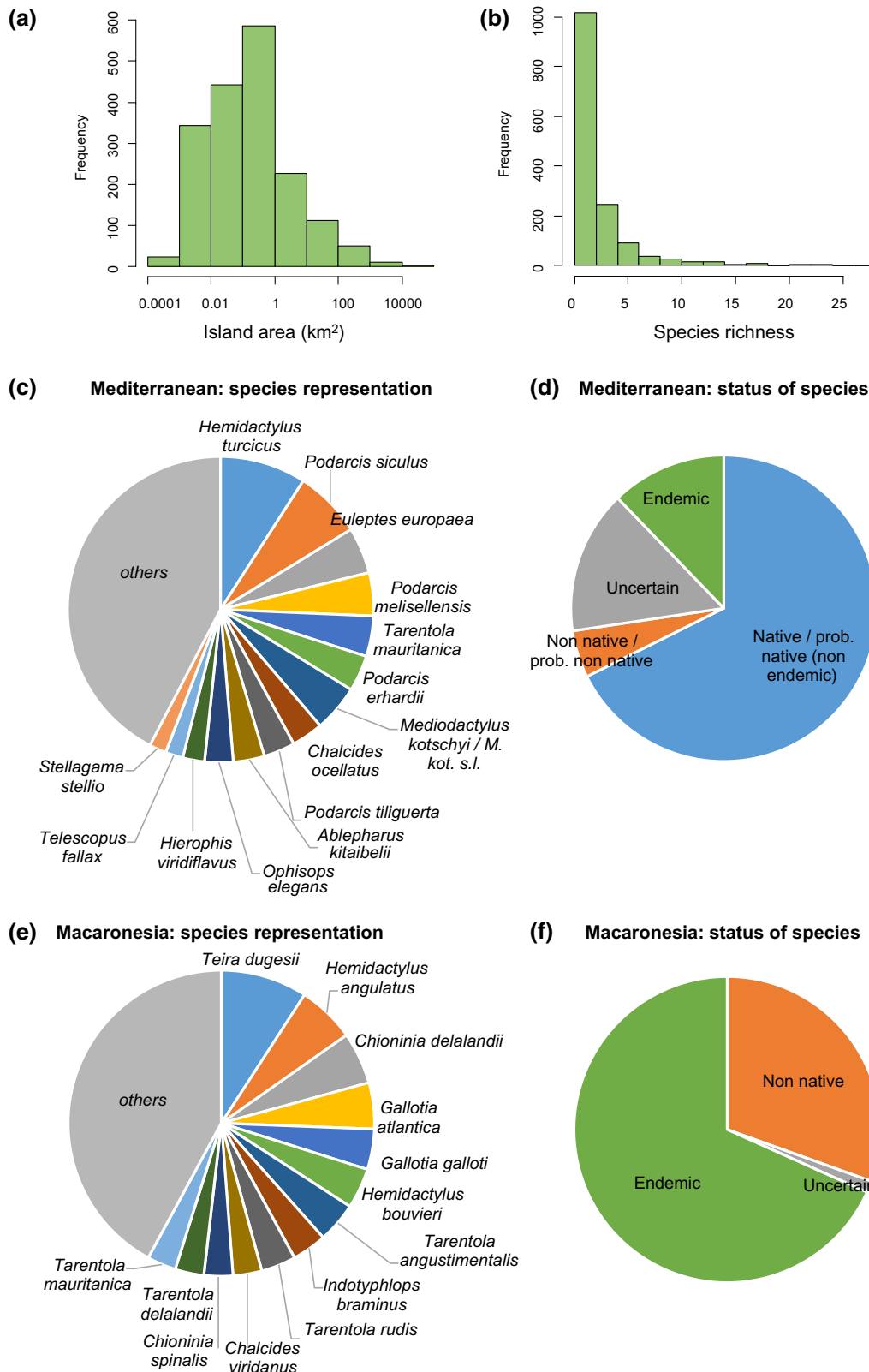


FIGURE 2 (a) Frequency of surface area of islands in the database. (b) Frequency of species richness across islands. (c,e) Representation of reptile species detected, with the names of the 14 most frequent species, within (c) the Mediterranean Sea and (e) Macaronesia. (d,f) Status of island populations of reptiles of islands of islands within (d) the Mediterranean Sea and (f) Macaronesia

4 | RESULTS AND DISCUSSION

The database includes 1875 islands, with surfaces ranging from 0.01 ha to 25,000 km². We obtained a total of 4157 occurrence

records from 198 taxonomic units, spread across 1482 islands. For islands with at least one reptile record, the number of detected species ranged from one to 27, with most islands inhabited by three species or fewer (Figure 2). Owing to recent taxonomic changes for

some reptiles, and to the complexity of identification in the absence of genetic data, taxonomic uncertainties exist for 2.5% of data (for examples, see Table 1). For 0.14% of records (i.e., six records), only old bibliographical sources were available (first half of the 20th century). The most frequent species included geckos (e.g., *Hemidactylus turcicus*, *Euleptes europaea*, *Mediodactylus kotschy* and *Tarentola mauritanica*) and *Podarcis* lizards (e.g., *Podarcis siculus*, *Podarcis melisellensis* and *Podarcis erhardii*; Figure 2). The most frequent snakes were *Hierophis viridiflavus* and *Telescopus fallax*, while turtles represented only 5.0% of all the records. Within Macaronesia, the most frequent species were lizards (*Gallotia* in the Canaries, *Teira* in the Madeira archipelago), geckos (*Tarentola* in the Canaries and Madeira, *Hemidactylus* in the Cabo Verde archipelago) and skinks (*Chalcides* in the Canaries, *Chioninia* in Cabo Verde). Across the whole study region, 12.0% of records referred to island endemics, 6.1% referred to non-native/probably non-native species, and 66.8% of records referred to non-endemic but native/probably native species. The frequency of non-native species was significantly higher in Macaronesia compared with the islands within the Mediterranean sea (30% vs. 5%; $\chi^2_1 = 148.4$, $p < .001$; Figure 2). The status (native/non-native) was highly uncertain for 15% of records, and 2.8% of records were flagged as dubious/possibly wrong.

We have collated the largest database on reptile distribution in Mediterranean islands, and the availability of such detailed information on island features and species distribution can be useful for biogeographers working on reptiles or on other taxonomic groups. Nevertheless, our dataset has some limitations. First, it is not exhaustive, and we did not find reptile records for a relevant number of islands (>300). Some species, such as geckos and *Podarcis* lizards, can have large populations even on tiny islets with surfaces well below 1 ha, thus it is likely that some reptiles also inhabit many of these islands. Incomplete data are a pervasive issue in biogeographical studies and occur even in the best-studied areas of the world. For reptiles, data can be particularly incomplete in poorly accessible or uninhabited areas, where biodiversity inventories are more challenging to perform (Ficetola et al., 2013; Guedes Thaís et al., 2017; Meiri et al., 2018; Yang et al., 2014). Such an issue is also evident within Mediterranean islands where, for instance, several missing data probably occur for Greek and Turkish islets, for which comprehensive atlases or large published datasets are lacking (Ficetola, Cagnetta, et al., 2014). Our database can help to identify areas where further surveys are needed. Potential gaps might be identified by comparing the richness of islands of the same archipelago having similar geographical features (area, isolation, etc.) but different human accessibility; still, this approach is far from ideal, for instance if similar islands differ for unaccounted factors (age, past catastrophic events, etc.). Furthermore, the publications referring to each island can provide an indirect measure of sampling effort, thus enabling estimation of the reliability and completeness of data for each island (Santos et al., 2010).

Second, despite targeting a relatively well-studied area, our database revealed frequent uncertainties on the status of populations, with several data flagged as dubious or with unclear taxonomic

status. The information is particularly incomplete for the occurrence of non-native species and of multiple genetic lineages. There are certainly cases where non-native species hybridize with native species, or where native and introduced lineages of the same species coexist in the same area (Gippoliti et al., 2017; Podnar et al., 2005). Accurate data on interactions between native and non-native lineages would provide invaluable insights for conservation, ecological and evolutionary studies.

Future updates of this database and more detailed genetic and genomic information will allow a better definition of our understanding of the status of reptile populations on islands. Obtaining more accurate data on the distribution and status of island reptiles is also extremely important for conservation. The loss of biodiversity is disproportionately rapid on islands and, even if small islands host only a limited number of species, many of them can be endemic or threatened by extinction (Gippoliti et al., 2017; Spatz et al., 2017). The information available in the database will thus help to identify management and conservation priorities.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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