

Article

Checklist of the Mammal Collection Preserved at the University of Palermo under the Framework of the National Biodiversity Future Center

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Abstract: The latest reorganization of the Vertebrate collections preserved at the “Pietro Doderlein” Museum of Zoology of the University of Palermo (Italy) has made it possible to draw up a check-list of the Mammal taxa present in the stuffed (M), fluid-preserved (ML) and anatomical (AN) collections. The intervention was planned under the National Biodiversity Future Center (NBFC) agenda, focused on the enhancement of Italian natural history museums. The growing interest in museum collections strongly demands databases available to the academic and policy world. In this paper, we record 679 specimens belonging to 157 specific taxa arranged in 58 families and 16 orders. Most of the species (75.1%) come from the Palaearctic Region (southern Mediterranean and North Africa), with a minority of taxa coming from the Afrotropical (7.8%), Neotropical (4.6%), Indo-Malayan (3.4%) and Australasian (1%) regions. Among the 24% of the taxa listed in the IUCN categories as threatened (VU, EN, CR, RE) the specimens of the Sicilian wolf, a regional endemic subspecies that became extinct in the last century, stand out. Even if small (<1000 specimens), the collection of mammals of the Museum of Zoology is an important asset for research on biodiversity in the Mediterranean area, representing an international reference for those wishing to conduct morphological and genetic studies in this area.

Keywords: natural history museum; zoological collections; collection-holding universities; mammalia; museomics; tissue repositories; biodiversity



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1. Introduction

Natural history museums are a source of public entertainment and are useful to observe and understand the richness of life around us. At the same time, they play a key role in supporting biodiversity and nature conservation-related research. The museum collections, often associated only with taxonomy, support the studies of a much wider range of topics that have practical applications for biodiversity conservation. They have a fundamental role in preserving the historical wildlife heritage of a region, mirroring its past and current biodiversity [1–3], and they enable researchers to track the genetic modification of species, in light of the anthropogenic impacts regarding habitat destruction and degradation. In addition, they can provide a spatiotemporal window into a broad range of research fields, such as taxonomy, anatomy, ecology, conservation, and public health [4].

The potential of natural history museums to serve as a large reservoir of historical/ancient DNA has long been recognized [4]. In fact, despite the degradation processes of biological material over time [5], methodological advances now allow us to obtain precious genetic inferences from degraded samples, such as the ones from museums and

archives [6–9]. In this context, museomics represents an emergent and promising field, which takes advantage of the potentiality of genomics, paleogenomics, and paleoproteomics applied to natural history museum specimens [10]. Therefore, every single museum sample can potentially preserve a genetic record, which can be useful to understand the evolutionary history of the species to which it belongs.

As many of the samples date to before the extreme biodiversity loss caused by anthropogenic drivers, we can generate baseline data for most of the endangered species, which can be compared to the current situation to quantify the human impact [11]. However, despite this enormous potential, the natural history collections remain largely unexplored and unused, mainly because updated and standardized taxonomic lists are still lacking. This situation hinders the formation of an open-access database that can be easily consulted online by all scientific institutions interested in wildlife biodiversity.

Italy is the most biodiverse country in Europe; as indicated in Italy's fifth national report to the convention on biological diversity 2009–2013, Italy hosts about 30% of the animals and 50% of the plants present on the continent, in an area that represents just 1/30 of the total. This condition is mainly due to habitat richness, the geographical position of the peninsula in the centre of the Mediterranean area, and the historical legacy of the Quaternary glaciations (e.g., [12]). Moreover, Italy has a high level of endemism; about 10% of the Italian mammal fauna is endemic [13,14].

The diversity and richness of species are mirrored in the big and small museums distributed throughout the country. Millions of specimens are stored in Italian museums and represent a highly valuable resource, available for research (e.g., [15,16]) and lifelong learning [1]. The rationalization and aggregation of this biological heritage in modern and usable repositories are prerequisites for the enhancement of the Italian natural history collections, still scattered and underutilized both in the country and in terms of dissemination and science teaching [1].

In this paper, we provide the inventory of all the mammal species preserved in the collection of the Museum of Zoology of the University of Palermo (hereafter MZPA), now named after its founder, professor Pietro Doderlein, established in Sicily, southern Italy, in 1863. Its collections, dating back to the time of activity (1863–1920) of the founder and his collaborators [1], have recently been re-evaluated. Specialists have given impetus to new research that has enriched the knowledge of the Mediterranean fauna through the study of old documents and specimens, such as the first historical evidence of the presence of the copper shark *Carcharinus brachyurus* in the Mediterranean Sea [17], the taxonomic validation of *Cerna sicana* (Doderlein, 1882), the specific name of a grouper described by Doderlein [18]; or through the molecular analysis of museum materials, like the description of a new genetically divergent wolf population, named *Canis lupus cristaldii* [19,20] or the identification of the geographical origin of a lion skeleton [1]. Further, previous works have examined and presented biological materials stored in the MZPA, such as the catalogues of the anatomical collection [21], the fish collection [22], the primate collection [23,24], the cetacean collection [25], and the raptor collection [26].

To follow this process of valorisation and public sharing of MZPA resources, we, for the first time, present here the inventory of mammalian species preserved in fluid or stuffed, and their anatomical parts. This constitutes a starting point to facilitate the use of museum collections of interest for researchers and may contribute to the interconnection of the institutions involved in the activities of the National Biodiversity Future Center (NBFC <https://www.nbfc.it/> accessed on 10 February 2023), geared toward the digitalization of natural history museum collections and the development of national information repositories.

2. Materials and Methods

The mammals present in the MZPA are preserved in three ways: the stuffed specimens collected in the Mammal collection (M), the fluid-preserved, mainly in ethanol, in the ML

collection, and the anatomical parts of the former specimens (or of others lost during the bombings of the Second World War) collected in the anatomical collection (AN).

The basic information for each piece shows the capture data (location and date, sex, age, etc.) together with the conditions of the specimens and the names of the collectors. In most cases, the primary data for historical specimens came from old notes, old books and manuscripts, or from handwritten labels; in other cases, they were missing. All the specific information for the individual pieces in the collection can be obtained upon request at museozoologia@unipa.it.

The work of taxonomic determination and labelling of the specimens carried out in the past years by the museum staff and by specific contributions [21,23–25] has been reviewed and updated to create the most complete inventory of the collection.

For each species, we provide the following information: scientific name and English common name, worldwide distribution, and risk of extinction. We also provide the type of collection (M = stuffed, ML = fluid-preserved, AN = anatomical) and the number of specimens per taxon.

We use the most updated and widely agreed upon taxonomical nomenclature (order, family, and species) as reported in [27–34].

As English common names, we adopt those provided in the IUCN red list (www.iucnredlist.org, accessed on 10 February 2023); the worldwide distribution is summarized in the biogeographical regions where the taxa occur and is mainly based on [27] and on the IUCN red list (www.iucnredlist.org, accessed on 10 February 2023). Finally, depending on the distribution of the taxon and the collection localities, we provide the extinction risk summarized by the IUCN categories, using the Italian Red List [35] and the European or global Red List (based on www.iucnredlist.org, accessed on 10 February 2023).

3. Results

The checklist of the Mammal collection at the MZPA is reported in Table 1 and includes 679 specimens, belonging to 16 orders, 58 families, and 157 specific taxa. Rodentia represents the most abundant order, with 36.7% of specimens, followed by the Carnivora (16.6%), the Soricomorpha (shrews, moles, and similar), with the 12.8%, and the Cetartiodactyla, which includes the former Cetacea and Artiodactyla, with the 10.3%. Altogether, these four orders comprise 76.4% of the specimens. Primates follow, with a remarkable 9.4%, and after come the 11 remaining orders. The latter are underrepresented, with the remaining 14% of specimens.

The specimens of 18 taxa in Table 1 are not identified to species level. Most are incomplete body parts or old stuffed specimens in poor condition. More than 30 other specimens are in even worse condition and are not listed in Table 1.

The collection is focused on Italian and southern Mediterranean fauna; it is not by chance that 75% of the specimens come from the Palaearctic. However, the collection holds a good number of mammals from distant regions (Figure 1), such as the Afrotropical (7.8%), Neotropical (5.7%), Indo-Malayan (3.4%), and even Australasian (1.0%). About 40 specimens are domestic taxa, and 11 belong to *Homo sapiens*.

Table 1. List of the species preserved in the Mammal collection at the Museum of Zoology “P. Doderlein”, University of Palermo, Italy. The specimens are stored in the stuffed and mounted (M), fluid-preserved (ML), and anatomical (AN) collections (AN* when skeletons or skeletal remains are present). REG = biogeographic region of specimen origin (PAL = Palaearctic, AFR = Afrotropical, IND = Indo-Malayan, NEA = Nearctic, NEOT = Neotropical, AUS = Australasian, DOM = domestic taxa), N = number of specimens per taxon, IUCN = Italian, European, or Global Red List category, depending from the specimen origin (LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered, CR = critically endangered, RE = regionally extinct, DD = data deficient, NA = not applicable). The Red List status for each taxon is evidenced with a colour (the footnote describes the association between colour and IUCN category).

Order	Family	Species	Authority	Common Name	REG	IUCN	N	Collection
Monotremata	Ornithorhynchidae	<i>Ornithorhynchus anatinus</i>	(Shaw, 1799)	Platypus	AUS	NT	2	M, AN*
Monotremata	Tachyglossidae	<i>Tachyglossus aculeatus</i>	(Shaw, 1792)	Short-beaked echidna	AUS	LC	1	AN*
Didelphimorphia	Didelphidae	<i>Marmosa murina</i>	(Linnaeus, 1758)	Linnaeus’s mouse opossum	NEOT	LC	2	M
Didelphimorphia	Didelphidae	<i>Chironectes minimus</i>	(Zimmermann, 1780)	Water opossum	NEOT	LC	1	M
Didelphimorphia	Didelphidae	<i>Didelphis marsupialis</i>	Linnaeus, 1758	Common opossum	NEA	LC	1	M
Diprotodontia	Macropodidae	<i>Osphranter rufus</i>	(Desmarest, 1822)	Red kangaroo	AUS	LC	1	M
Diprotodontia	Petauridae	<i>Petaurus breviceps</i>	Linnaeus, 1758	Sugar glider	AUS	LC	1	M
Diprotodontia	Phalangeridae	<i>Trichosurus vulpecula</i>	(Kerr, 1792)	Common brush-tailed possum	AUS	LC	1	M
Hyracoidea	Procaviidae	<i>Procavia capensis</i>	(Pallas, 1766)	Rock hyrax	PAL	LC	1	M
Cingulata	Dasypodidae	<i>Chaetophractus villosus</i>	(Desmarest, 1804)	Large hairy armadillo	PAL	LC	2	M, AN*
Cingulata	Dasypodidae	<i>Chaetophractus</i> sp.			NEOT		1	M
Cingulata	Dasypodidae	<i>Dasypus</i> sp.			NEOT		1	M
Pilosa	Choloepodidae	<i>Choloepus hoffmanni</i>	W. Peters, 1858	Hoffmann’s two-toed sloth	NEOT	LC	1	AN*
Primates	Atelidae	<i>Lagothrix lagothricha</i>	(Humboldt, 1812)	Brown woolly monkey	NEOT	VU	1	M
Primates	Atelidae	<i>Lagothrix</i> sp.			NEOT		1	M
Primates	Callitrichidae	<i>Callithrix penicillata</i>	(É. Geoffroy Saint-Hilaire, 1812)	Black-eared marmoset	NEOT	LC	1	M
Primates	Callitrichidae	<i>Callithrix</i> sp.			NEOT		1	M
Primates	Cebidae	<i>Leontopithecus rosalia</i>	(Linnaeus, 1766)	Golden lion tamarin	NEOT	EN	1	M
Primates	Cebidae	<i>Saimiri sciureus</i>	(Linnaeus, 1758)	Guianan squirrel monkey	NEOT	LC	1	M
Primates	Cebidae	<i>Sapajus apella</i>	(Linnaeus, 1758)	Black-capped capuchin	NEOT	LC	1	M
Primates	Cebidae	<i>Cebus capucinus</i>	(Humboldt, 1812)	Colombian white-faced capuchin	NEOT	VU	2	M
Primates	Cebidae	<i>Cebus</i> sp.			NEOT		2	M, AN
Primates	Cercopithecidae	<i>Chlorocebus aethiops</i>	Linnaeus, 1758	Grivet monkey	AFR	LC	2	M
Primates	Cercopithecidae	<i>Chlorocebus cynosuros</i>	(Scopoli, 1786)	Malbrouck monkey	AFR	LC	1	M
Primates	Cercopithecidae	<i>Chlorocebus sabaues</i>	(Linnaeus, 1766)	Green monkey	AFR	LC	3	AN
Primates	Cercopithecidae	<i>Chlorocebus</i> sp.			AFR		2	AN
Primates	Cercopithecidae	<i>Cephalophus</i> sp.			AFR		2	AN*
Primates	Cercopithecidae	<i>Cercopithecus</i> sp.			AFR		2	M

Table 1. Cont.

Order	Family	Species	Authority	Common Name	REG	IUCN	N	Collection
Primates	Cercopithecidae	<i>Colobus guereza</i>	Ruppell, 1835	Guereza coloon	AFR	LC	2	M
Primates	Cercopithecidae	<i>Macaca mulatta</i>	(Zimmermann, 1780)	Rhesus monkey	IND	LC	2	M, AN*
Primates	Cercopithecidae	<i>Macaca sylvanus</i>	(Linnaeus, 1758)	Barbary macaque	AFR	EN	5	M, AN*
Primates	Cercopithecidae	<i>Papio anubis</i>	(Lesson, 1827)	Olive baboon	AFR	LC	8	M, AN*
Primates	Cercopithecidae	<i>Papio</i> sp.			AFR		2	AN
Primates	Cercopithecidae	<i>Semnopithecus entellus</i>	(Dufresne, 1797)	Bengal gray langur	IND	LC	2	M
Primates	Hominidae	<i>Gorilla gorilla</i>	(Savage, 1847)	Western gorilla	AFR	CR	1	AN*
Primates	Hominidae	<i>Homo sapiens</i>	Linnaeus, 1758			NA	11	AN*
Primates	Hominidae	<i>Pan troglodytes</i>	(Blumenbach, 1775)	Chimpanzee	AFR	EN	3	M, AN*
Primates	Hominidae	<i>Pongo pygmaeus</i>	(Linnaeus, 1760)	Bornean orangutan	IND	CR	2	M, AN*
Primates	Lemuridae	<i>Eulemur coronatus</i>	(J.E. Gray, 1842)	Crowned lemur	AFR	EN	1	M
Primates	Lemuridae	<i>Eulemur rufus</i>	(Audebert, 1799)	Rufous brown lemur	AFR	VU	1	M
Primates	Lemuridae	<i>Eulemur</i> sp.			AFR		1	AN
Rodentia	Caviidae	<i>Hydrochoerus hydrochaeris</i>	(Linnaeus, 1766)	Capybara	NEOT	LC	2	M, AN*
Rodentia	Caviidae	<i>Cavia porcellus</i>	Pallas, 1766	Domestic guinea pig	DOM	NA	6	AN*
Rodentia	Caviidae	<i>Cavia aperea</i>	Erleben, 1777	Brazilian guinea pig	NEOT	LC	1	M
Rodentia	Chinchillidae	<i>Lagostomus maximus</i>	(Desharest, 1817)	Argentine plains viscacha	NEOT	LC	1	M
Rodentia	Cricetidae	<i>Arvicola amphibius</i>	(Linnaeus, 1758)	Water vole	PAL	NT	1	M
Rodentia	Cricetidae	<i>Lemmus lemmus</i>	(Linnaeus, 1758)	Norway lemming	PAL	LC	1	M
Rodentia	Cricetidae	<i>Microtus arvalis</i>	(Pallas, 1778)	Common vole	PAL	LC	2	M
Rodentia	Cricetidae	<i>Microtus nebrodensis</i>	(Minà-Palumbo, 1868)	Sicilian pine vole	PAL	LC	16	ML
Rodentia	Cricetidae	<i>Microtus savii</i>	(Selys-Longchamps, 1838)	Savi's pine vole	PAL	LC	4	M, ML, AN*
Rodentia	Cricetidae	<i>Cricetus cricetus</i>	(Linnaeus, 1758)	Common hamster	PAL	LC	1	M
Rodentia	Dipodidae	<i>Jaculus jaculus</i>	(Linnaeus, 1758)	Lesser egyptian jerboa	AFR	LC	3	M
Rodentia	Dipodidae	<i>Jaculus orientalis</i>	Erleben, 1777	Greater egyptian jerboa	PAL	LC	1	M
Rodentia	Geomyidae	<i>Geomys bursarius</i>	(Shaw, 1800)	Plains pocket gopher	NEA	LC	1	M
Rodentia	Gliridae	<i>Eliomys</i> sp.			PAL		1	AN
Rodentia	Gliridae	<i>Glis glis</i>	(Linnaeus, 1766)	Edible dormouse	PAL	LC	12	M, AN*
Rodentia	Gliridae	<i>Eliomys quercinus</i>	(Linnaeus, 1766)	Garden dormouse	PAL	NT	10	M, AN
Rodentia	Gliridae	<i>Muscardinus avellanarius</i>	(Linnaeus, 1758)	Hazel dormouse	PAL	LC	18	M, ML, AN*
Rodentia	Hystriidae	<i>Hystrix cristata</i>	Linnaeus, 1758	Crested porcupine	PAL	LC	17	M, AN*
Rodentia	Muridae	<i>Apodemus mystacinus</i>	(Danford and Alston, 1877)	Eastern broad-toothed field mouse	PAL	LC	1	ML
Rodentia	Muridae	<i>Apodemus sylvaticus</i>	(Linnaeus, 1758)	Wood mouse	PAL	LC	38	M, ML, AN

Table 1. Cont.

Order	Family	Species	Authority	Common Name	REG	IUCN	N	Collection
Rodentia	Muridae	<i>Hydromys chrysogaster</i>	Geoffroy, 1804	Australian water rat	AUS	LC	1	M
Rodentia	Muridae	<i>Mus domesticus</i>	Schwarz and Schwarz, 1943	House mouse	PAL	NA	79	M, ML
Rodentia	Muridae	<i>Mus musculus</i>	(Linnaeus, 1758)	House mouse	PAL	NA	1	M
Rodentia	Muridae	<i>Rattus norvegicus</i>	(Berkenhout, 1769)	Brown rat	PAL	NA	6	M, AN*
Rodentia	Muridae	<i>Rattus rattus</i>	(Linnaeus, 1758)	Black rat	PAL	NA	13	M, AN*
Rodentia	Myocastoridae	<i>Myocastor coypus</i>	(Molina, 1782)	Coypu	PAL	NA	3	AN
Rodentia	Sciuridae	<i>Marmota marmota</i>	(Linnaeus, 1758)	Alpine marmot	PAL	LC	2	M
Rodentia	Sciuridae	<i>Atlantoxerus getulus</i>	(Linnaeus, 1758)	Barbary ground squirrel	PAL	LC	1	M
Rodentia	Sciuridae	<i>Pteromys volans</i>	(Linnaeus, 1758)	Siberian flying squirrel	NEA	LC	1	M
Rodentia	Sciuridae	<i>Sciurus vulgaris</i>	Linnaeus, 1758	Eurasian red squirrel	PAL	LC	3	M, AN*
Rodentia	Sciuridae	<i>Spermophilus citellus</i>	(Linnaeus, 1766)	European souslik	PAL	EN	1	M
Rodentia	Spalacidae	<i>Spalax microphthalmus</i>	Guldenstaedt, 1770	Greater blind mole-rat	IND	LC	1	M
Erinaceomorpha	Erinaceidae	<i>Erinaceus europaeus</i>	Linnaeus, 1758	Western European hedgehog	PAL	LC	8	M, AN*
Lagomorpha	Leporidae	<i>Lepus corsicanus</i>	De Winton, 1898	Apennine hare or Italian hare	PAL	LC	7	M, AN*
Lagomorpha	Leporidae	<i>Oryctolagus cuniculus</i>	(Linnaeus, 1758)	European rabbit	PAL	NA	18	AN*
Soricomorpha	Soricidae	<i>Sorex</i> sp.			PAL		2	ML
Soricomorpha	Soricidae	<i>Suncus etruscus</i>	(Savi, 1822)	Etruscan shrew	PAL	LC	12	ML
Soricomorpha	Soricidae	<i>Crocidura canariensis</i>	Hutterer, López-Jurado, Vogel 1987	Canarian white-toothed shrew	PAL	EN	1	M
Soricomorpha	Soricidae	<i>Crocidura pachyura</i>	(Küster, 1835)	Mediterranean shrew	PAL	DD	26	M, AN
Soricomorpha	Soricidae	<i>Crocidura russula</i>	(Hermann, 1780)	Greater white-toothed shrew	PAL	LC	3	M, AN*
Soricomorpha	Soricidae	<i>Crocidura sicula</i>	Miller, 1901	Sicilian shrew	PAL	LC	29	M, ML, AN
Soricomorpha	Soricidae	<i>Crocidura</i> sp.			PAL		1	ML
Soricomorpha	Soricidae	<i>Crocidura suaveolens</i>	(Pallas, 1811)	Lesser shrew	PAL	LC	2	ML
Soricomorpha	Talpidae	<i>Talpa caeca</i>	Savi, 1822	Blind mole	PAL	DD	1	ML
Soricomorpha	Talpidae	<i>Talpa europaea</i>	Linnaeus, 1758	Common mole	PAL	LC	6	M, AN*
Soricomorpha	Talpidae	<i>Talpa</i> sp.			PAL		3	ML AN*
Soricomorpha	Talpidae	<i>Desmana moschata</i>	(Linnaeus, 1758)	Russian desman	PAL	VU	1	M
Chiroptera	Miniopteridae	<i>Miniopterus schreibersii</i>	(Kuhl, 1817)	Common bent-wing bat	PAL	VU	3	ML
Chiroptera	Molossidae	<i>Tadarida teniotis</i>	(Rafinesque, 1814)	European free-tailed bat	PAL	LC	3	M
Chiroptera	Phyllostomidae	<i>Vampyrum spectrum</i>	(Linnaeus, 1758)	Spectral bat	NEOT	NT	1	M
Chiroptera	Pteropodidae	<i>Pteropus vampyrus</i>	(Linnaeus, 1758)	Large flying fox	IND	EN	1	M
Chiroptera	Rhinolophidae	<i>Rhinolophus euryale</i>	Blasius, 1853	Mediterranean horseshoe bat	PAL	VU	1	AN
Chiroptera	Rhinolophidae	<i>Rhinolophus ferrumequinum</i>	(Schreber, 1774)	Greater horseshoe bat	PAL	VU	5	ML, AN*
Chiroptera	Rhinolophidae	<i>Rhinolophus hipposideros</i>	Bechstein, 1800	Lesser horseshoe bat	PAL	EN	1	M

Table 1. Cont.

Order	Family	Species	Authority	Common Name	REG	IUCN	N	Collection
Chiroptera	Vespertilionidae	<i>Myotis emarginatus</i>	(Geoffroy, 1806)	Geoffroy's bat	PAL	NT	1	M
Chiroptera	Vespertilionidae	<i>Myotis myotis</i>	(Borkhausen, 1797)	Greater mouse-eared bat	PAL	VU	11	M, AN*
Chiroptera	Vespertilionidae	<i>Pipistrellus kuhlii</i>	(Kuhl, 1817)	Kuhl's pipistrelle	PAL	LC	4	M, AN*
Chiroptera	Vespertilionidae	<i>Pipistrellus maderensis</i>	(Dobson, 1878)	Madeira pipistrelle	PAL	VU	1	M
Chiroptera	Vespertilionidae	<i>Pipistrellus pipistrellus</i>	(Schreber, 1774)	Common pipistrelle	PAL	LC	2	AN
Chiroptera	Vespertilionidae	<i>Pipistrellus</i> sp.			PAL		1	M
Chiroptera	Vespertilionidae	<i>Eptesicus serotinus</i>	(Schreber, 1774)	Serotine	PAL	NT	1	M
Chiroptera	Vespertilionidae	<i>Hypsugo savii</i>	(Bonaparte, 1837)	Savi's pipistrelle	PAL	LC	2	M, AN
Chiroptera	Vespertilionidae	<i>Nyctalus noctula</i>	(Schreber, 1774)	Common noctule	PAL	VU	2	M
Chiroptera	Vespertilionidae	<i>Plecotus auritus</i>	(Linnaeus, 1758)	Brown long-eared bat	PAL	NT	2	M
Pholidota	Manidae	<i>Manis javanica</i>	Desmarest, 1822	Sunda pangolin	IND	CR	2	M, AN*
Carnivora	Hyaenidae	<i>Hyaena hyaena</i>	(Linnaeus, 1758)	Striped hyaena	AFR	NT	3	M, AN*
Carnivora	Mephitidae	<i>Mephitis mephitis</i>	(Schreber, 1776)	Striped skunk	NEA	LC	1	M
Carnivora	Mephitidae	<i>Spilogale putorius</i>	(Linnaeus, 1758)	Eastern spotted skunk	NEOT	VU	1	M
Carnivora	Canidae	<i>Canis aureus</i>	Linnaeus, 1758	Golden jackal	AFR	LC	4	M, AN*
Carnivora	Canidae	<i>Canis familiaris</i>	Linnaeus, 1758	Dog	DOM	NA	11	AN*
Carnivora	Canidae	<i>Canis lupus cristaldii</i>	Angelici and Rossi, 2018	Sicilian wolf	PAL	RE	5	M, AN*
Carnivora	Canidae	<i>Vulpes vulpes</i>	(Linnaeus, 1758)	Red fox	PAL	LC	10	M, AN*
Carnivora	Felidae	<i>Panthera leo</i>	(Linnaeus, 1758)	Lion	AFR	VU	1	AN*
Carnivora	Felidae	<i>Felis catus</i>	Linnaeus, 1758	Cat	DOM	NA	7	AN*
Carnivora	Felidae	<i>Felis silvestris</i>	Schreber, 1777	European wild cat	PAL	NT	6	AN*
Carnivora	Felidae	<i>Leopardus pardalis</i>	(Linnaeus, 1758)	Ocelot	NEOT	LC	3	M, AN
Carnivora	Herpestidae	<i>Herpestes ichneumon</i>	Linnaeus, 1758	Egyptian mongoose	PAL	LC	7	M, AN*
Carnivora	Mustelidae	<i>Martes foina</i>	(Erxleben, 1777)	Stone marten or Beech marten	PAL	LC	3	M
Carnivora	Mustelidae	<i>Martes martes</i>	(Linnaeus, 1758)	Pine marten	PAL	LC	11	M, AN*
Carnivora	Mustelidae	<i>Martes</i> sp.			PAL		1	AN
Carnivora	Mustelidae	<i>Meles meles</i>	(Linnaeus, 1758)	European badger	PAL	LC	2	M
Carnivora	Mustelidae	<i>Mustela erminea</i>	(Linnaeus, 1758)	Stoat	PAL	LC	4	M
Carnivora	Mustelidae	<i>Mustela nivalis</i>	(Linnaeus, 1758)	Least weasel	PAL	LC	13	M, AN*
Carnivora	Mustelidae	<i>Mustela putorius</i>	(Linnaeus, 1758)	European polecat	PAL	LC	3	M, AN
Carnivora	Mustelidae	<i>Galictis vittata</i>	(Schreber, 1776)	Greater grison	NEA	LC	1	M
Carnivora	Mustelidae	<i>Lutra lutra</i>	(Linnaeus, 1758)	Eurasian otter	PAL	EN	1	M
Carnivora	Phocidae	<i>Pusa caspica</i>	Gmelin, 1788	Caspian seal	IND	EN	1	M
Carnivora	Phocidae	<i>Monachus monachus</i>	Hermann, 1779	Mediterranean monk seal	PAL	DD	2	AN*
Carnivora	Procyonidae	<i>Nasua</i> sp.			NEOT		2	M, AN

Table 1. Cont.

Order	Family	Species	Authority	Common Name	REG	IUCN	N	Collection
Carnivora	Procyonidae	<i>Procyon lotor</i>	(Linnaeus, 1758)	Northern raccoon	NEOT	LC	1	M
Carnivora	Ursidae	<i>Helarctos malayanus</i>	(Raffles, 1821)	Sun bear	IND	VU	4	M, AN*
Carnivora	Ursidae	<i>Melursus ursinus</i>	(Shaw, 1791)	Sloth bear	IND	VU	3	M, AN*
Carnivora	Viverridae	<i>Arctictis binturong</i>	(Raffles, 1821)	Binturong or Bearcat	IND	VU	1	M
Carnivora	Viverridae	<i>Genetta genetta</i>	(Linnaeus, 1758)	Common genet	PAL	LC	1	M
Perissodactyla	Equidae	<i>Equus caballus</i>	Linnaeus, 1758	Horse	PAL	NA	3	AN*
Cetartiodactyla	Balaenopteridae	<i>Balaenoptera physalus</i>	(Linnaeus, 1758)	Fin whale	PAL	VU	1	AN*
Cetartiodactyla	Bovidae	<i>Bos taurus</i>	Linnaeus, 1758	Cattle	DOM	NA	2	AN*
Cetartiodactyla	Bovidae	<i>Boselaphus tragocamelus</i>	(Pallas, 1766)	Nilgai	IND	LC	2	M
Cetartiodactyla	Bovidae	<i>Gazella dorcas</i>	(Linnaeus, 1758)	Dorcas gazelle	AFR	VU	4	M, AN*
Cetartiodactyla	Bovidae	<i>Oreotragus oreotragus</i>	(Zimmermann, 1783)	Klipspringer	AFR	LC	2	M, AN*
Cetartiodactyla	Bovidae	<i>Ovis aries</i>	Linnaeus, 1758	European mouflon	PAL	NA	2	M, AN
Cetartiodactyla	Bovidae	<i>Antilope cervicapra</i>	(Linnaeus, 1758)	Blackbuck	IND	LC	1	M
Cetartiodactyla	Bovidae	<i>Capra hircus</i>	Linnaeus, 1758	Domestic goat	DOM	NA	9	M, AN*
Cetartiodactyla	Bovidae	<i>Hemitragus jemlahicus</i>	(C.H. Smith, 1826)	Himalayan tahr	IND	NT	1	AN
Cetartiodactyla	Camelidae	<i>Camelus dromedarius</i>	Linnaeus, 1758	Dromedary	DOM	NA	3	AN
Cetartiodactyla	Camelidae	<i>Lama glama</i>	(Linnaeus, 1758)	Lama	DOM	NA	1	M
Cetartiodactyla	Cervidae	<i>Cervus</i> sp.			PAL		2	AN*
Cetartiodactyla	Cervidae	<i>Ozotoceros bezoarticus</i>	(Linnaeus, 1758)	Pampas deer	NEOT	NT	2	M
Cetartiodactyla	Cervidae	<i>Dama dama</i>	(Linnaeus, 1758)	Fallow deer	PAL	LC	7	M, AN*
Cetartiodactyla	Delphinidae	<i>Delphinus delphis</i>	Linnaeus, 1758	Common dolphin	PAL	EN	8	M, AN*
Cetartiodactyla	Delphinidae	<i>Grampus griseus</i>	(G. Cuvier, 1812)	Risso's dolphin	PAL	DD	3	AN*
Cetartiodactyla	Delphinidae	<i>Stenella coeruleoalba</i>	(Meyen, 1833)	Striped dolphin	PAL	LC	2	AN*
Cetartiodactyla	Delphinidae	<i>Tursiops truncatus</i>	(Montagu, 1821)	Common bottlenose dolphin	PAL	LC	4	AN*
Cetartiodactyla	Monodontidae	<i>Monodon monoceros</i>	Linnaeus, 1758	Narwhal	PAL	LC	2	AN*
Cetartiodactyla	Physeteridae	<i>Physeter macrocephalus</i>	Linnaeus, 1758	Sperm whale	PAL	EN	3	AN*
Cetartiodactyla	Suidae	<i>Sus scrofa</i>	(Linnaeus, 1758)	Wild boar	PAL	LC	9	M, AN*

Association colour and IUCN category: LC, green, NT light green, VU yellow, EN orange, CR red, RE violet.



(a)



(b)

Figure 1. Some characteristic specimens of the Mammal collection at the Museum of Zoology “P. Doderlein”, University of Palermo, Italy. The stuffed and mounted Golden lion tamarin *Leontopithecus rosalia* (a) and Sicilian wolf *Canis lupus cristaldii* (b) from the original nucleus of the Doderlein era.

About 24% of the 139 taxa classified in the IUCN red lists have an unfavourable conservation status (VU, EN, CR, RE). Among these are the two apes (*Pongo pygmaeus*, *Gorilla gorilla*) and the Sunda pangolin (*Manis javanica*), classified as critically endangered (CR), and the regionally extinct (RE) Sicilian wolf (*Canis lupus cristaldii*) (Figure 1). The five specimens (2 M, 3 AN) of the latter taxon are among the most notable local taxa in the Mammal collection.

4. Discussion

Museum material can represent an important resource for biodiversity conservation, because zoological collections are the main non-living archive of animal genomes on Earth; the investigation of such collections can help to understand the dynamics of the decline of entire animal groups and the importance of the biodiversity crisis for human and non-human prosperity [36]. In addition to their research potential, museum collections also

have a strong impact on the education and dissemination of environmental protection topics to the general public.

The Mediterranean basin is an exceptional hotspot of biodiversity and regional endemisms, with a complex and multifaceted geological history that shaped the biogeographical evolution of the mammalian fauna, particularly in the islands [37]. Sicily, the largest island in the Mediterranean Sea, represents an interesting context for the study of modern Mediterranean mammalian species. In fact, the island is attested to have been connected to the Italian peninsula for the last time through a land bridge that disappeared between 17,000 and 25,000 years ago [38]. This favoured the penetration of man and a new stock of mammals, causing the replacement of the previous fauna. The complex history of extinctions and new waves of colonization over the last 10,000 years, together with the action of man on the habitats, has shaped the peculiar community of mammals on the island [39].

For this reason, Sicily and, consequently, the Sicilian Museum collections can be recognized as a significant source of genetic data for the conservation of biodiversity and for reconstructing the history of the populations of mammalian species on the island and throughout the Mediterranean. To date, the continuous phylogeographic investigations of Sicilian mammals have revealed the marked genetic footprint of this fauna, thus leading to the description of endemic species, like the Sicilian pine vole, *Microtus nebrodensis* (Minà-Palumbo, 1868) [40]; or distinct haplogroups (e.g., *Apodemus sylvaticus* [41]; *Muscardinus avellanarius* [42]; *Martes martes* [43]), which offer an intriguing history of fauna colonization during the Quaternary up to more recent historical times.

Most likely, the Sicilian wolf summarizes the value of historical collections of the MZPA in the light of museomics, an emerging field in Italy [1]. This predator, present in Sicily with a rich fossil record since the upper Pleistocene, represented the only Mediterranean island population of this species before it was extirpated by humans at the beginning of the 19th century. The Sicilian wolf became extinct, leaving few documents and less than a dozen museum exhibits [44]. Half of these, which also include the paratype (a mounted adult male labelled M18) of *Canis lupus cristaldii* [19], have been preserved thanks to the presence of the MZPA collections. The results of the morphological and molecular analysis of historical DNA assigned it to the new subspecies *C. l. cristaldii* [19,20] and show a complex history of long-term isolation and admixture with ancient dogs [2]. Furthermore, the wolf is a charismatic species [45] in public perception and could be useful for targeting conservation campaigns and biodiversity erosion.

Regarding the whole collection of specimens housed in the MZPA, two main groups can be identified, with the first nucleus formed by mounted, stuffed specimens and anatomical parts dating back to the Doderlein era. Most of the Italian specimens from Modena (northern Italy), the former university chair of P. Doderlein, and from the Neotropical, Australasian and other distant biogeographical regions are found in this nucleus.

The second nucleus, mostly fluid-preserved and stored in jars, comes from collections from 1980–2020, collected during field expeditions to investigate the systematics and phylogeography of Mediterranean soricomorphs, mostly *Crocidura* shrews (cf. [46–48]) and *Talpa* moles, Muridae rodents [41], and Gliridae dormice (*Glis glis*: cf. [49–51] and *Muscardinus avellanarius*: [42,52]).

In this context, there is also an urgent need for the research community to adopt best practices and standardized protocols acquired by the historical/ancient DNA field, in order to justify the partial destruction of samples and to maximize results. Thus, while museomics can be a powerful tool, it should be undertaken with caution and accuracy by scholars with specialized skills to understand the extent of the technical challenges related to the conservation of the genetic material and evaluate the feasibility and the opportunity of the study [5].

Furthermore, for all the above reasons, it is clear that the checklist is the necessary baseline to implement future studies on mammalian diversity not only in Italy and in the Mediterranean area, but also globally. For example, the series of extra-Palaearctic specimens,

such as the Cebid monkeys collected in Doderlein's time, could be usefully employed in systematic reviews such as the latest papers, cf. [53].

In conclusion, this paper represents a contribution to the enhancement of the biological heritage contained in the MZPA, thus initiating the necessary process of interconnection between the institutions involved in the activities of the National Biodiversity Future Center. The collection could grow with the addition of new specimens in the future, as NBFC has planned monitoring activities and Citizen Science initiatives; further private collections are expected to be donated instead of being discarded by the successors of the amateurs who collected specimens in the past.

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