An Acad Bras Cienc (2024) 96(1): e20230622 DOI 10.1590/0001-3765202420230622
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

ANIMAL SCIENCE

Lack of country-wide systematic herpetology collections in Portugal jeopardizes future research and conservation

BRUNA S. SANTOS, MARIANA P. MARQUES & LUIS M.P. CERÍACO

Abstract: Natural History Collections (NHCs) represent the world's largest repositories of long-term biodiversity datasets. Specimen collection and voucher deposition has been the backbone of NHCs since their inception, but recent decades have seen a drastic decline in rates of growth via active collecting. Amphibians and reptiles are amongst the most threatened zoological groups on the planet and are historically underrepresented in most worldwide NHCs. As part of an ongoing project to review the Portuguese zoological collections in the country's NHCs, herpetological data from its three major museums and smaller collections was gathered and used to examine the coverage and representation of the different taxa extant in Portugal. These collections are not taxonomically, geographically, or temporally complete. Approximately 90% of the Portuguese herpetological taxa are represented in the country's NHCs, and around half of the taxa are represented by less than 50 specimens. Geographically, the collections cover less than 30% of the country's territory and almost all of the occurring taxa have less than 10% of their known distribution represented in the collections. A discussion on the implications for science of such incomplete collections and a review of the current status of Portuguese NHCs is presented.

Key words: History of Science, Natural History Collections, Taxonomy, Voucher Specimens.

INTRODUCTION

Human activities are causing the loss of the planet's biodiversity at an accelerated rate (Dirzo et al. 2014). The extinction rate of vertebrates has steeply increased over the last 200 years (Ceballos et al. 2015) and it is unclear how biodiversity will respond to the growing threat of climate change and what the long-term consequences of human activity will be (Johnson et al. 2011). Natural History Collections (NHCs) represent the world's biggest repositories of long-term biodiversity datasets, with unparalleled geographic, temporal, and taxonomic scope (Heberling et al. 2021, Hedrick et al. 2020, Hilton et al. 2021, Miller et al. 2020). More than 250 years of collecting history provide a unique glimpse into the evolution of species and constitute essential data for researchers and conservationists.

With the emergence of new technologies and novel approaches, NHCs have proven to be a unique resource to address newfound scientific questions, as well as current ecological and social demands (Gardner et al. 2014, Malaney & Cook 2018, Prather et al. 2004). These new approaches considerably increase the amount of data that each specimen can yield and, at the same time, digitization of associated data make information more readily available to the scientific community and the general public (Ferguson 2020, Hedrick et al. 2020, Meineke et al. 2018, Miller et al. 2020, Nelson &

Ellis 2018, Schindel & Cook 2018, Singer et al. 2018, Shirey et al. 2021, Soroye et al. 2020). The current importance of NHCs in public education and interdisciplinary research has also been highlighted (Bakker et al. 2020, Monfils et al. 2022), and the creation of an "extended specimen network" (Lendemer et al. 2020) has considerably enhanced the research potential of specimens. More recently, NHCs were also recognized as an invaluable resource in the fight against pathogens and pandemics (DiEuliis et al. 2016, Dunnum et al. 2017, Thompson et al. 2021), although still underutilized in this regard (Cook et al. 2020).

NHCs can also be seen as strategic repositories of the world's genetic diversity. Maybe the best example of such a global repository is the Svalbard Global Seed Vault (SGSV). Currently home to over one million seeds from more than 5,000 species, the SGSV serves as a "doomsday" vault, aiming to secure the world's future food supplies and the preservation of crop genetic diversity (Breen 2015, Fowler 2008, Svalbard Global Seed Vault 2022). In theory, the world's NHCs should altogether function as a distributed network of a global vault. Each country should have its own biodiversity and genetic diversity represented in its local NHCs, ready to be accessed, consulted, and used whenever necessary. However, it is unclear if local NHCs presently maintain well-characterized and complete coverage of the local biodiversity and its genetic diversity. Several questions remain to be answered for most countries and their NHCs: Do local NHCs currently possess a complete taxonomic coverage of their country's biodiversity? Do specimens housed in local NHCs represent the known geographic distribution (and therefore, genetic diversity) of the occurring taxa? Can existing collections of specimens be used as robust times series for a given taxon in a given region?

While specimen collection and deposition of voucher specimens in NHCs has served as the foundation of natural history and biological sciences over past centuries, voucher-collection rates have consistently declined in the last decades around the world (Gardner et al. 2014, Malaney & Cook 2018, Prather et al. 2004, Rocha et al. 2014, Rohwer et al. 2022, Singer et al. 2018, Shirey et al. 2021, Thompson et al. 2021, Troudet et al. 2018, Turney et al. 2015). This situation poses considerable challenges for present and future research, and threatens our ability to answer the problems posed by the current biodiversity crisis to the world's biota and humankind.

Amphibians and reptiles are amongst some of the most threatened zoological groups on the planet (Cox et al. 2022). Contrary to other charismatic and popular animal groups, which have been extensively collected and studied by both amateurs and professionals, such as butterflies and birds (Fischer et al. 2021, Wei et al. 2016), amphibians and reptiles are usually underrepresented in worldwide natural history collections. This global trend is evident when we scale down to country level and compare the size and richness of herpetological collections to their bird and insect counterparts. As part of an ongoing project to review the zoological collections in Portuguese natural history museums, we have gathered the available metadata of all specimens of Portuguese amphibians and terrestrial reptiles. Portugal is part of the Iberian Peninsula biodiversity hotspot (Myers et al. 2000, Rosso et al. 2017), and hosts a spectacular herpetological diversity considering its size, with a total of 22 and 37 species of terrestrial amphibians and reptiles occurring in the country, of which ⅔ are Iberian endemics (Frost 2023, Uetz et al. 2022). Of the non-endemic taxa, six represent established alien introductions. The majority of species are considered 'Least Concern', although six are currently assigned endangered status (see Table II; IUCN 2023). Using the available datasets, we examined the coverage and representation of the different taxa at a country level. We describe differences in collecting trends across different institutions, and explore potential taxonomic, temporal, and geographic biases in collecting efforts.

EVALUATION OF THE HERPETOLOGICAL SPECIMEN DATA

To assess the current situation of Portuguese herpetological NHCs, we consulted the collections of the three main Portuguese Natural History Museums (Figure 1) – the Museu Nacional de História Natural e da Ciência (MUHNAC, Lisbon), the Museu da Ciência da Universidade de Coimbra (MCUC, Coimbra), and the Museu de História Natural e da Ciência da Universidade do Porto (MHNC-UP, Porto) – all part of large public universities, as well as a smaller collection in the Madeira archipelago (MMF). For each collection, we gathered metadata associated with existing specimens, namely their taxonomic identification, collecting date, and locality. Data from MUHNAC specimens are already available on GBIF (Ceríaco 2016, Ceríaco & Marques 2019), while data from the remaining institutions were gathered through a combination of what was available in the existing non-published internal databases, catalogs, and physical examination of the collections. MUHNAC records prior to 1978 are based on published catalogs (Crespo 1971, 1972, 1975), as a catastrophic fire destroyed almost the entire zoological collection at that time. Whenever possible, and especially for dubious identifications/difficult taxonomic groups, we personally examined and reviewed the identification of the specimens. A total of 4950 specimens with associated data were recorded in the studied collections. Collecting

Figure 1. Herpetological collections of the three main NHCs in Portugal: a) Museu Nacional de História Natural e da Ciência (MUHNAC, Lisbon), b) Museu da Ciência da Universidade de Coimbra (MCUC, Coimbra), and c) Museu de História Natural e da Ciência da Universidade do Porto (MHNC-UP, Porto). Note that the herpetological collections of MCUC are mostly still deposited in the main exhibition areas, following the typical arrangement of nineteenth century museums. Photos by Luis M. P. Ceríaco.

date data was standardized following Darwin Core standards (Darwin Core 2022) and locality data was, whenever possible, georeferenced following the protocols of Chapman & Wieczorek (2020). Specimens lacking geographic and temporal data were not considered. Taxonomy and nomenclature follow Speybroeck et al. (2020), and the list of accepted occurring species in the country (both native and introduced) is presented in Table II. To assess the geographic representativeness of the available collections, we mapped the specimens of the different taxa against their known distribution ranges. For distribution range maps, we predominantly used those available from the IUCN Red List Assessments, but, when deemed necessary (due to the availability of new taxonomic arrangement or distribution data), these maps were updated to reflect current knowledge. Marine turtle species were not included in this assessment.

TAXONOMIC REPRESENTATION

Approximately 90% of the herpetological taxa (53 of the 59 species) occurring in Portugal are represented in the Portuguese museums. Of the species not represented in the collections, three are invasive (*Triturus carnifex*, *Podarcis siculus* and *Indotyphlops braminus*), one is of dubious presence in the country (*Podarcis vaucheri*), and the other two (*Lissotriton maltzani* and *Podarcis guadarramae*) were recently elevated to full species status after molecular analysis (Caeiro-Dias et al. 2021, Sequeira et al. 2019). Only two invasive species are represented in the collections, *Xenopus laevis* and *Hemidactylus mabouia*. When considering the taxonomic representation within individual collections, there are considerable differences amongst them. MUHNAC's collections are the most taxonomically diverse, with 52 out of 59 taxa represented, and holding 84.6% of the existing specimens in Portuguese museums (Table I). MCUC's collection covers 71.2% (42 of 59) of the occurring taxa, and its collections correspond to a total of 7.5% of the existing specimens in the country. MHNC-UP's collection contains 69.5% (41 of 59) of the taxa and correspond to a total of 7.2% of the existing specimens in the country. The remaining analyzed collections present an anecdotal number of specimens and taxa (Table I).

Lissotriton boscai, *Teira dugesii* and *Triturus marmoratus* are the three most represented native species in the collections, corresponding to 27% of all existing specimens – while *Pelodytes ibericus*, *Coronella austriaca* and *Macroprotodon brevis* are the least represented (Table I). The invasive species *Xenopus laevis* is the second most represented taxon. Almost half of the taxa (24) are represented by less than 50 specimens, and eight species are represented by 10 or less specimens in the combined country collections (Table I). Currently, 14 taxa exist in only one or two of the museums.

COLLECTING PATTERNS THROUGH TIME

Collecting has not been consistent through time, neither at national nor institutional level. Figure 2 summarizes the number of amassed Portuguese herpetological specimens in the three largest museums – MUHNAC, MHNC-UP, and MCUC – throughout the years, from the first recorded collections in the mid-1850s to late 2020. MCUC and MHNC-UP specimens date back to the nineteenth century, while MUHNAC's collections are mostly from the 1980s onwards, as its previous collections were completely destroyed by the 1978 fire (Figure 3). Prior to that event, MUHNAC had six times more specimens than the other two museums combined. MUHNAC had its collecting peak during the 1970s and 1980s (Figure 2a). At the time, several research groups were associated with the museum and yearly collecting expeditions contributed a great deal to the growth of the collection. The trend continued in the 1980s, especially in an effort to rebuild the collections after the fire

Table I. Taxonomic diversity of amphibians and terrestrial reptiles occurring in Portugal, and corresponding number of existing specimens for each species in the consulted museum/collection. Asterisks (*) denote introduced species.

Taxa	MCUC	MHNC-UP	MUHNAC	MMF	TOTAL
Amphibia					
Golden-striped Salamander *Chioglossa lusitanica*	5	5	27	-	37
Sharp-ribbed Newt *Pleurodeles waltl*	6	8	27	-	41
Fire Salamander *Salamandra salamandra*	6	6	34	-	46
Bosca's Newt *Lissotriton boscai*	13	18	705	-	736
Palmate Newt *Lissotriton helveticus*	2	3	47	-	52
Algarve Newt *Lissotriton maltzani*	-	-	-	-	0
Italian Crested Newt * *Triturus carnifex*	-	-	-	-	0
Marbled Newt *Triturus marmoratus*	9	12	280	-	301
Southern Marbled Newt *Triturus pygmaeus*	-	-	97	-	97
Iberian Midwife Toad *Alytes cisternasii*	2	-	29	-	31
Common Midwife Toad *Alytes obstetricans*	11	10	179	-	200
Iberian Painted Frog *Discoglossus galganoi*	6	6	67	-	79
Western Spadefoot Toad *Pelobates cultripes*	6	4	77	-	87
Lusitanian Parsley Frog *Pelodytes atlanticus*	5	2	77	-	84
Iberian Parsley Frog *Pelodytes ibericus*	-	-	4	-	4
Spiny Toad *Bufo spinosus*	11	7	28	-	46
Natterjack Toad *Epidalea calamita*	15	6	33	-	54
Mediterranean Tree Frog *Hyla meridionalis*	5	2	86	-	93
Iberian Tree Frog *Hyla molleri*	9	1	155	-	165

Table I. Continuation.

Iberian Stream Frog *Rana iberica*	6	18	62	-	86
Iberian Water Frog *Pelophylax perezi*	9	15	196	-	220
Platanna Frog * *Xenopus laevis*	-	-	307	-	307
Reptilia					
European Pond Terrapin *Emys orbicularis*	2	2	5	-	9
Spanish Terrapin *Mauremys leprosa*	8	6	40	-	54
Tropical House Gecko * *Hemidactylus mabouia*	-	-	-	9	9
Turkish Gecko *Hemidactylus turcicus*	3	-	7	-	10
Moorish Gecko *Tarentola mauritanica*	10	10	32	6	58
Selvagens' Gecko *Tarentola boettgeri bischoffi*	-	-	16	3	19
Mediterranean Chameleon *Chamaeleo chamaeleon*	3	4	18	3	25
Slow Worm *Anguis fragilis*	11	9	21	-	41
Spinyfooted Lizard *Acanthodactylus erythrurus*	8	5	8	-	21
West Iberian Rock Lizard *Iberolacerta monticola*	-	1	41	-	42
Schreiber's Green Lizard *Lacerta schreiberi*	9	6	18	-	33
Bocage's Wall Lizard *Podarcis bocagei*	22	6	155	-	183
Carbonell's Wall Lizard *Podarcis carbonelli*	-	1	121	-	122
Guadarrama Wall Lizard *Podarcis guadarramae*	-	-	-	-	0
Lusitanian Wall Lizard *Podarcis lusitanicus*	-	-	186	-	186
Vaucher's Wall Lizard * *Podarcis vaucheri*	-	-	-	-	0
Geniez's Wall Lizard *Podarcis* cf. *virescens*	-	-	94	-	94

Table I. Continuation.

Italian Wall Lizard * *Podarcis siculus*	-	-	-	-	0
Large Psammodromus *Psammodromus algirus*	16	4	62	-	82
Western Psammodromus *Psammodromus occidentalis*	6	3	28	-	37
Madeiran Wall Lizard *Teira dugesii*	-	-	283	17	300
Ocellated Lizard *Timon lepidus*	22	16	107	-	145
Bedriaga's Skink *Chalcides bedriagai*	6	2	6	-	14
Iberian Threetoed Skink *Chalcides striatus*	14	6	28	-	48
Iberian Worm Lizard *Blanus cinereus*	3	2	31	-	36
Vandelli's Worm Lizard *Blanus vandellii*	6	2	2	-	10
Flowerpot Snake * *Indotyphlops braminus*	-	-	-	-	0
Horseshoe Whip Snake *Hemorrhois hippocrepis*	18	5	39	-	62
Smooth Snake *Coronella austriaca*	2	-	2	-	4
Southern Smooth Snake *Coronella girondica*	12	1	20	-	33
Ladder Snake *Zamenis scalaris*	10	9	58	-	77
Iberian False Smooth Snake *Macroprotodon brevis*	-	-	6	-	6
Iberian Grass Snake *Natrix astreptophora*	13	8	28	-	49
Viperine Snake *Natrix maura*	17	13	118	-	148
Western Montpellier Snake *Malpolon monspessulanus*	15	8	71	-	94
Lataste's Viper *Vipera latastei*	6	100	15	-	121
Seoane's Viper *Vipera seoanei*	2	2	4	-	8
TOTAL	370	354	4188	38	4950

(Figure 3). Historically, MUHNAC held the oldest herpetological collections in the country and reached the highest collecting peaks, with over 400 amphibians and 400 reptiles collected during the most productive years (Figure 2a). The most recent collecting peak results from an on-going eradication project of the invasive platanna frog, *Xenopus laevis* (Sousa et al. 2021), with MUHNAC housing the resulting collections. MCUC had an initial collecting peak between 1880 and early 1890s, a time when the museum was particularly active in the study of Portuguese fauna (Ceríaco 2021), but observed a considerable decrease of collected specimens in the following decades, reaching a complete halt in 1956 (Figure 2b). MHNC-UP's collection was also predominantly amassed between the late 1890s and early 1900s, which largely correspond to the founding of the museum (Ceríaco 2021), and spent the majority of the following century with less than five specimens recorded per year (Figure 2c). The 1990s to early 2000s collecting peak results from recent additions to the collections, donated from the personal collection of a researcher.

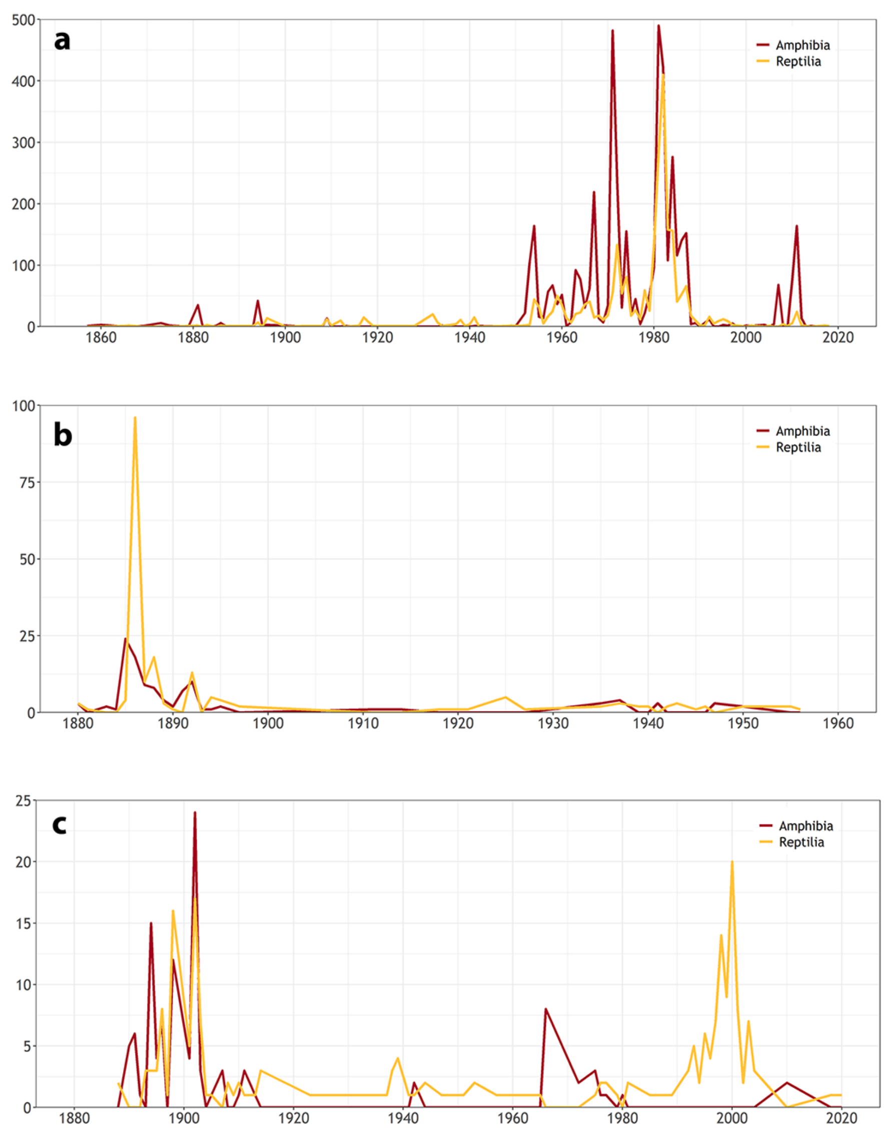

Figure 2. **Recorded collections of Portuguese amphibians and reptiles per year from the 1850s to 2020 for the MUHNAC (a), MCUC (b) and MHNC-UP (c). Only specimens with available collecting date were used in this analysis. Note that the scales differ in each graphic representation, and the most recent MCUC record dates from the 1950s.**

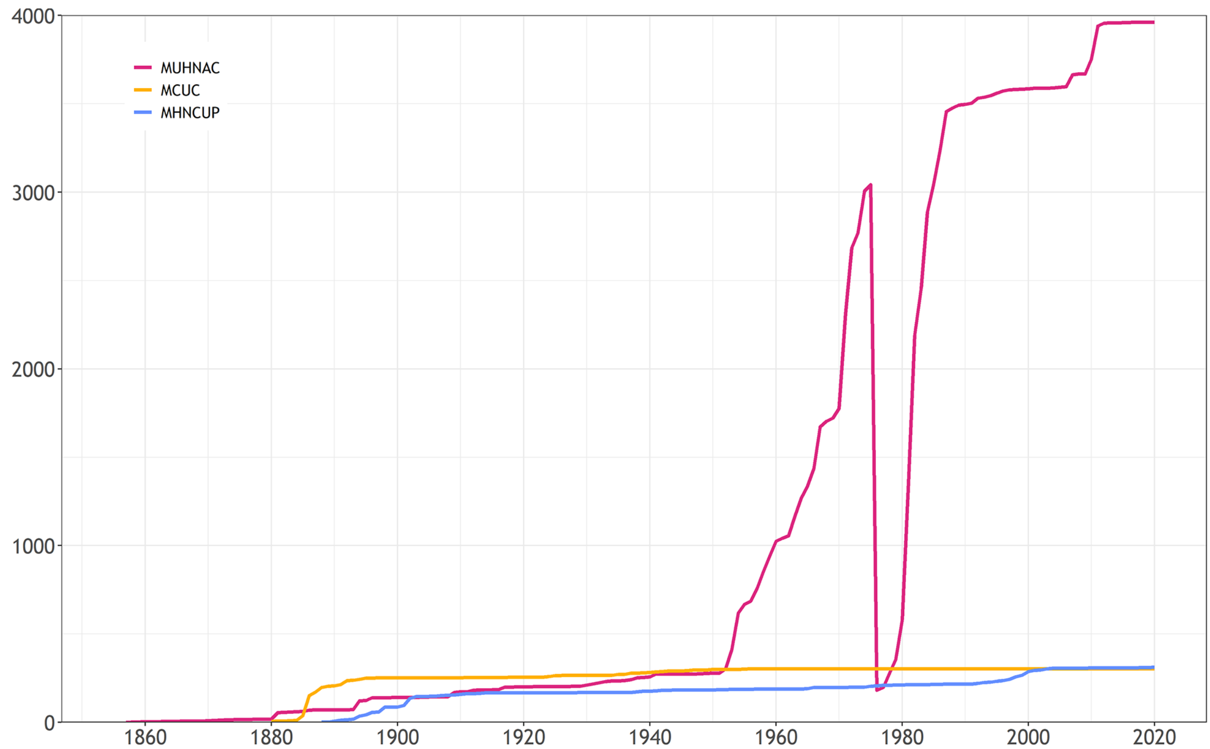

Figure 3. Aggregated growth of the MUHNAC (pink), MCUC (yellow) and MHNC-UP (blue) herpetological collections through time. Only specimens with available collecting date were used in this analysis.

GEOGRAPHIC COVERAGE

Overall, the country-wide collecting effort is geographically biased, with some quadrants more intensely surveyed than others (Figure 4). Several regions, such as conservation areas [Parque Nacional da Peneda-Gerês (PNPG); Serra de São Mamede] or the vicinities of where the three main museums are located (Lisbon, Coimbra and Porto) have considerably higher collecting efforts, while smaller clusters are also found in the southwestern-most region of the country, as well as Trás-os-Montes, Serra da Estrela and Alto Alentejo. A total of 613 distinct localities were recorded, although 326 (53%) of those are based on the collection of a single specimen.

Focusing on the collecting effort associated with the different institutions, the biases become more evident. MHNC-UP specimens are mainly from northern Portugal, with particular bias towards the metropolitan area of Porto; MCUC specimens also originated mostly from Coimbra and its surroundings, while MUHNAC covers much of the Portuguese continental territory, and even has some records from the archipelagos (Figure 5). MUHNAC also holds considerable numbers from two of the main conservation areas in the country, the Parque Nacional da Peneda-Gerês and its surroundings, as well as Serra de São Mamede and vicinities, reflecting specific interests of contemporaneous collectors (Caetano 1982, 1990, Caetano M.H., unpublished data, Crespo et al. 1995, Pargana et al. 1996). Not surprisingly, the MMF collections all originate from the Madeira, Porto Santo and Selvagens Islands.

Dividing the country into a 10x10 km UTM grid based on the European Terrestrial Reference System 1989 (ETRS89), as used in the most recent atlas of the Portuguese herpetofauna (Loureiro et al. 2008), shows that only 31.9% of

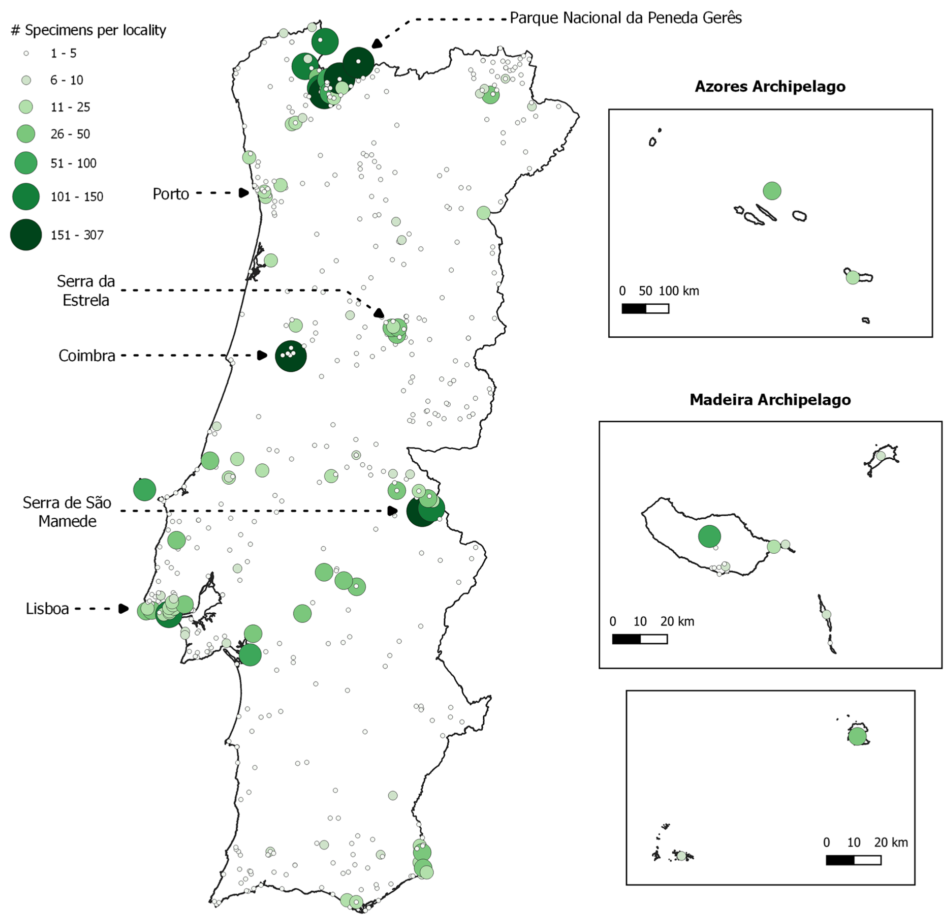

Figure 4. Map of collecting localities for all collections. Increasing circle size and color intensity correspond to the number of records for each location.

the mainland territory and 34.6% and 2.9% of the Madeira and Azores archipelagos respectively, have records (Figure 6). Around 67.2% of these squares are represented by a unique collecting locality. Detailed accounts for each species using the same 10x10 km grid and specimen records in comparison to their known distribution are presented in Figures 7–16.

All but three taxa, the Iberian endemic *Vipera seoanei*, the invasive *Xenopus laevis* and *Tarentola boettgeri bischoffi*, endemic to the Selvagens islets, have less than 10% of their known distribution represented in the collections (Table II; Figures 16f, 10b, 12a respectively). There are no significant differences between endemic and non-endemic species, nor between species with different conservation status. Only one taxon has its distribution completely represented in the collections, *Xenopus laevis*, which is easily understandable as the species is limited to a small stream on the outskirts of the Oeiras municipality, western Portugal (Figure 10a; Sousa et al. 2021). As an island endemic, *Tarentola boettgeri bischoffi* has 25% of its known extent of occurrence covered in the collections, also explained by its very limited distribution range in the Selvagens islets (Figure 12a).

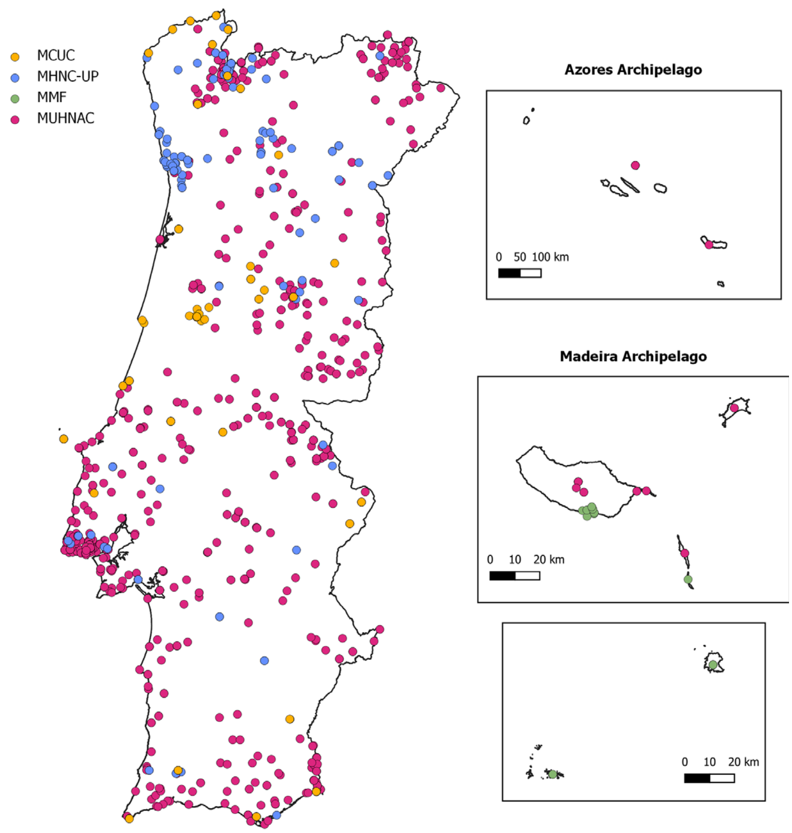

Figure 5. Map of collecting localities for all collections: MCUC (yellow), MHNC-UP (blue), MUHNAC (pink) and MMF (green).

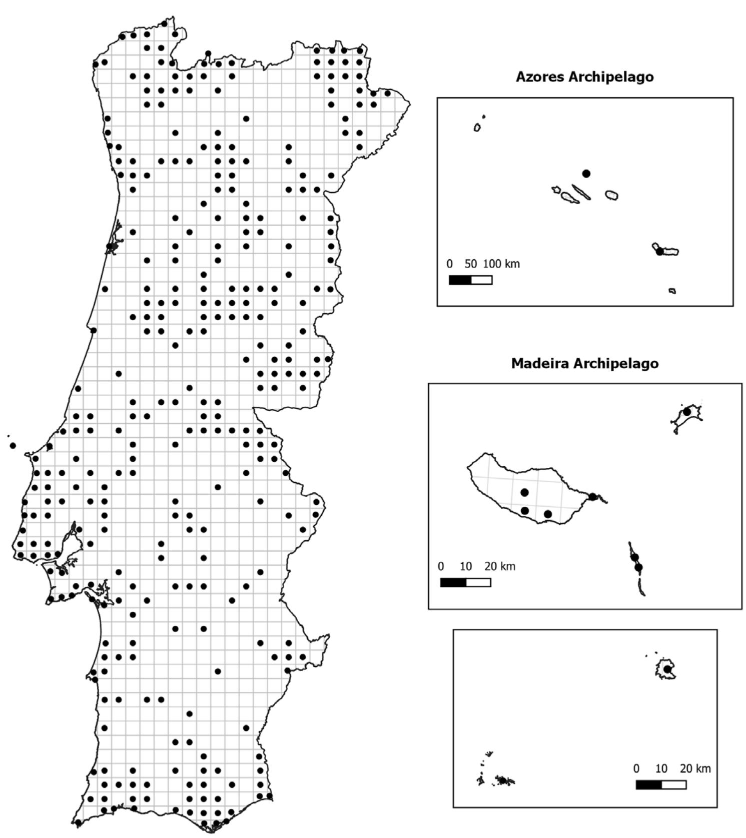

Figure 6. Map of collecting localities for all collections, presented on a 10x10 km UTM grid, based on the coordinate reference systems PT-TM06/ETRS89 and WGS 84/UTM Zones for continental Portugal and the archipelagos, respectively.

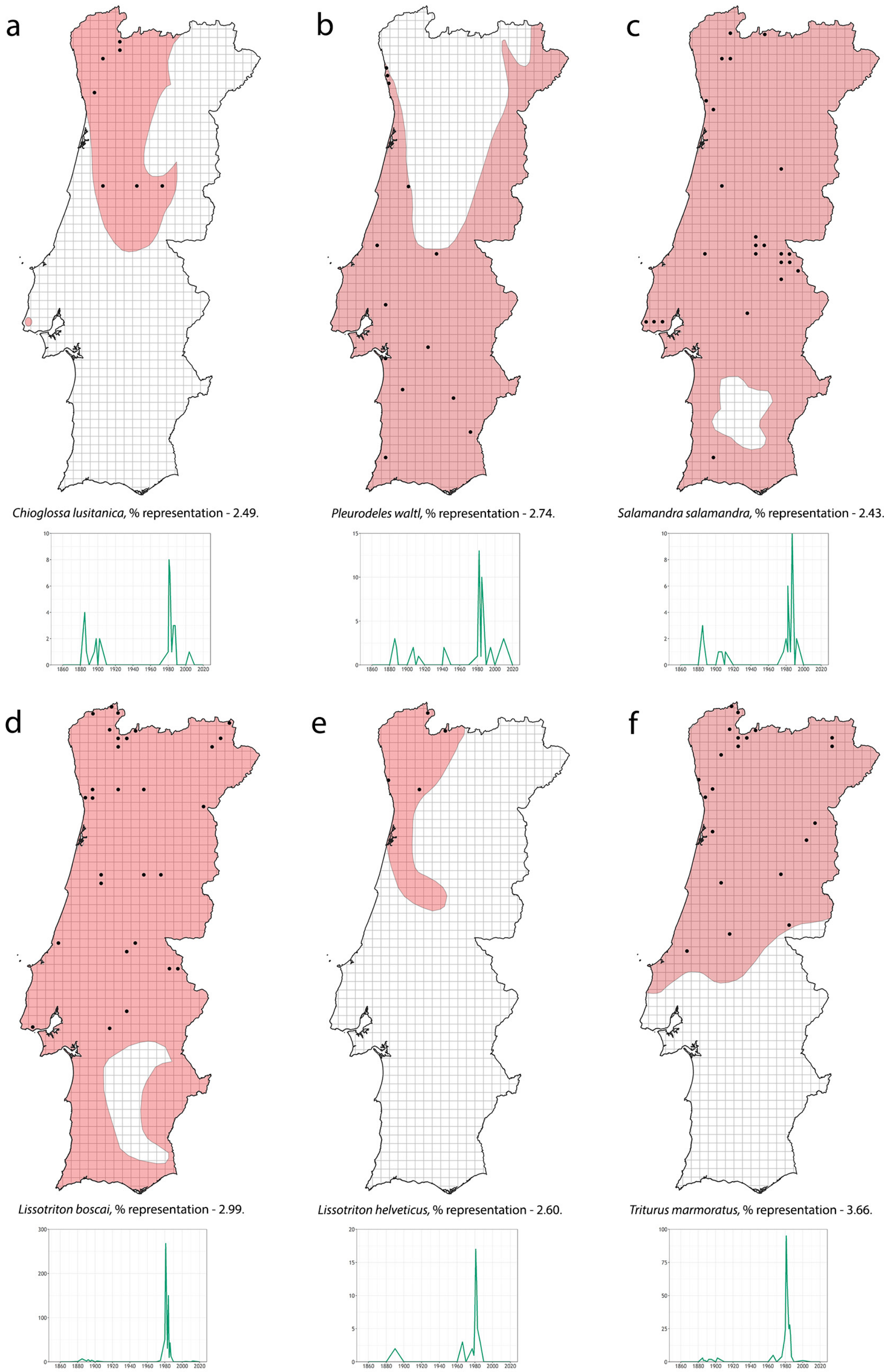

Figure 7. Distribution maps of **a)** *Chioglossa lusitanica*, **b)** *Pleurodeles waltl*, **c)** *Salamandra salamandra*, **d)** *Lissotriton boscai*, **e)** *Lissotriton helveticus*, and **f)** *Triturus marmoratus* comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

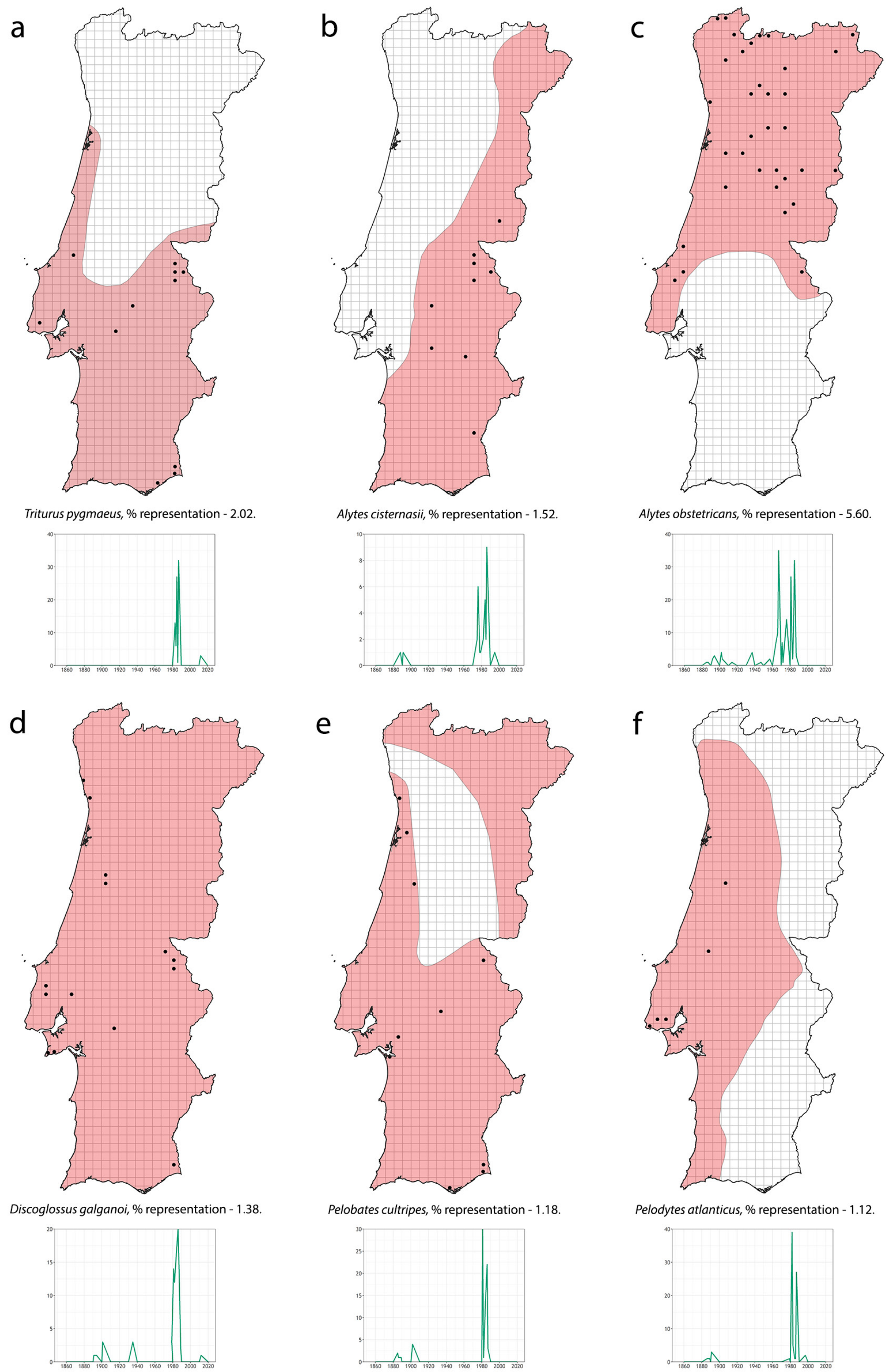

Figure 8. Distribution maps of **a)** *Triturus pygmaeus*, **b)** *Alytes cisternasii*, **c)** *Alytes obstetricans*, **d)** *Discoglossus galganoi*, **e)** *Pelobates cultripes*, and **f)** *Pelodytes atlanticus* comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

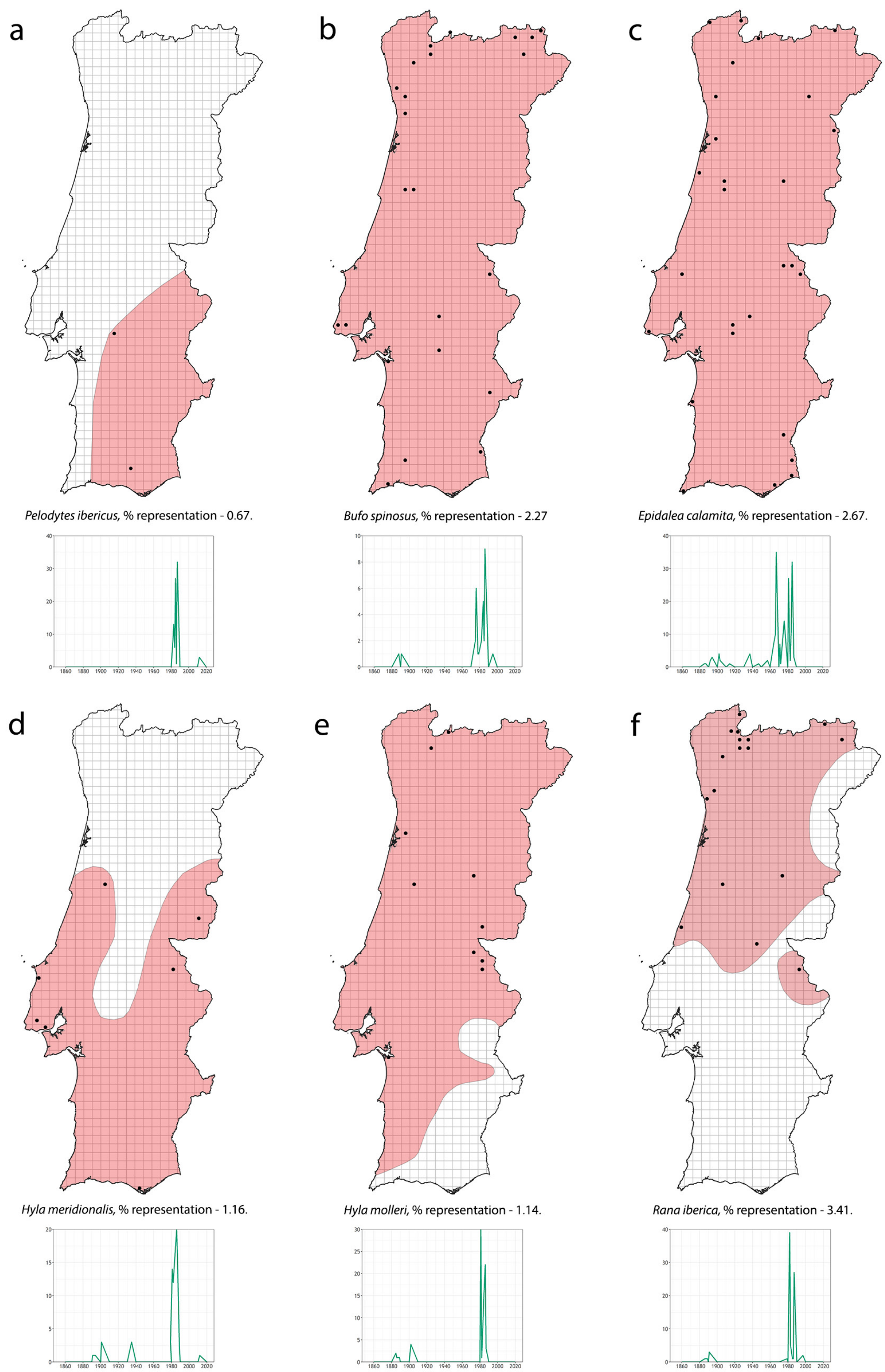

Figure 9. Distribution maps of **a)** *Pelodytes ibericus*, **b)** *Bufo spinosus*, **c)** *Epidalea calamita*, **d)** *Hyla meridionalis*, **e)** *Hyla molleri*, and **f)** *Rana iberica* comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

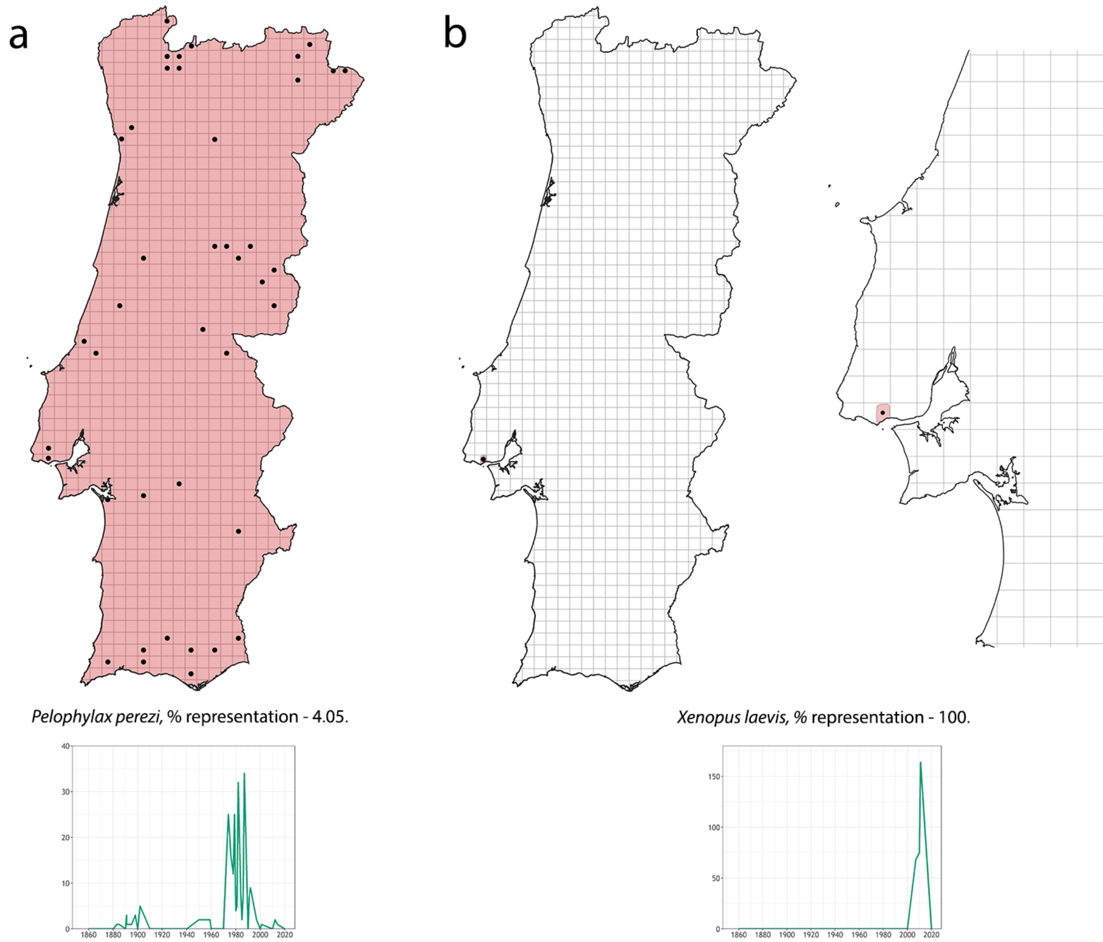

Figure 10. Distribution maps of a) *Pelophylax perezi*, b) *Xenopus laevis* (with close up), comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

COLLECTION DECLINE

Although specimen collecting remains an essential tool for biological research (Rocha et al. 2014) and the enrichment of collections is fundamental to keep NHCs relevant for future research (Fischer et al. 2021, Hope et al. 2018, Miller et al. 2020, Prather et al. 2004), the global trend for over half a century has been a steep decline in collecting efforts. A recent analysis of GBIF data from 245 institutions uncovered a decline of more than 50% in new records for amphibians, reptiles, birds and mammals between 1965 and 2018 (Rohwer et al. 2022). Both the emergence of legislation like the Wildlife Conservation and Protection Acts in the 1950s and the CITES treaty, as well as a change in societal values and strong feelings against killing animals (Hope et al. 2018) contributed to a reduction of collected specimens throughout the years. Other major drivers were global events like the World Wars, economic crashes and pandemics. In fact, World War II (WWII) caused the first major dip in specimen deposition in NHCs (Rohwer et al. 2022), with collecting efforts becoming very scarce for most vertebrate groups globally. The only event with an impact of the same magnitude was the COVID-19 pandemic, with collecting numbers hitting rock bottom,

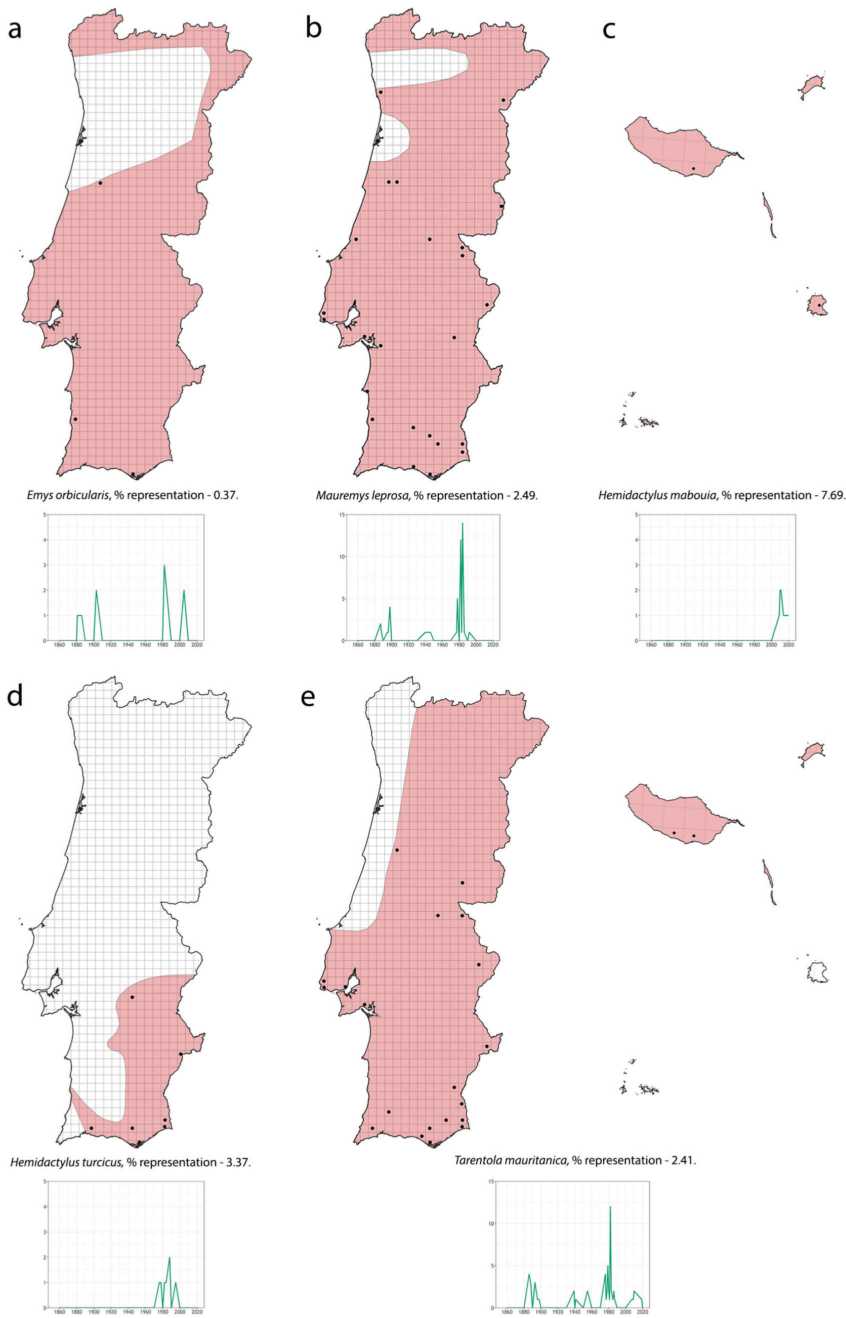

Figure 11. Distribution maps of **a)** *Emys orbicularis*, **b)** *Mauremys leprosa*, **c)** *Hemidactylus mabouia*, **d)** *Hemidactylus turcicus* and **e)** *Tarentola mauritanica*, comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

fewer even than during WWII and comparable to those recorded for most vertebrate groups prior to the 1900s (see data in Rohwer et al. 2022). Changes in societal values are reflected in the scientific community, and a growing number of researchers are opting not to collect zoological specimens, arguing that this can play a significant role in species extinctions (Byrne 2023, Minteer et al. 2014, Rocha et al. 2014). Despite that being discounted almost a decade ago (Rocha et al. 2014), observation-based occurrences and non-invasive sampling are increasingly common practice (Gaiji et al. 2013, Troudet et al. 2018), with new methods being developed (Balázs et al. 2020, Emami-Khoyi et al. 2021, Schilling et al. 2022). Salvador &

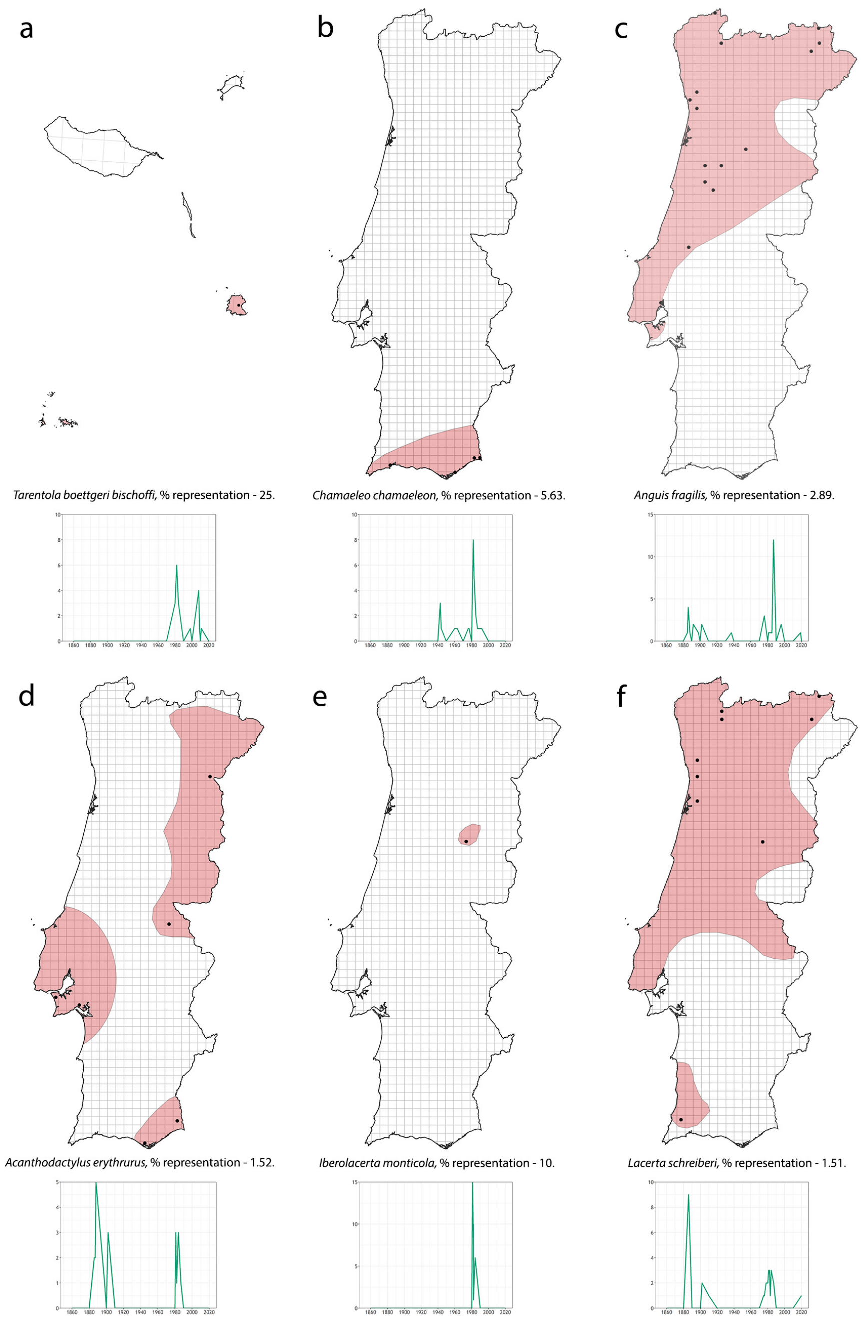

Figure 12. Distribution maps of **a)** *Tarentola boettgeri bischoffi*, **b)** *Chamaeleo chamaeleon*, **c)** *Anguis fragilis*, **d)** *Acanthodactylus erythrurus*, **e)** *Iberolacerta monticola* and **f)** *Lacerta schreiberi*, comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

Cunha (2020) warned of the dangers of declines in collecting, which contradict the "scientific standards of reproducibility" and jeopardize future research with emerging gaps in collection coverage.

Portuguese NHCs have been experiencing a considerable deceleration in accessioning new specimens and collections, probably in a considerably more drastic way than most of its international counterparts. Some collections have not significantly incorporated any new material during the last two decades (Figure 2). Portuguese NHCs growth has always been impacted by external factors and was never regular enough to be able to build and establish good temporal series of the occurring taxa. Each

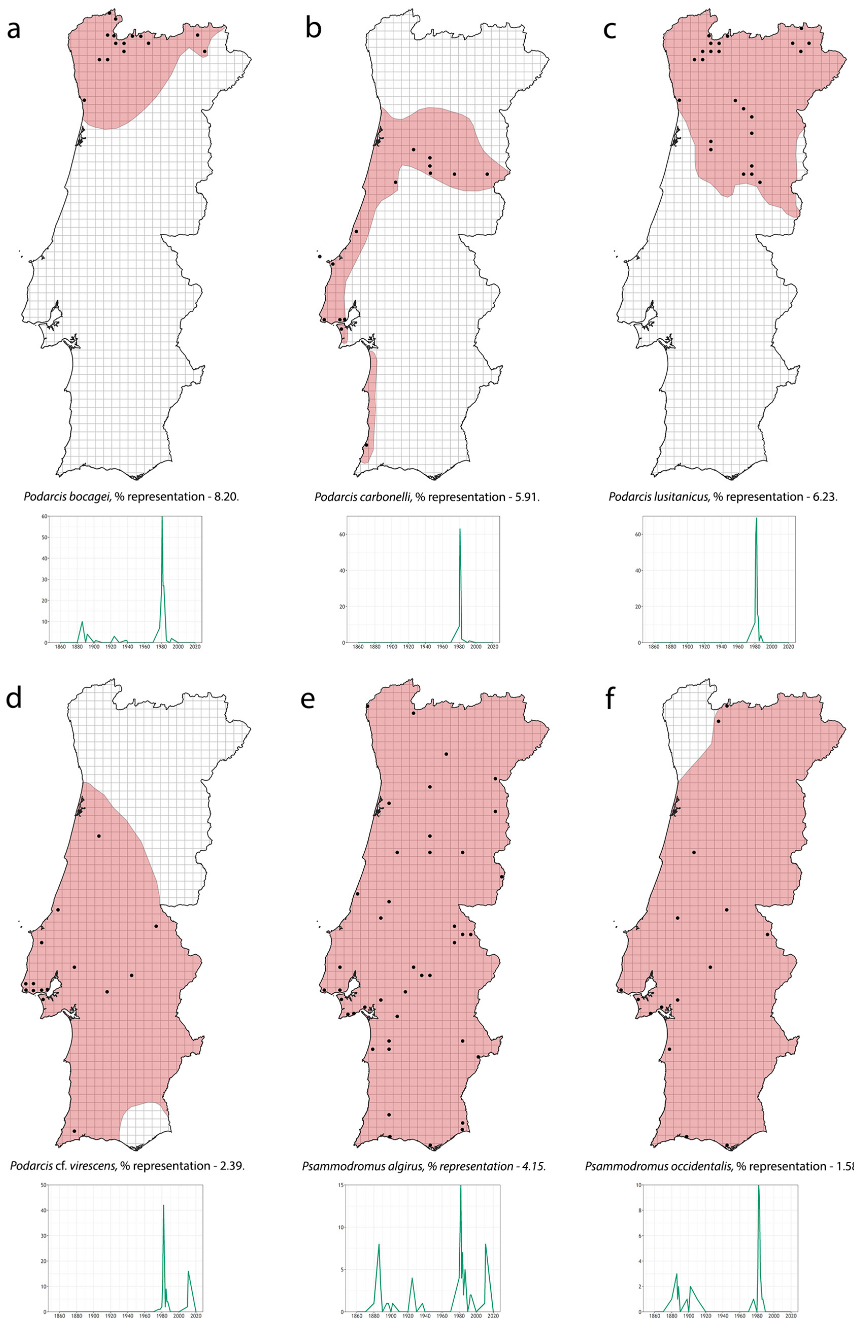

Figure 13. **Distribution maps of a)** ***Podarcis bocagei*****, b)** ***Podarcis carbonelli*****, c)** ***Podarcis lusitanicus*****, d)** ***Podarcis* cf. *virescens*****, e)** ***Psammodromus algirus*** **and f)** ***Psammodromus occidentalis*****, comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.**

museum's collecting history reflects both the internal struggles of the institutions and their importance from a national standpoint. In the case of MUHNAC, most notably during the 1970s and 1980s, expeditions would somewhat regularly be organized by researchers affiliated with the museum, which greatly contributed to collection growth. Another common way collections received new specimens during the nineteenth and early twentieth century was through amateur naturalists, in many cases represented by regional locals, who would collect specimens and donate them to the closest museum. This increased locality bias but provided, at least in theory, better time-series for some of the species.

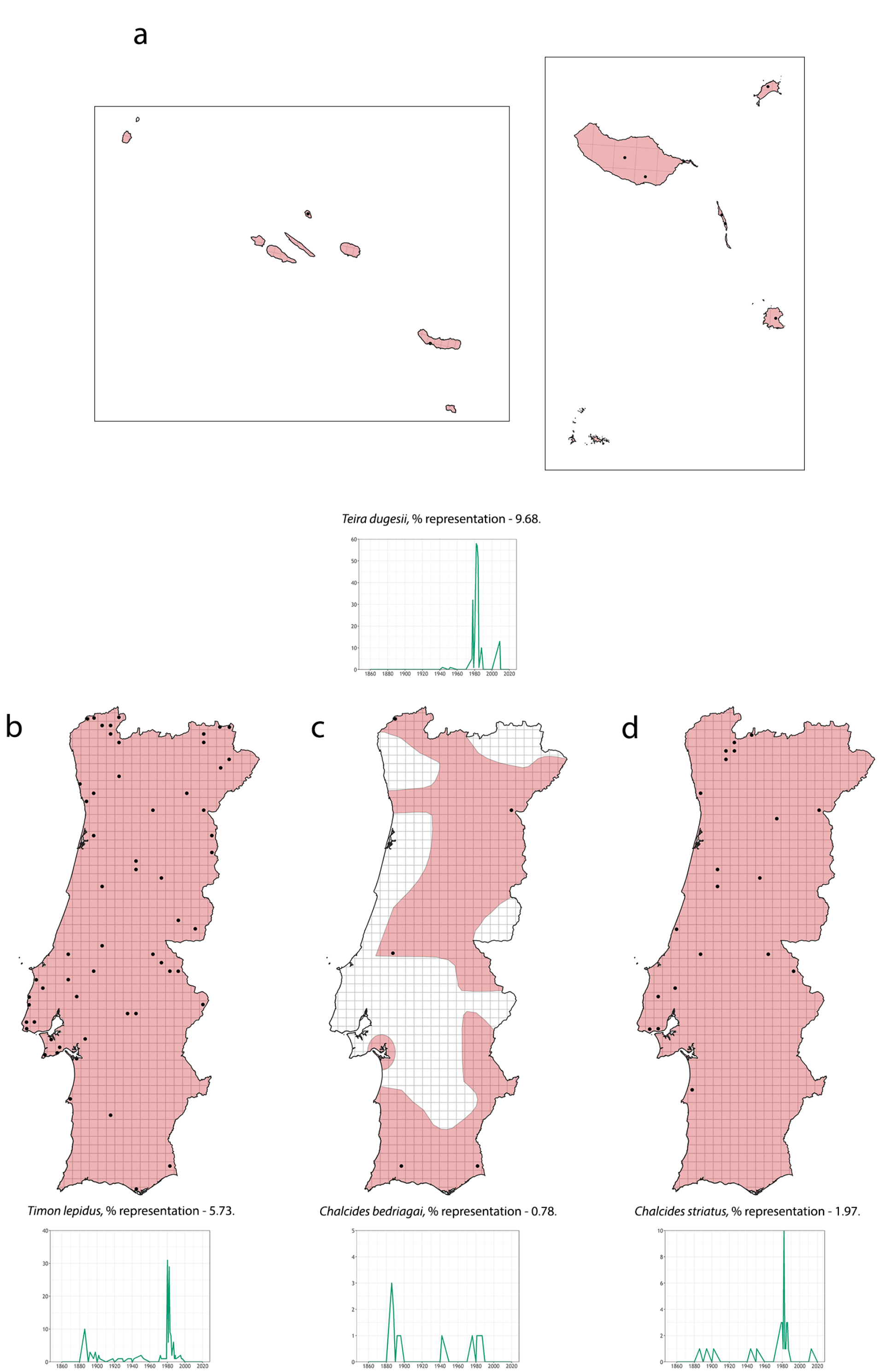

Figure 14. Distribution maps of **a)** *Teira dugesii*, **b)** *Timon lepidus*, **c)** *Chalcides bedriagai* and **d)** *Chalcides striatus*, comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

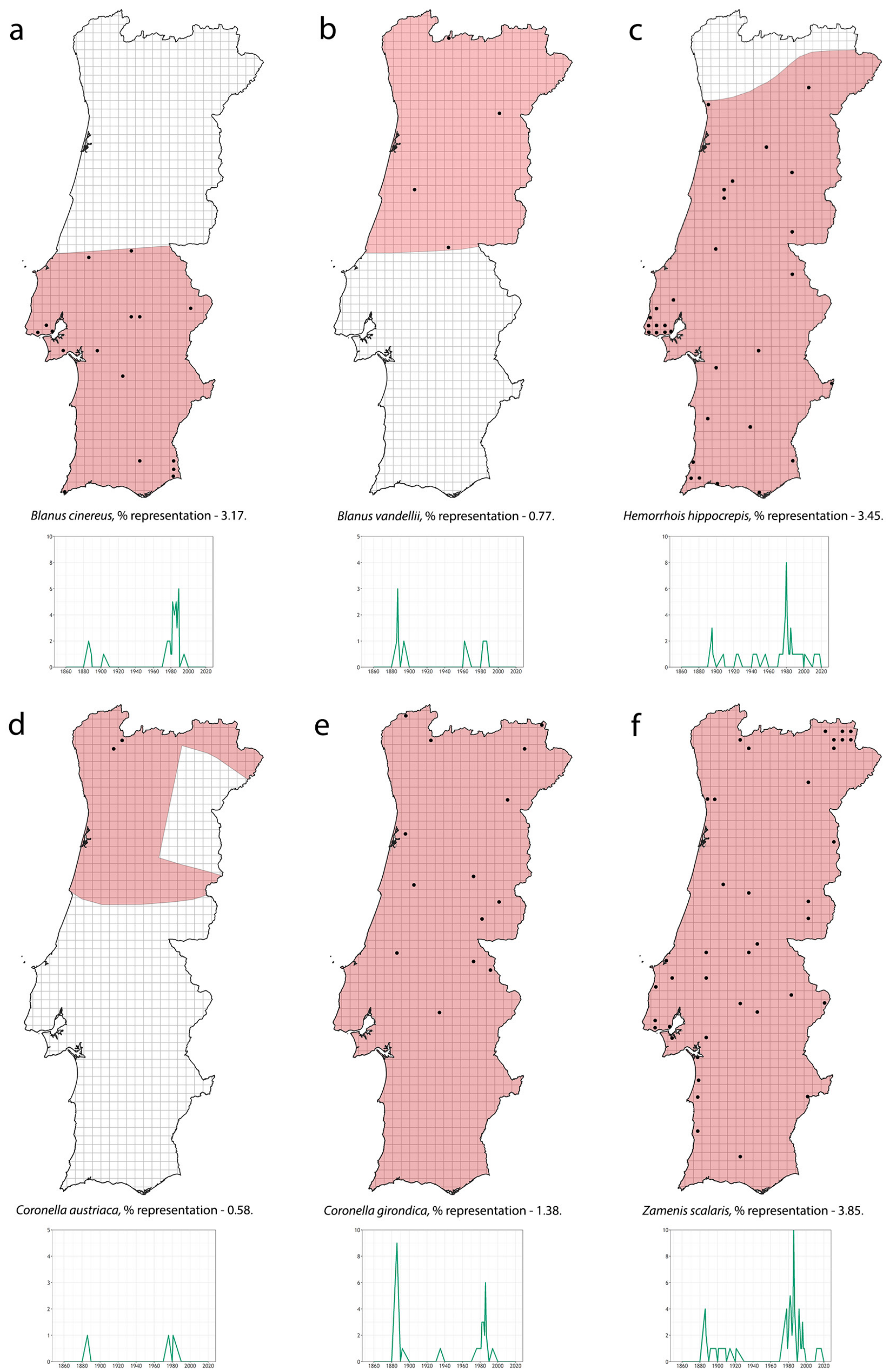

Figure 15. Distribution maps of **a)** *Blanus cinereus*, **b)** *Blanus vandellii*, **c)** *Hemorrhois hippocrepis* and **d)** *Coronella austriaca*, **e)** *Coronella girondica* and **f)** *Zamenis scalaris*, comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

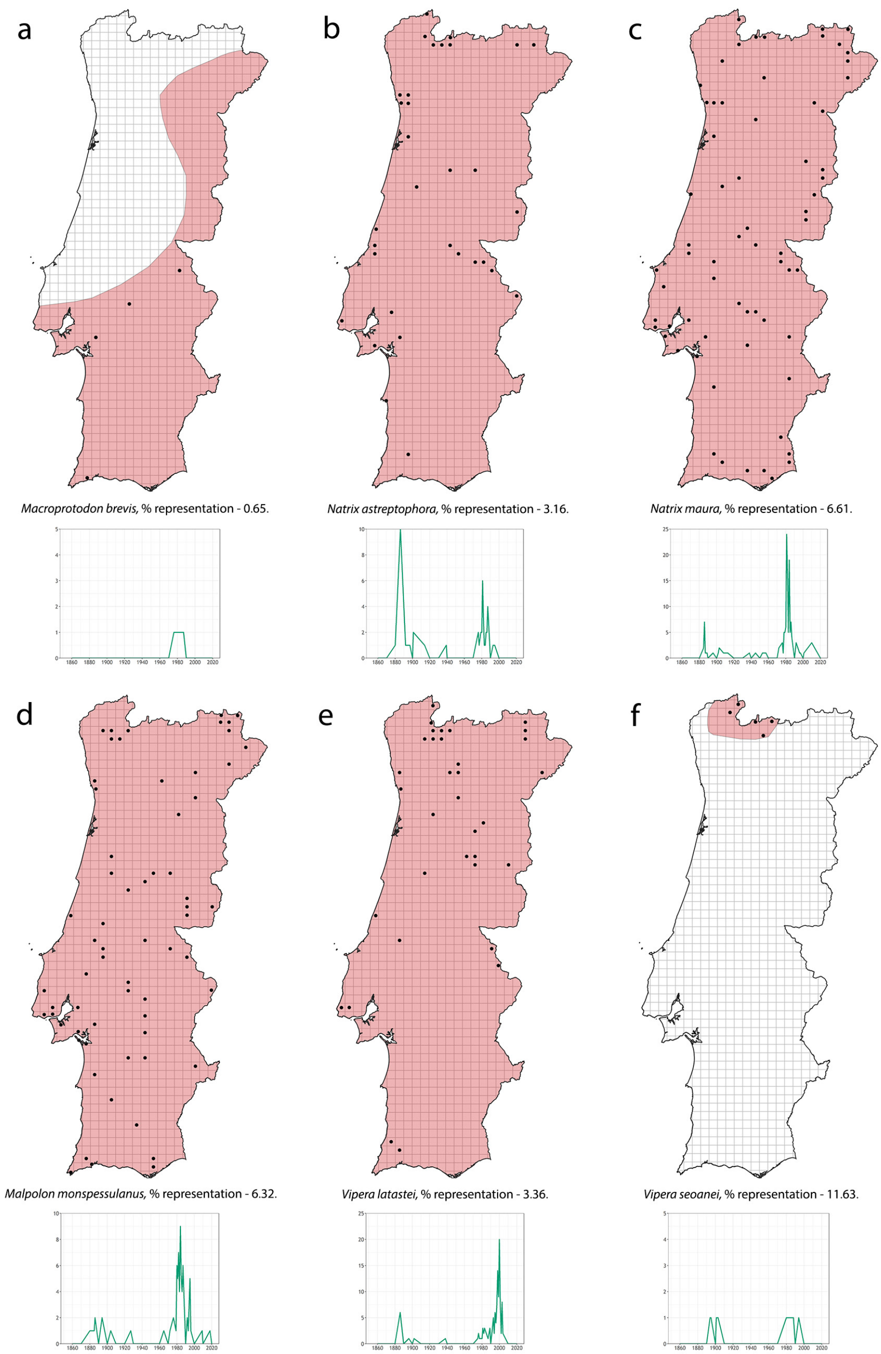

Figure 16. Distribution maps of **a)** *Macroprotodon brevis*, **b)** *Natrix astreptophora*, **c)** *Natrix maura* and **d)** *Malpolon monspessulanus*, **e)** *Vipera latastei* and **f)** *Vipera seoanei*, comparing museum records (black dots) with the species' known extent in Portugal (pink). Respective collecting event chronograms are also presented.

IMPACTS ON PRESENT AND FUTURE RESEARCH

The taxonomic, geographical and temporal biases of the Portuguese herpetological collections have clear impacts on current and future scientific research, as well as species conservation and teaching applications. The disconnect between Portuguese museums and its scientific community starts early in the academic career of researchers due to little to no interaction between museums and faculty students. This minimal exposure combined with lack of funds and training of new personnel in museum techniques and specimen preservation, leads to recruitment of professionals for paid positions in museums becoming rarer and rarer (Dalton 2003, Salvador & Cunha 2020). This situation affects the accessibility and reliability of the associated data, as several types of studies rely on digitized NHCs data, which at this point is neither publicly available through accessible databases, nor fully digitized or taxonomically reviewed due to lack of staff.

The absence of new accessioned specimens does not reflect the current landscape of studies regarding Portuguese herpetofauna. In the last fifteen years, several studies addressed the phylogeography and biogeography of Portuguese herpetofauna (Ambu et al. 2023, Camacho-Sanchez et al. 2020, Faria et al. 2021, Machado et al. 2021, Marques et al. 2022 b, Pinho et al. 2009, 2011, Rato et al. 2013, 2016, Sampaio et al. 2014, Santos et al. 2012a, b, Vences et al. 2014), its morphology and physiology (Enriquez-Urzelai et al. 2015, Kaliontzopoulou et al. 2012, Lucchini et al. 2020, Marques et al. 2022 a, Martínez-Castro et al. 2021, Martínez-Gil et al. 2022, Massetti et al. 2017, 2018, Pinho et al. 2022), the revision of long-standing taxonomic and nomenclatural problems (Arntzen 2018, Arntzen et al. 2021, Ceríaco & Bauer 2018, Caeiro-Dias et al. 2018, 2021, Dubois & Raffaëlli 2009, Geniez et al. 2014, Sequeira et al. 2019), the impact of pathogens on natural populations (De Sousa et al. 2012, Rosa et al. 2022, Stöhr et al. 2015, Thumsová et al. 2022), and even the description of new species (Dias-Rodríguez et al. 2017, Geniez et al. 2014, Fitze et al. 2012). However, the majority of specimens used in these studies were either not deposited in Portuguese NHCs or voucher specimens were simply not collected at all and instead substituted by non-lethal methods such as a tail and/or toe clipping and photographs.

There are several examples of this lack of collection and deposition of voucher specimens in the above cited studies. Caeiro-Dias et al. (2018, 2021) have been dealing with the phylogeography and taxonomy of the *Podarcis hispanicus* species complex. Despite the large number of studies published in the last twenty years on the subject (see Caeiro-Dias et al. 2018 for a detailed list), the specimens used in these studies have not been deposited in any of the Portuguese NHCs. The *P. hispanicus* species complex has a considerable conservative morphology, which led Caeiro-Dias et al. (2021) to consider two of the recently elevated species, *P. lusitanicus* and *P. guadarramae*, "real cryptic species'', only distinguishable through the analysis of their mitochondrial DNA. However, the authors provided no morphological data nor the catalog numbers of the examined specimens, only stating that they were housed in the author's research center (not a public NHC). This lack of data regarding the specimens, and those not being housed in any accessible collection blocks any attempts to replicate the author's results or to review the specimens using other morphological methods in order to attempt to find diagnosable characters for the two putatively morphologically indistinguishable species. The authors also did not refer to any of the available specimens in the MUHNAC, MCUC or MHNC-UP collections, reinforcing the notion of the dissociation between researchers and the Portuguese museums. This disconnect is observed in almost all of the above cited recent studies, where the authors do not refer to the deposition of specimens in Portuguese NHCs, nor the use of the already available specimens. This is showcased, e.g., in a recent study on the phenotypic variation of Eurasian viper species, where the authors used data from photographs and museum specimens to assess its relation with macroevolutionary patterns and environmental factors (Martínez-Castro et al. 2021). Despite the existence of several specimens of two of the

Table II. **Conservation status and percentage of representation of Portuguese herpetofauna. * Denotes invasive species. ** IUCN assessment as *Podarcis hispanicus*. *** IUCN assessment as *Psammodromus hispanicus*. Conservation Status: LC - Least Concern, NT - Near Threatened, VU - Vulnerable, EN - Endangered, NE - Not evaluated.**

Taxa	IUCN Conservation Status	Iberian Endemic	Number of represented squares	Percentage of representation	Map
Amphibia					
Chioglossa lusitanica	NT	Yes	7/281	2.49	Figure 7a
Pleurodeles waltl	NT	Yes	13/745	2.74	Figure 7b
Salamandra salamandra	LC	No	24/987	2.43	Figure 7c
Lissotriton boscai	LC	Yes	29/970	2.99	Figure 7d
Lissotriton helveticus	LC	No	4/154	2.60	Figure 7e
Lissotriton maltzani	LC	Yes	-	-	-
* *Triturus carnifex*	LC	No	-	-	-
Triturus marmoratus	LC	Yes	21/574	3.66	Figure 7f
Triturus pygmaeus	NT	Yes	11/544	2.02	Figure 8a
Alytes cisternasii	LC	Yes	9/592	1.52	Figure 8b
Alytes obstetricans	LC	No	34/607	5.60	Figure 8c
Discoglossus galganoi	LC	Yes	14/1013	1.38	Figure 8d
Pelobates cultripes	VU	No	10/844	1.18	Figure 8e
Pelodytes atlanticus	LC	Yes	6/532	1.12	Figure 8f
Pelodytes ibericus	LC	Yes	2/297	0.67	Figure 9a
Bufo spinosus	LC	No	23/1013	2.27	Figure 9b
Epidalea calamita	LC	No	27/1013	2.67	Figure 9c
Hyla meridionalis	LC	Yes	7/601	1.16	Figure 9d
Hyla molleri	LC	Yes	10/879	1.14	Figure 9e
Rana iberica	VU	Yes	17/498	3.41	Figure 9f
Pelophylax perezi	LC	Yes	41/1013	4.05	Figure 10a
* *Xenopus laevis*	LC	No	1/1	100	Figure 10b
Reptilia					
Emys orbicularis	NT	No	3/814	0.37	Figure 11a
Mauremys leprosa	VU	Yes	24/963	2.49	Figure 11b
* *Hemidactylus mabouia*	LC	No	2/26	7.69	Figure 11c

Table II. Continuation.

Hemidactylus turcicus	LC	No	7/208	3.37	Figure 11d
Tarentola mauritanica	LC	No	22/910	2.41	Figure 11e
Tarentola boettgeri bischoffi	LC	Yes	1/4	25	Figure 12a
Chamaeleo chamaeleon	LC	Yes	4/71	5.63	Figure 12b
Anguis fragilis	LC	No	15/519	2.89	Figure 12c
Acanthodactylus erythrurus	LC	Yes	6/394	1.52	Figure 12d
Iberolacerta monticola	VU	Yes	1/10	10	Figure 12e
Lacerta schreiberi	NT	Yes	9/597	1.51	Figure 12f
Podarcis bocagei	LC	Yes	15/183	8.20	Figure 13a
Podarcis carbonelli	EN	Yes	15/254	5.91	Figure 13b
Podarcis guadarramae **	LC	Yes	-	-	-
Podarcis lusitanicus **	LC	Yes	24/385	6.23	Figure 13c
* *Podarcis vaucheri*	LC	Yes	-	-	-
Podarcis cf. *virescens*	NE	Yes	15/628	2.39	Figure 13d
* *Podarcis siculus*	LC	No	-	-	-
Psammodromus algirus	LC	Yes	42/1013	4.15	Figure 13e
Psammodromus occidentalis ***	LC	Yes	15/952	1.58	Figure 13f
Teira dugesii	LC	Yes	10/93	9.68	Figure 14a
Timon lepidus	NT	Yes	58/1013	5.73	Figure 14b
Chalcides bedriagai	NT	Yes	5/642	0.78	Figure 14c
Chalcides striatus	LC	No	20/1013	1.97	Figure 14d
Blanus cinereus	LC	Yes	16/505	3.17	Figure 15a
Blanus vandellii	NE	Yes	4/520	0.77	Figure 15b
* *Indotyphlops braminus*	LC	No	-	-	-

Table II. Continuation.

Hemorrhois hippocrepis	LC	Yes	31/898	3.45	Figure 15c
Coronella austriaca	LC	No	2/344	0.58	Figure 15d
Coronella girondica	LC	No	14/1013	1.38	Figure 15e
Zamenis scalaris	LC	Yes	39/1013	3.85	Figure 15f
Macroprotodon brevis	NT	Yes	4/616	0.65	Figure 16a
Natrix astreptophora	LC	Yes	32/1013	3.16	Figure 16b
Natrix maura	LC	No	67/1013	6.61	Figure 16c
Malpolon monspessulanus	LC	Yes	64/1013	6.32	Figure 16d
Vipera latastei	VU	Yes	34/1013	3.36	Figure 16e
Vipera seoanei	LC	Yes	5/43	11.63	Figure 16f

reviewed species (*V. latastei* and *V. seoanei*) in Portuguese NHCs, none of these specimens were consulted by the authors. The same happened in the recent revision of the impacts of climate and phylogeographic history on the morphology of Mediterranean amphibians (Martínez-Gil et al. 2022).

Few contemporary studies actively use or take advantage of available specimens in Portuguese NHCs. The recent paper on the impacts of *Ranavirus* on the Portuguese northern populations of *Triturus marmoratus* and *Lissotriton boscai* by Rosa et al. (2022) is one of the few exceptions. The authors relied on available samples collected in the 1980s, which were deposited in MUHNAC's collections, to assess the presence of pathogens in these populations in the past, allowing them to compare historical records to their recently collected data. However, while the authors recognized the importance and utility of these historical specimens in MUHNAC to their research, no specimens of the newly sampled populations were deposited in an NHC, thus impeding use of this newly sampled material to conduct a similar study 40 years in the future.

The importance of time series for molecular ecology and conservation biology has been demonstrated in novel research based on historical collections (Habel et al. 2013). Jungblut & Hawes (2017) used cyanobacteria specimens collected in the early 1900s by Captain R.F. Scott's 'Discovery' Expedition to assess how the Antarctica cyanobacterial diversity has changed since then, particularly with climate change, another topic in which museum specimens have proven to be useful (e.g., Kharouba et al. 2018, MacLean et al. 2018, Riddell et al. 2021). Evolutionary responses to urbanization are currently being studied (Santangelo et al. 2018) and NHCs specimens provide critical resources in assessing those changes (e.g., Kern & Langerhans 2018, Putman et al. 2019, Shultz et al. 2020). A recent example comes from Zimova et al. (2023), who assessed avian morphological change with datasets encompassing four decades of records. Conservation assessments can utilize centuries old datasets that provide a unique perspective to better understand how to intervene and ensure species protection (Beissinger & Peery 2007, Colla et al. 2012, Dures et al. 2019, Mathiasson & Rehan 2019).

The above cited examples, especially in the case of the northern Portuguese *T. marmoratus* and *L. boscai*, also show how specimens can help answer questions that were not envisioned by their original collectors and/or questions for which the technology did not yet exist. MUHNAC's *T. marmoratus* and *L. boscai* collected in the 1980s were originally aimed at basic natural history and population dynamics studies by the collector (Caetano 1982, 1990, Caetano M.H., unpublished data), without any kind of future study on pathogens in mind. In fact, the technology to extract such data from preserved specimens was not even developed at the time. But it was this deposition in a public collection that allowed Rosa et al. (2022) to, four decades later, study the impacts of *Ranavirus* on these populations.

Recent advancements in technology have also allowed for the emergence of "museomics", that is, the study of ancient and historic DNA from museum specimens (Raxworthy & Smith 2021), which is shedding light on the taxonomy and evolutionary history of species (e.g., Call et al. 2021, Ernst et al. 2022, Guschanski et al. 2013), in particular that of extinct (Pyron et al. 2022, Roycroft et al. 2021, Zedane et al. 2015), rare (Twort et al. 2021), and endangered taxa (Castañeda-Rico et al. 2022). All of these and other potential future uses depend on the existence and accessibility of NHCs specimens.

STATUS OF PORTUGUESE RESEARCH COLLECTIONS

Portuguese NHCs house around 13.500 herpetological specimens, of which approximately one third (4950 specimens) represent Portuguese fauna. Although these numbers may seem small when compared to other major NHCs in Europe, Portuguese NHCs are rich in specimens from biodiversity hotspots, such as the Mediterranean basin and the tropical regions spanned by their former colonial possessions, and range from the mid-eighteenth century to present day. As recently noted by Casas-Marce et al. (2012), these smaller regional collections play a fundamental role in modern biodiversity research and conservation, comparable to those of larger museums. However, as shown by our results, the country's herpetofauna is not taxonomically well covered in the Portuguese NHCs, and its geographic and temporal coverage are severely incomplete and biased.

The three major Portuguese herpetological collections are currently part of larger interdisciplinary university museums, which were recently created through the merging of former more discipline-oriented museums. The University of Lisbon manages the MUHNAC, which houses zoological, botanical (herbaria), geological, paleontological, anthropological, and scientific instrument collections, as well as an assortment of memorabilia and other smaller collections related to the history of science in the university. Similarly, the University of Porto and the University of Coimbra manage the MHNC-UP and MCUC, respectively, which also house comparably diverse and interdisciplinary collections from the historical museums of the two universities. Both these interdisciplinary museums are directly under the management of their respective dean's offices, not by biological or natural sciences departments.

There are various reasons why these disciplinarily distinct collections were merged under the same university museum structure, although one of the major drivers was the economic and management burden caused by having several independent museums within the universities. There are certainly pros and cons related to such mergers, which have raised several challenges at the methodological, management and even epistemological levels. Curating a biological collection is radically different from curating a collection of historical scientific instruments and developing a functional database that serves both the interests and needs of curators of almost opposite typologies of collections is challenging.

Being a university museum is, *a priori*, a very interesting opportunity in favor of NHCs, as this relation can foster important research collaborations and teaching partnerships between the museum and the rest of the academic community, from professors, researchers to graduate and undergraduate students (Cook et al. 2014). Some of the larger and more important NHCs in the USA or in Brazil are part of universities, as it is the case of the Museum of Comparative Zoology (Harvard University), the Museum of Vertebrate Zoology (University of California – Berkeley), or the Natural History Museums of the universities of Kansas, Michigan and Florida in the USA, and the Museu Nacional (Universidade Federal do Rio de Janeiro) or the Museu de Zoologia (Universidade de São Paulo). In any of these examples, their collections are used on a daily basis by their university's community, as well as by national and international researchers. Contrary to this proficuous relationship between NHCs and universities, the Portuguese case has produced different outcomes. Suffering from decades of abandonment,Portuguese NHCs are generally perceived by the academic community as the dusty remains of past scientific practices, cumbersome to manage and use, and mostly oriented towards low-impact factor science of taxonomy. Its merging with other type of "museological material", like old scientific instruments and academic memorabilia, has reinforced the idea of museums as repositories of historical heritage and time capsules of the science of the past (Lourenço & Dias 2017), rather than tools of modern and impactful research.

This association is pernicious and has consequences across different levels of the relationship between the museum and its academic community. Firstly, it has led to a physical and emotional separation of professors, researchers, and students from the museum. This has resulted in several immediate problems, such as the abandonment of systematic and taxonomic studies associated with the collections, fostering the already worrisome gap between taxonomists and the rest of the academic community and the well-known negative consequences that it has for biodiversity studies as a whole (Britz et al. 2020). The lack of continuity in the use of collections and reduced transmission of collections-related practices, has led to the loss of basic curatorial and natural history competencies by the community, such as specimen collecting, fixation and taxidermy techniques, and NHCs management, and even to the deterioration and loss of specimens (Figure 17).

Divorced from its research and teaching objectives, collection staff is usually reduced to a minimum level, which has immediate repercussions on the curation and maintenance of its collections, its cataloging and digitizing, leading to drastic limitations on accessibility (Ceríaco et al. 2021). Currently, neither MUHNAC, MHNC-UP or MCUC have a full-time herpetologist as curator, collection manager or technician for its herpetological collections, and all of the work around these collections is conducted either by external invited curators, volunteers, non-expert and/or non-permanent staff. This absence of permanent and specialized staff undermines the trust of external researchers who may have considered depositing their specimens and collections in Portuguese NHCs. As an observable result of this mistrust, no specimens have been regularly accessioned in these collections, despite the existence of an active herpetological research community in the country. The problem goes beyond specimen deposition. As highlighted in some of the above cited examples, Portuguese herpetological specimens available in Portuguese NHCs are not even being requested or used by the scientific community. There are several possible explanations for that, but they all essentially relate to the growing separation between researchers and national NHCs, to a lack of recognition of museums as research facilities, and to, at some point, the accessibility difficulties caused by the inadequate number of staff and unclear accessibility policies. As a policy of the dean's office of the three universities, their museums are not seen as research centers. All research conducted on the collections is expected to be done by outside researchers, with the museum staff merely acting as access facilitators to the collections.

The situation of Portuguese herpetological collections mirrors the remaining vertebrate and invertebrate collections in the country (Santos et al., unpublished data) . The lack of investment and valorization of this unique research tool has farfetched consequences not only for Portugal, but also for global research. Similar cases have been reported (Andreone 2015, Andreone et al. 2014, 2022, Kemp 2015). The present paper serves not only as a report on the scientific consequences of this type of situation in NHCs around the globe, but also as a warning of what can happen to these institutions when they lose their main research and collecting missions.

Figure 17. Lack of curatorial practices resulting in conservation problems in the MHNC-UP collections. Photo by Luis M. P. Ceríaco.

Acknowledgments

The authors want to present an acknowledgement to the collection managers and curators who provided access and data from the collections under their care: Ana Cristina Rufino from the Museu da Ciência da Universidade de Coimbra, Manuel Biscoito from the Museu de História Natural do Funchal and Francisco Calado from the Aquário Vasco da Gama. Data from the collections of the Museu Nacional de História Natural e da Ciência da Universidade de Lisboa, and the Museu de História Natural e da Ciência da Universidade do Porto, was gathered by the second and last authors. Luis M. P. Ceríaco has been the invited curator of the MUHNAC herpetological collections, and was the head of collections and researcher in charge of the herpetological collections of MHNC-UP until February 2022, when the position was suppressed by the dean of the University of Porto. Mariana P. Marques was the invited assistant curator of the MUHNAC herpetological collections until she became the collection manager of the Section of Amphibians and Reptiles of the Carnegie Museum of Natural History in May 2023. Special thanks are owed to Diogo Parrinha, for his constant support in the herpetological collections of MUHNAC and MHNC-UP. We thank Adam Ferguson for his invaluable comments and suggestions on this manuscript. Bruna S. Santos is funded by the Fundação para a Ciência e a Tecnologia (FCT) grant 2021.06659.BD, while Mariana P. Marques was funded by FCT grants SFRH/BD/129924/2017 and COVID/BD/152155/2022. Work supported by National Funds through FCT-Fundação para a Ciência e a Tecnologia in the scope of the project UIDP/50027/2020. Work co-funded by the project NORTE-01-0246-FEDER-000063, supported by Norte Portugal Regional Operational Programme (NORTE2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF).

REFERENCES

AMBU J, MARTÍNEZ-SOLANO I, SUCHAN T, HERNANDEZ A, WIELSTRA B, CROCHET P-A & DUFRESNES C. 2023. Genomic phylogeography illuminates deep cyto-nuclear discordances in midwife toads (*Alytes*). Mol Phylogenetics Evol 183: 107783.

ANDREONE F. 2015. Natural history: save Italy's museums. Nature 517: 271.

ANDREONE F ET AL. 2014. Italian natural history museums on the verge of collapse. ZooKeys 456: 139-146.

ANDREONE F, BOERO F, BOLOGNA MA, CARPANETO GM, CASTIGLIA R, GIPPOLITI S, MASSA B & MINELLI A. 2022. Reconnecting research and natural history museums in Italy and the need of a national collection biorepository. ZooKeys 1104: 55-68.

ARNTZEN JW. 2018. Morphological and molecular characters to describe a marbled newt hybrid zone in the Iberian peninsula. Contrib Zool 87: 167-185.

ARNTZEN JW, LÓPEZ-DELGADO J, VAN RIEMSDIJK I & WIELSTRA B. 2021. A genomic footprint of a moving hybrid zone in marbled newts. J Zool Syst Evol Res 59: 459-465.

BAKKER FT ET AL. 2020. The Global Museum: natural history collections and the future of evolutionary science and public education. PeerJ 8: e8225.

BALÁZS G, VÖRÖS J, LEWARNE B & HERCZEG G. 2020. A new non-invasive in situ underwater DNA sampling method for estimating genetic diversity. Evol Ecol 34: 633-644.

BEISSINGER SR & PEERY MZ. 2007. Reconstructing the historic demography of an endangered seabird. Ecology 88(2): 296-305.

BREEN SD. 2015. Saving seeds: The Svalbard Global Seed Vault, Native American seed savers, and problems of property. J Agric Food Syst Community Dev 5(2): 39-52.

BRITZ R, HUNDSDÖRFER A & FRITZ U. 2020. Funding, training, permits - the three big challenges of taxonomy. Megataxa 1(1): 49-52.

BYRNE AQ. 2023. Reimagining the future of natural history museums with compassionate collection. PLoS Biol 21(5): e3002101.

CAEIRO-DIAS G, LUÍS C, PINHO C, CROCHET P-A, SILLERO N,& KALIONTZOPOULOU A. 2018. Lack of congruence of genetic and niche divergence in *Podarcis hispanicus* complex. J Zool Syst Evol Res 56(4): 479-492.

CAEIRO-DIAS G, ROCHA S, COUTO A, PEREIRA C, BRELSFORD A, CROCHET P-A & PINHO C. 2021. Nuclear phylogenies and genomics of a contact zone establish the species rank of *Podarcis lusitanicus* (Squamata, Lacertidae). Mol Phylogenet Evol 164: 107270.

CAETANO MH. 1982. Les amphibiens et les reptiles du Parc National de Peneda-Gerês (Portugal). Bull Soc herpétol Fr 23: 33-44.

CAETANO MH. 1990. Use and results of skeletochronology in some Urodeles (*Triturus marmoratus*, Latreille, 1800 and *Triturus boscai*, Lataste 1879). Ann sci nat Zool biol anim 11(13): 197-199.

CALL E, MAYER C, TWORT V, DIETZ L, WAHLBERG N & ESPELAND M. 2021. Museomics: Phylogenomics of the Moth Family

Epicopeiidae (Lepidoptera) Using Target Enrichment. Insect Syst Divers 5(2): 1-10.

CAMACHO-SANCHEZ M, VELO-ANTÓN G, HANSON JO, VERÍSSIMO A, MARTÍNEZ-SOLANO I, MARQUES A, MORITZ C & CARVALHO SB. 2020. Comparative assessment of range-wide patterns of genetic diversity and structure with SNPs and microsatellites: A case study with Iberian amphibians. Ecol Evol 10(19): 10353-10363.

CASAS-MARCE M, REVILLA E, FERNANDES M, RODRÍGUEZ A, DELIBES M & GODOY JÁ. 2012. The Value of Hidden Scientific Resources: Preserved Animal Specimens from Private Collections and Small Museums. BioScience 62(12): 1077-1082.

CASTAÑEDA-RICO S, EDWARDS CW, HAWKINS MTR & MALDONADO JE. 2022. Museomics and the holotype of a critically endangered cricetid rodent provide key evidence of an undescribed genus. Front Ecol Evol 10: 930356.

CEBALLOS G, EHRLICH PR, BARNOSKY AD, GARCÍA A, PRINGLE RM & PALMER TM. 2015. Accelerated modern human-induced species losses: Entering the sixth mass extinction. Sci Adv 1(5): e1400253.

CERÍACO L. 2016. Amphibia collection of the Museu Nacional de História Natural e da Ciência, Universidade de Lisboa, Portugal. Museu Nacional de História Natural e da Ciência. Occurrence dataset available at: https://doi.org/10.15468/qe8u2w, accessed on 15 June 2022.

CERÍACO L & MARQUES M. 2019. Reptilia collection of the Museu Nacional de História Natural e da Ciência, Universidade de Lisboa, Portugal. Museu Nacional de História Natural e da Ciência. Occurrence dataset available at: https://doi.org/10.15468/2ukmcs, accessed on 15 June 2022.

CERÍACO LMP. 2021. Zoologia e Museus de História Natural em Portugal (Séculos XVIII-XX). São Paulo: Editora da Universidade de São Paulo, 720 p.

CERÍACO LMP & BAUER AM. 2018. An integrative approach to the nomenclature and taxonomic status of the genus *Blanus* Wagler, 1830 (Squamata: Blanidae) from the Iberian Peninsula. J Nat Hist 52(13-16): 849-880.

CERÍACO LMP, PARRINHA D & MARQUES MP. 2021. Saving collections: taxonomic revision of the herpetological collections of the Instituto de Investigação Científica Tropical, Lisbon (Portugal) with a protocol to rescue abandoned collections. ZooKeys 1052: 83-156.

CHAPMAN AD & WIECZOREK JR. 2020. Georeferencing Best Practices. Version 1.0. Copenhagen: GBIF Secretariat, 112 p.

COLLA SR, GADALLAH F, RICHARDSON L, WAGNER D & GALL L. 2012. Assessing declines of North American bumble bees (*Bombus* spp.) using museum specimens. Biodivers Conserv 21: 3585-3595.

COOK JA ET AL. 2014. Natural history collections as emerging resources for innovative education in biology. BioSciences 64: 725-724.

COOK JA ET AL. 2020. Integrating Biodiversity Infrastructure into Pathogen Discovery and Mitigation of Emerging Infectious Diseases. BioScience 70(7): 531-534.

COX N ET AL. 2022. A global reptile assessment highlights shared conservation needs of tetrapods. Nature 605: 285-290.

CRESPO EG. 1971. Anfíbios de Portugal Continental das Colecções do Museu Bocage. Arq Mus Boc 2ª série 3(8): 203-304.

CRESPO EG. 1972. Répteis de Portugal Continental das Colecções do Museu Bocage. Arq Mus Boc 2ª série 3(17): 447-612.

CRESPO EG. 1975. Aditamento aos catálogos dos répteis e anfíbios de Portugal Continental das colecções do Museu Bocage. Arq Mus Boc 2ª série 5(3): 479-497.

CRESPO EG, OLIVEIRA ME, ZUIDERWIJK A, PAULO OS, ROSA HD, VIEGAS AM, PARGANA JM, RAIMUNDO ND, MOREIRA PL & BRITO-E-ABREU F. 1995. Amphibian diversity in Portuguese Natural Parks: a study project. In: Llorente al. (Eds), Scientia Herpetologica, Barcelona: Asociación Herpetológica Española, p. 303-306.

DALTON R. 2003. Natural history collections in crisis as funding is slashed. Nature 423: 575.

DARWIN CORE. 2022. Darwin Core. Available at: https://dwc.tdwg.org, accessed on 13 November 2022.

DE SOUSA R, CARVALHO IL, SANTOS AS, BERNARDES C, MILHANO N, JESUS J, MENEZES D & NÚNCIO MS. 2012. Role of the Lizard *Teira dugesii* as a Potential Host for *Ixodes ricinus* Tick-Borne Pathogens. Appl Environ Microbiol 78(10): 3767-3769.

DIAS-RODRÍGUEZ J, GEHARA M, MÁRQUEZ R, VENCES M, GONÇALVES H, SEQUEIRA F, MARTÍNEZ-SOLANO I & TEJEDO M. 2017. Integration of molecular, bioacoustical and morphological data reveals two new cryptic species of *Pelodytes* (Anura, Pelodytidae) from the Iberian Peninsula. Zootaxa 4243(1): 001-041.

DIEULIIS D, JOHNSON KR, MORSE SS & SCHINDEL DE. 2016. Specimen collections should have a much bigger role in infectious disease research and response. Proc Natl Acad Sci USA 113(1): 4-7.

DIRZO R, YOUNG HS, GALLETI M, CEBALLOS G, ISAAC NJB & COLLEN B. 2014. Defaunation in the Anthropocene. Science 345(6195): 401-406.

DUBOIS A & RAFFAËLLI J. 2009. A new ergotaxonomy of the family Salamandridae Goldfuss, 1820 (Amphibia, Urodela). Alytes 26(1-4): 1-85.

DUNNUM JL, YANAGIHARA R, JOHNSON KM, ARMIEN B, BATSAIKHAN N, MORGAN L & COOK JA. 2017. Biospecimen Repositories and Integrated Databases as Critical Infrastructure for Pathogen Discovery and Pathobiology Research. PLoS Negl 11(1): e0005133.

DURES SG, CARBONE C, LOVERIDGE AJ, MAUDE G, MIDLANE N, ASCHENBORN O & GOTTELLI D. 2019. A century of decline: Loss of genetic diversity in a southern African lion-conservation stronghold. Divers Distrib 25(6): 870-879.

EMAMI-KHOYI A ET AL. 2021. A New Non-invasive Method for Collecting DNA From Small Mammals in the Field, and Its Application in Simultaneous Vector and Disease Monitoring in Brushtail Possums. Front Environ Sci 9: 701033.

ENRIQUEZ-URZELAI U, MONTORI A, LLORENTE GA & KALIONTZOPOULOU A. 2015. Locomotor Mode and the Evolution of the Hindlimb in Western Mediterranean Anurans. Evol Biol 42: 199-209.

ERNST M, JØNSSON KA, ERICSON PGP, BLOM MPK & IRESTEDT M. 2022. Utilizing museomics to trace the complex history and species boundaries in an avian-study system of conservation concern. Heredity 128: 159-168.

FARIA JF, CARRETERO MA & HARRIS DH. 2021. Further molecular assessment of the distribution of Spanish sand racers (Lacertidae; *Psammodromus*). Basic Appl Herpetol 35: 77-83.

FERGUSON AW. 2020. On the role of (and threat to) natural history museums in mammal conservation: an African small mammal perspective. J Vertebr Biol 69(2): 20028.1-23.

FISCHER EF, COBB NS, KAWAHARA AY, ZASPEl JM & COGNATO AI. 2021. Decline of Amateur Lepidoptera Collectors Threatens the Future of Specimen-Based Research. BioScience 71(4): 396-404.

FITZE PS, GONZALEZ-JIMENA V, SA-JOSE LM, MAURO DS & ZARDOTA R. 2012. A new species of sand racer, *Psammodromus* (Squamata: Lacertidae), from the Western Iberian Peninsula. Zootaxa 3205: 41-52.

FOWLER C. 2008. The Svalbard Seed Vault and Crop Security. BioScience 58(3): 190-191.

FROST DR. 2023. Amphibian Species of the World: an Online Reference. Version 6.1. Available at: https://amphibiansoftheworld.amnh.org/index.php, accessed on 1 December 2022.

GAIJI S, CHAVAN V, ARIÑO AH, OTEGUI J, HOBERN D, SOOD R & ROBLES E. 2013. Content assessment of the primary biodiversity data published through GBIF network: Status, challenges and potentials. Biodivers inform 8: 94-172.

GARDNER JL, AMANO T, SUTHERLAND WJ, JOSEPH L & PETERS A. 2014. Are natural history collections coming to an end as time-series? Front Ecol Environ 12: 436-438.

GENIEZ P, SÁ-SOUSA P, GUILLAUME CP, CLUCHIER A & CROCHET P-A. 2014. Systematics of the *Podarcis hispanicus* complex (Sauria, Lacertidae) III: valid nomina of the western and central Iberian forms. Zootaxa 3794(1): 001-051.

GUSCHANSKI K ET AL. 2013. Next-Generation Museomics Disentangles One of the Largest Primate Radiations. Syst Biol 62(4): 539-554.

HABEL JC, HUSEMANN M, FINGER A, DANLEY PD & ZACHOS FE. 2013. The relevance of time series in molecular ecology and conservation biology. Biol Rev 89(2): 484-492.

HEBERLING JM, MILLER JT, NOESGAARD D, WEINGART SB & SCHIGEL D. 2021. Data integration enables global diversity synthesis. PNAS 118(6): 1-7.

HEDRICK BP ET AL. 2020. Digitization and the Future of Natural History Collections. BioScience 70(3): 243-251.

HILTON EJ, WATKINS-COLWELL J & HUBER SK. 2021. The Expanding Role of Natural History Collections. Ichthyol Herpetol 109(2): 379-391.

HOPE AG, SANDERCOCK BK & MALANEY JL. 2018. Collection of Scientific Specimens: Benefits for Biodiversity Sciences and Limited Impacts on Communities of Small Mammals. BioScience 68(1): 35-42.

IUCN. 2023. The IUCN Red List of Threatened Species. Version 2022-2. Available at https://www.iucnredlist.org, accessed on 1 December 2022.

JOHNSON KG ET AL. 2011. Climate Change and Biosphere Response: Unlocking the Collections Vault. BioScience 61(2): 147-153.

JUNGBLUT AD & HAWES I. 2017. Using Captain Scott's Discovery specimens to unlock the past: has Antarctic cyanobacterial diversity changed over the last 100 years? Proc Royal Soc B 284: 20170833.

KALIONTZOPOULOU A, CARRETERO MA & LLORENTE GA. 2012. Morphology of the *Podarcis* wall lizards (Squamata: Lacertidae) from the Iberian Peninsula and North

Africa: Patterns of variation in a putative cryptic species complex. Zool J Linn Soc 164(1): 173-193.

KEMP C. 2015. Museums: The endangered dead. Nature 518: 292-294.

KERN EMA & LANGERHANS RB. 2018. Urbanization drives contemporary evolution in stream fish. Glob Change Biol 24(8): 3791-3803.

KHAROUBA HM, LEWTHWAITE JMM, GURALNICK R, KERR JT & VELLEND M. 2018. Using insect natural history collections to study global change impacts: challenges and opportunities. Philos Trans R Soc Lond B Biol Sci 374: 20170405.

LENDEMER J ET AL. 2020. The Extended Specimen Network: A Strategy to Enhance US Biodiversity Collections, Promote Research and Education. BioScience 70(1): 23-30.

LOUREIRO A, ALMEIDA NF, CARRETERO MA & PAULO OS. 2008. Atlas dos Anfíbios e Répteis de Portugal. Lisboa: Instituto da Conservação da Natureza e da Biodiversidade, 257 p.

LOURENÇO MC & DIAS JPS. 2017. “Time Capsules” of Science: Museums, Collections, and Scientific Heritage in Portugal. Isis 108(2): 390-398.

LUCCHINI N, KALIONTZOPOULOU A, VAL GA & MARTÍNEZ-FREIRÍA. 2020. Sources of intraspecific morphological variation in *Vipera seoanei*: allometry, sex, and colour phenotype. Amphib-Reptil 42(1): 1-16.

MACHADO L, HARRIS DH & SALVI D. 2021. Biogeographic and demographic history of the Mediterranean snakes *Malpolon monspessulanus* and *Hemorrhois hippocrepis* across the Strait of Gibraltar. BMC Ecol Evo 21: 210.

MACLEAN HJ, NIELSEN ME, KINGSOLVER JG & BUCKLEY LB. 2018. Using museum specimens to track morphological shifts through climate change. Philos Trans R Soc Lond B Biol Sci 374: 20170404.

MALANEY JL & COOK JA. 2018. A perfect storm for mammalogy: declining sample availability in a period of rapid environmental degradation. J Mammal 99(4): 773-788.

MARQUES AJD, HANDON JO, CAMACHO-SANCHEZ M, MARTÍNEZ-SOLANO I, MORITZ C, TARROSO P, VELO-ANTÓN G, VERÍSSIMO A & CARVALHO SB. 2022a. Range-wide genomic scans and tests for selection identify non-neutral spatial patterns of genetic variation in a non-model amphibian species (*Pelobates cultripes*). Conserv Genet 23: 387-400.

MARQUES V, RIAÑO GM, CARRETERO MA, SILVA-ROCHA I & RATO C. 2022b. Sex determination and optimal development in the Moorish gecko, *Tarentola mauritanica*. Acta Zoo 00: 1-15.

MARTÍNEZ-CASTRO A, KALIONTZOPOULOU A, FREITAS I & MARTÍNEZ-FREIRÍA F. 2021. Macroevolutionary variation and environmental correlates of scalation traits in Eurasian vipers (Serpentes: Viperinae). Biol J Linn Soc 132(2): 318-327.

MARTÍNEZ-GIL H, MARTÍNEZ-FREIRÍA F, PERERA A, ENRIQUEZ-URZELAI U, MARTÍNEZ-SOLANO I, VELO-ANTÓN G & KALIONTZOPOULOU A. 2022. Morphological diversification of Mediterranean anurans: the roles of evolutionary history and climate. Biol J Linn Soc 135(3): 462-477.

MASSETTI F, GOMES V, PERERA A, RATO C & KALIONTZOPOULOU A. 2017. Morphological and functional implications of sexual size dimorphism in the Moorish gecko, *Tarentola mauritanica*. Biol J Linn Soc 122(1): 1-13.

MASSETTI F, KALIONTZOPOULOU A, GOMES V & RATO C. 2018. Variation in morphology and functional performance across distinct evolutionary lineages of the Moorish gecko (*Tarentola mauritanica*) from the Iberian Peninsula. J Zool Syst Evol Res 57(2): 431-444.

MATHIASSON ME & REHAN SM. 2019. Status changes in the wild bees of north-eastern North America over 125 years revealed through museum specimens. Insect Conserv Divers 12(4): 278-288.

MEINEKE EK, DAVIES TJ, DARU BH & DAVIS CC. 2018. Biological collections for understanding biodiversity in the Anthropocene. Philos Trans R Soc Lond B Biol Sci 374(1763): 20170386.

MILLER SE ET AL. 2020. Building Natural History Collections for the Twenty-First Century and Beyond. BioScience 70(8): 674-687.

MINTEER BA, COLLINS JP, LOVE KE & PUSCHENDORF R. 2014. Avoiding (Re)extinction. Science 344(6181): 260-261.

MONFILS AK, KRIMMEL ER, LINTON DL, MARSICO TD, MORRIS AB & RUHFEL BR. 2022. Collections Education: The Extended Specimen and Data Acumen. BioScience 72(2): 177-188.

MYERS N, MITTERMEIER RA, MITTERMEIER CG, DA FONSECA GAB & KENT J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

NELSON G & ELLIS S. 2018. The history and impact of digitization and digital data mobilization on biodiversity research. Philos Trans R Soc Lond B Biol Sci 374(1763): 20170391.

PARGANA JM, PAULO OS & CRESPO EG. 1996. Anfíbios e Répteis do Parque Natural da Serra de S. Mamede. Portalegre: Parque Natural da Serra de S. Mamede, Instituto da Conservação da Natureza, 101 p.

PINHO C, KALIONTZOPOULOU A, CARRETERO MA, HARRIS DH & FERRAND N. 2009. Genetic admixture between the Iberian endemic lizards *Podarcis bocagei* and *Podarcis carbonelli*: Evidence for limited natural hybridization and a bimodal hybrid zone. J Zool Syst Evol Res 47(4): 368-377.

PINHO C, KALIONTZOPOULOU A, HARRIS DH & FERRAND N. 2011. Recent evolutionary history of the Iberian endemic lizards *Podarcis bocagei* (Seoane, 1884) and *Podarcis carbonelli* Pérez-Mellado, 1981 (Squamata: Lacertidae) revealed by allozyme and microsatellite markers. Zool J Linn Soc 162(1): 184-200.

PINHO C, KALIONTZOPOULOU A, FERREIRA CA & GAMA J. 2022. Identification of morphologically cryptic species with computer vision models: wall lizards (Squamata: Lacertidae: *Podarcis*) as a case study. Zool J Linn Soc 198(1): 184-201.

PRATHER LA, ALVAREZ-FUENTES A, MAUFIELD MH & FERGUSON CJ. 2004. The Decline of Plant Collecting in the United States: A Threat to the Infrastructure of Biodiversity Studies. Syst Bot 29(1): 15-28.

PUTMAN BJ, GASCA M, BLUMSTEIN DT & PAULY GB. 2019. Downsizing for downtown: limb lengths, toe lengths, and scale counts decrease with urbanization in western fence lizards (*Sceloporus occidentalis*). Urban Ecosyst 22: 1071-1081.

PYRON RA, BEAMER DA, HOLZHEUSER CR, LEMMON EM, LEMMON AR, WYNN AH & O'CONNELL KA. 2022. Contextualizing enigmatic extinctions using genomic DNA from fluid-preserved museum specimens of *Desmognathus* salamanders. Conserv Genet 23: 375-386.

RATO C, PERERA A, CARRANZA S & HARRIS DH. 2013. Evolutionary patterns of the mitochondrial genome in the Moorish gecko, *Tarentola mauritanica*. Gene 512(1): 166-173.

RATO C, HARRIS DJ, CARRANZA S, MACHADO L & PERERA A 2016. The taxonomy of the *Tarentola mauritanica* species complex (Gekkota: Phyllodactylidae): Bayesian species delimitation supports six candidate species. Mol Phylogenet Evol 94: 271-278.

RAXWORTHY CJ & SMITH BT. 2021. Mining museums for historical DNA: advances and challenges in museomics. Trends Ecol Evol 36(11): 1049-1060.

RIDDELL EA, IKNAYAN KJ, HARGROVE L, TREMOR S, PATTON JL, RAMIREZ R, WOLF BO & BEISSINGER SR. 2021. Exposure to climate change drives stability or collapse of desert mammal and bird communities. Science 371(6529): 633-636.

ROCHA LA ET AL. 2014. Specimen collection: An essential tool. Nature 344(6186): 814-815.

ROHWER VG, ROHWER Y & DILLMAN CB. 2022. Declining growth of natural history collections fails future generations. PLoS Biol 20(4): e3001613.

ROSA GM ET AL. 2022. Invasive fish disrupt host-pathogen dynamics leading to amphibian declines. Biol Conserv 276: 109785.

ROSSO A ET AL. 2017. Effectiveness of the Natura 2000 network in protecting Iberian endemic fauna. Anim Conserv 21: 262-271.

ROYCROFT E, MACDONALD AJ, MORITZ C, MOUSSALLI A, MIGUEZ RP & ROWE KC. 2021. Museum genomics reveals the rapid decline and extinction of Australian rodents since European settlement. Proc Natl Acad Sci USA 118(27): e2021390118.

SALVADOR RB & CUNHA CM. 2020. Natural history collections and the future legacy of ecological research. Oecologia 192: 641-646.

SAMPAIO F, HARRIS DH, PERERA A & SALVI D. 2014. Phylogenetic and diversity patterns of *Blanus* worm lizards (Squamata: Amphisbaenia): insights from mitochondrial and nuclear gene genealogies and species tree. J Zool Syst Evol Res 53(1): 45-54.

SANTANGELO JS, RIVKIN LR & JOHNSON MTJ. 2018. The evolution of city life. Proc Royal Soc B 285(1884): 20181529.

SANTOS X, RATO C, CARRANZA S, CARRETERO MA, DE LA VEGA JPG & PLEGUEZUELOS JM. 2012a. Morphology matches mtDNA lineages in the southern smooth snake (*Coronella girondica*) from Iberia. Zoology 115(6): 398-404.

SANTOS X, RATO C, CARRANZA S, CARRETERO MA & PLEGUEZUELOS JM. 2012b. Complex phylogeography in the Southern Smooth Snake *Coronella girondica* supported by mtDNA sequences. J Zool Syst Evol Res 50(3): 210-219.

SCHILLING A-K, MAZZAMUTO MV & ROMEO C. 2022. A Review of Non-Invasive Sampling in Wildlife Disease and Health Research: What's New? Animals (Basel) 12(13):1719.

SCHINDEL DE & COOK JA. 2018. The next generation of natural history collections. PLOS Biology 16(7): e2006125.

SEQUEIRA F, BESSA-SILVA A, TARROSO P, SOUSA-NEVES T, VALLINOTO M, GONÇALVES H & MARTÍNEZ-SOLANO I. 2019. Discordant patterns of introgression across a narrow hybrid zone between two cryptic lineages of an Iberian endemic newt. J Evol Biol 33(2): 202-216.

SHIREY V, BELITZ MW, BARVE V & GURALNICK R. 2021. A complete inventory of North American butterfly occurrence data:

narrowing data gaps, but increasing bias. Ecography 44:1-11.

SHULTZ AJ, ADAMS BJ, BELL KC, LUDT WB, PAULY GB & VENDETTI JE. 2020. Natural history collections are critical resources for contemporary and future studies of urban evolution. Evol Appl 14(1): 233-247.

SINGER RA, LOVE KJ & PAGE LM. 2018. A survey of digitized data from U.S. fish collections in the iDigBio data aggregator. PLoS ONE 13(12): e0207636.

SOROYE P, NEWBOLD T & KERR J. 2020. Climate change contributes to widespread declines among bumble bees across continents. Nature 367(6478): 685-688.

SOUSA M, ALMEIDA S, BENTO S, MAURÍCIO A, NEVES P, SAMPAIO M & REBELO R. 2021. Plano de erradicação de *Xenopus laevis* nas ribeiras do concelho de Oeiras. Relatório Ano XII (2021). ICNF/MO/cE3C (FCUL). Report no. R DCM /I-023636/2021.

SPEYBROECK J ET AL. 2020. Species list of the European herpetofauna - 2020 update by the Taxonomic Committee of the Societas Europaea Herpetologica. Amphib-Reptil 41(2): 139-189.

STÖHR AC, LÓPEZ-BUENO A, BLAHAK S, CAEIRO MF, ROSA GM, MATOS APA, MARTEL A, ALEJO A & MARSCHANG RE. 2015. Phylogeny and Differentiation of Reptilian and Amphibian Ranaviruses Detected in Europe. PLoS ONE 10(2): e0118633.

SVALBARD GLOBAL SEED VAULT. 2022. Svalbard Global Seed Vault - A site about seeds! Available at: https://www.seedvault.no, accessed on 3 February 2022.

THOMPSON CW ET AL. 2021. Preserve a Voucher Specimen! The Critical Need for Integrating Natural History Collections in Infectious Disease Studies. mBio 12(1): e02698-20.

THUMSOVÁ B, PRICE SJ, GONZÁLEZ-CASCÓN V, VÖRÖS J, MARTÍNEZ-SILVESTRE A, ROSA GM, MACHORDOM & BOSCH J. 2022. Climate warming triggers the emergence of native viruses in Iberian amphibians. iScience 25(12): 105541.

TROUDET J, VIGNES-LEBBE R, GRANDCOLAS P & LEGENDRE F. 2018. The Increasing Disconnection of Primary Biodiversity Data from Specimens: How Does It Happen and How to Handle It? Syst Biol 67(6): 1110-1119.

TURNEY S, CAMERON ER, CLOUTIER CA & BUDDLE CM. 2015. Non-repeatable science: assessing the frequency of voucher specimen deposition reveals that most arthropod research cannot be verified. PeerJ 3: e1168.

TWORT VG, MINET J, WHEAT CW & WAHLBERG N. 2021. Museomics of a rare taxon: placing Whalleyanidae in the Lepidoptera Tree of Life. Syst Entomol 46(4): 926-937.

UETZ P, FREED P, AGUILAR R, REYES F & HOŠEK J. 2022. The Reptile Database. Available at: http://www.reptile-database.org, accessed on 1 December 2022.

VENCES ET AL. 2014. New insights on phylogeography and distribution of painted frogs (*Discoglossus*) in northern Africa and the Iberian Peninsula. Amphib-Reptil 35(3): 305-320.

WEI JW, LEE BPY-H & WEN LB. 2016. Citizen Science and the Urban Ecology of Birds and Butterflies — A Systematic Review. PLoS ONE 11(6): e0156425.

ZEDANE L, HONG-WA C, MURIENNE J, JEZIORSKI C, BALDWIN BG, BESNARD G. 2015. Museomics illuminate the history of an extinct, paleoendemic plant lineage (Hesperelaea, Oleaceae) known from an 1875 collection from Guadalupe Island, Mexico. Biol J Linn Soc 117(1): 44-57.

ZIMOVA M, WEEKS BC, WILLARD DE, GIERY ST, JIRINEC V, BURNER RC, WINGER BM. 2023. Body size predicts the rate of contemporary morphological change in birds. Proc Natl Acad Sci USA 120(20): e2206971120.

How to cite

SANTOS BS, MARQUES MP & CERÍACO LMP. 2024. Lack of country-wide systematic herpetology collections in Portugal jeopardizes future research and conservation. An Acad Bras Cienc 96: e20230622. DOI 10.1590/0001-3765202420230622.

Manuscript received on May 31, 2023;
accepted for publication on August 27, 2023

BRUNA S. SANTOS[1,2,3]
https://orcid.org/0000-0002-3798-2664

MARIANA P. MARQUES[1,2,3,4]
https://orcid.org/0000-0002-1712-2632

LUIS M.P. CERÍACO[1,3,4,5,6]
https://orcid.org/0000-0002-0591-9978

[1]CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Campus de Vairão, 4485-661 Vairão, Portugal

[2]Universidade do Porto, Departamento de Biologia, Faculdade de Ciências, Rua do Campo Alegre 1021, 4169-007 Porto, Portugal

[3]BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Campus de Vairão, 4485-661, Vairão, Portugal

[4]Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, PA 15213, U.S.A.

[5]Universidade Federal do Rio de Janeiro, Departamento de Vertebrados, Museu Nacional, Quinta da Boavista, São Cristóvão, 20940-040 Rio de Janeiro, RJ, Brazil

[6]Departamento de Zoologia e Antropologia (Museu Bocage), Museu Nacional de História Natural e da Ciência, Rua da Escola Politécnica, 58, 1269-102 Lisboa, Portugal

Correspondence to: **Bruna S. Santos**
E-mail: brunascesantos@gmail.com

Author contributions

Bruna S. Santos and Luis M. P. Ceríaco led the conceptualization and methodology of the project. Bruna S. Santos performed formal analysis and data collection, while Mariana P. Marques and Luis M. P. Ceríaco contributed to data collection. All authors discussed the results, wrote the manuscript, and contributed to its final version.