

Which mammal species can I see at the zoo? A first analysis of mammal collections of Italian licensed zoological gardens

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Abstract

Zoological gardens (*sensu lato*) are among the institutions which manage to better connect the general public with biodiversity as every year they receive millions of visitors. This study consists of an analysis of the mammalian collections of 26 Italian zoos which have been granted a zoo license according to the Legislative Decree DL73/2005. In our study, we also took into account the EAZA (European Association of Zoos and Aquaria) membership of the institutions, the biogeographical realms and the IUCN Red List Category of the different species. Italian zoos keep 221 mammalian species belonging to 16 orders out of 29. EAZA zoos keep 159 species belonging to 14 orders while non-EAZA zoos keep 154 species belonging to 12 orders. Nearly three quarters of the species belong to either the Artiodactyla, Carnivora, or Primates orders. Rodentia represent nearly 11% of the species, Perissodactyla 3.17%, while the other orders represent 8.57% of the species. No species belonging to Lagomorpha and Soricomorpha is kept in EAZA zoos, while no Hyracoidea, Cingulata, Erinaceomorpha, and Sirenia are kept in non-EAZA zoos. More threatened species (*sensu* IUCN) are kept in EAZA zoos than in non-EAZA ones (36.60% vs 27.21%). Australasian and Palearctic Realms are the least represented ones. Non-EAZA zoos in Italy play a significant role regarding species diversity and their Red List Category.

KEYWORDS: EAZA / Italy / IUCN Red List Category / Mammals / Zoological gardens

Riassunto

Quali mammiferi posso vedere allo zoo? Una prima analisi delle collezioni di mammiferi dei giardini zoologici italiani licenziati

Con diversi milioni di visitatori annui, i giardini zoologici (in senso lato) rappresentano le istituzioni che maggiormente possono consentire alla popolazione di conoscere la biodiversità planetaria. In questo lavoro viene presentata una prima analisi delle specie di mammiferi presenti in 26 strutture zoologiche italiane licenziate secondo il DL73/2005. Si è considerata anche l'appartenenza della struttura all'EAZA (European Association Zoos and Aquaria), la regione biogeografica di appartenenza e lo status IUCN di ogni specie. In Italia risultano presenti 221 specie appartenenti a 16 ordini su 29. Gli zoo EAZA ospitano 159 specie appartenenti a 14 ordini; gli altri 154 specie in 12 ordini. Quasi tre quarti delle specie appartengono agli ordini Carnivora, Primates e Artiodactyla. Membri dell'ordine Rodentia rappresentano quasi l'11% del totale, i Perissodactyla il 3,17% mentre l'8,57% è rappresentato dagli altri ordini. Gli zoo EAZA non ospitano specie di Lagomorpha e Soricomorpha, mentre i non-EAZA non presentano specie di Hyracoidea, Cingulata, Erinaceomorpha e Sirenia. Gli zoo EAZA presentano una maggiore percentuale di specie a rischio secondo i criteri IUCN che i non-EAZA (36,60% vs 27,21%). Le Regioni Neartica e Australasia sono quelle meno rappresentate. Il contributo delle strutture non-EAZA in Italia appare tutt'altro che marginale sia per diversità di specie che loro grado di minaccia.

PAROLE CHIAVE: categoria di minaccia IUCN / EAZA / Giardini Zoologici / Italia / Mammiferi

INTRODUCTION

The last two decades of the 20th Century saw a growing radical critique of zoological gardens in Italy, leading to the closure of several municipal institutions in urban areas (Gippoliti, 2000). In 2005 Italy finally passed a specific zoo legislation (DL 73/2005) by

accepting the Directive 1999/22 EC (Zoo Directive) and thus establishing a legal definition of 'zoo' and a national licensing system. In 2007 it was reported that Italian zoos and aquariums were visited approximately by 12 million of visitors every year (Costa, 2007),

although the current number of yearly visitors could range between 8 and 10 million. However, relatively little is known about Italian zoological gardens, their collections, and their educational and scientific activities (see Gippoliti, 2021).

Here we present a first assessment of the mammal collection in Italian licensed zoos. Our goal was to describe the current situation (end of 2021), to compare it with the few available historical data, and to assess if differences exist between zoos that are members of EAZA and non-EAZA zoos. EAZA (European Association of Zoos and Aquaria) is an organization whose aim is to facilitate cooperation within the European zoo and aquarium community towards the goals of education, research and conservation⁽¹⁾. Membership is provided through the achievement and maintenance of high standards and breeding of threatened species kept in the zoos. Thus, its members are more involved with continental coordinated breeding programs than non-members. Finally, we evaluated if mammal diversity is exhibited in an unbiased way both taxonomically and geographically or, as is common also elsewhere (Gusset *et al.*, 2014), some taxonomic groups are more present than others.

(1) <https://www.eaza.net/>

MATERIALS AND METHODS

We compiled a list of the mammalian species kept by Italian facilities, including aquariums and marine parks, which have been granted the “Licenza Zoo” by the Ministry of Ecological Transition as of 31st December 2021^(2,3). We gathered data from 26 of such institutions known to held mammals (Tab. I). Data were retrieved from the species list and the maps found on the website of each facility on 31st December 2021. For Zoosafari Fasanolandia we used a checklist provided by Dr. Fabio Rausa as the website did not feature a complete list of animals. For Oasi degli animali, Zoomarine, Oltremare, Acquario di Genova, and Acquario di Cattolica we used species listed on the Zootierliste database as no comprehensive species list was available on the website. As a taxonomic reference work, we followed Wilson and Reeder (2005). No subspecies was reported. When only a generic name was found on the website (i.e. gibbon) we reported the species listed on the website Zootierliste⁽⁴⁾. Also domesticated species such as *Bos grunniens* (Linnaeus, 1766), *Bubalus bubalis* (Linnaeus, 1758), *Ovis aries musimon* (Pallas, 1811), *Lama glama* (Linnaeus, 1758), *Vicunia pacos* (Linnaeus, 1758), *Camelus*

(2) <https://www.mite.gov.it>

(3) <https://www.gazzettaufficiale>

(4) <https://www.zootierliste.de>

Tab. I. List of Italian licensed zoological institutions used for our study. For each structure we listed the number of kept orders, families, genera and species. The EAZA membership status was also listed.

Zoo	Orders	Families	Genera	Species	EAZA-member
Zoomarine	4	5	8	8	Yes
Parco Zoo Punta Verde	8	20	27	32	Yes
Parco Faunistico Le Cornelle	8	22	33	40	Yes
Acquario di Genova	3	3	3	3	Yes
Giardino Zoologico di Pistoia	8	24	26	27	Yes
Parco Zoo di Falconara	5	17	24	26	Yes
Parco Faunistico La Torbiera	6	10	24	27	Yes
Parco Natura Viva	8	28	48	59	Yes
Parco faunistico Cappeller	8	23	36	41	No
Safari Park Ravenna	9	22	42	46	No
Bioparco di Roma	8	26	45	50	Yes
Parco faunistico Valcorba	6	16	33	40	Yes
Bioparco di Sicilia	6	15	19	19	No
Safari Park Pombia	6	12	20	23	No
Zoom Torino	5	14	24	26	Yes
Acquario di Cattolica “Le Navi”	1	1	1	1	No
Parco Zoo della fauna europea di Poppi	5	15	25	25	No
Zoo delle Maitine	8	21	26	27	Yes (temporary)
Oltremare	3	3	3	3	No
Parco Safari delle Langhe	6	15	21	22	No
Zoo di Napoli	7	25	39	45	No
Bioparco Gallorose	7	18	28	33	No
Parco Faunistico di Spormaggiore	2	5	7	7	No
Oasi degli animali	5	14	23	24	No
Zoosafari Fasanolandia	6	20	44	53	No
Zoo d’Abruzzo	7	14	14	14	No

bactrianus (Linnaeus, 1758), and *Camelus dromedarius* (Linnaeus, 1758) were included.

For every species, we reported the number of zoos in which it is kept, the IUCN Red List Category, and the biogeographical realms according to Udvardy (1975) derived from IUCN geographic ranges⁽⁵⁾. As some species are distributed across more than one biogeographical realm, we assigned all the biogeographical realms to these species. Aquatic species such as *Tursiops truncatus* (Montagu, 1821) and *Trichechus manatus* (Linnaeus, 1758) were not assigned to biogeographical regions. We also took into account the difference between zoos with and without EAZA membership⁽⁶⁾. We investigated how different orders, IUCN Red List Categories and biogeographical realms are represented in Italian zoos according to their EAZA membership status. We carried out a chi-squared test in order to investigate whether species frequencies in Italian zoos

(5) <https://www.iucnredlist.org/>

(6) <https://www.gazzettaufficiale>

(4) <https://www.zootierliste.de>

broken down by respective orders, Red List Categories and biogeographical realms significantly differ according to EAZA membership. We assumed independence between frequencies and EAZA membership as the null hypothesis; P-value was set at 0.05. We used the function chisq.test of package stats v. 4.0.5 on R v. 4.0.5 (R Core Team, 2021). Furthermore, we investigated at family level the orders which constitute the majority of mammals kept in Italian zoos. In this instance we calculated how much each family is represented by the collections of Italian zoos. We then carried out a chi-squared test to investigate whether families' distribution per order significantly differs between EAZA and Non-EAZA zoos.

RESULTS

221 mammalian species belonging to 16 orders are kept in Italian zoological gardens (Tab. II). Among these, 159 species belonging to 14 orders are kept in zoos with EAZA membership while 154 species belonging to 12 orders are kept in zoos without EAZA membership. Of these species, 213 have been assessed by the IUCN.

Tab II. List of all mammalian species kept in Italian Zoos. For each species we listed the number of zoos that keeps it (also accounting for EAZA membership), the IUCN Red List Categories, and the biogeographical realms. Abbreviations read as it follows: "Ord. and Fam": order and families (with the first in **bold**); "Afr": "Afrotropical", "Aust.": "Australasian". "Indo": "Indomalayan", "Near.": "Nearctic", "Neot.": "Neotropical", "Pal.": "Palearctic",

Ord. and Fam.	Species	Zoo	Eaza	n-Eaza	IUCN	Realms
Artiodactyla						
Bovidae	<i>Addax nasomaculatus</i> de Blainville, 1816	4	2	2	CR	Afr.
	<i>Aepyceros melampus</i> Lichtenstein, 1812	1	1	-	LC	Afr.
	<i>Ammotragus lervia</i> Pallas, 1777	4	-	4	VU	Pal. Afr.
	<i>Antidorcas marsupialis</i> Zimmermann, 1780	1	1	-	LC	Afr.
	<i>Antilope cervicapra</i> Linnaeus, 1758	8	3	5	LC	Ind.
	<i>Bison bison</i> Linnaeus, 1758	5	-	5	NT	Near.
	<i>Bison bonasus</i> Linnaeus, 1758	1	1	-	NT	Pal.
	<i>Bos gaurus</i> C.H. Smith, 1827	1	-	1	VU	Ind.
	<i>Bos grunniens</i> Linnaeus, 1766	2	-	2	-	Pal.
	<i>Bos javanicus</i> d'Alton, 1823	1	1	-	EN	Ind.
	<i>Boselaphus tragocamelus</i> Pallas, 1766	1	-	1	LC	Ind.
	<i>Bubalus bubalis</i> Linnaeus, 1758	1	-	1	-	Ind.
	<i>Capra falconeri</i> Wagner, 1839	1	1	-	NT	Pal. Ind.
	<i>Capra ibex</i> Linnaeus, 1758	1	-	1	LC	Pal.
	<i>Connochaetes taurinus</i> Burchell, 1824	7	3	4	LC	Afr.
	<i>Damaliscus pygargus</i> Pallas, 1767	2	2	-	LC	Afr.
	<i>Eudorcas thomsonii</i> Günther, 1884	1	1	-	LC	Afr.
	<i>Hemitragus jemlahicus</i> C.H. Smith, 1826	2	2	-	NT	Pal. Ind.
	<i>Hippotragus equinus</i> É. Geoffroy Saint-Hilaire, 1803	3	1	2	LC	Afr.
	<i>Hippotragus niger</i> Harris, 1838	1	-	1	LC	Afr.
	<i>Kobus ellipsiprymnus</i> Ogilby, 1833	4	2	2	LC	Afr.
	<i>Kobus leche</i> Gray, 1850	5	3	2	NT	Afr.

Ord. and Fam.	Species	Zoo	Eaza	n-Eaza	IUCN	Realms
	<i>Kobus megaceros</i> Fitzinger, 1855	10	3	7	EN	Afr.
	<i>Madoqua kirkii</i> Günther, 1880	2	-	2	LC	Afr.
	<i>Nanger dama</i> Pallas, 1766	3	2	1	CR	Afr.
	<i>Oryx dammah</i> Cretzschmar, 1827	6	4	2	EW	Afr.
	<i>Oryx gazella</i> Linnaeus, 1758	1	1	-	LC	Afr.
	<i>Oryx leucoryx</i> Pallas, 1777	1	1	-	VU	Afr. Pal.
	<i>Ovis aries musimon</i> Pallas, 1811	4	1	3		Pal.
	<i>Pseudois nayaur</i> Hodgson, 1833	1	-	1	LC	Pal.
	<i>Rupicapra rupicapra</i> Linnaeus, 1758	1	-	1	LC	Pal.
	<i>Syncerus caffer</i> Sparrman, 1779	2	-	2	NT	Afr.
	<i>Taurotragus oryx</i> Pallas, 1766	7	3	4	LC	Afr.
	<i>Tragelaphus angasii</i> Angas, 1848	4	3	1	LC	Afr.
	<i>Tragelaphus eurycerus</i> Ogilby, 1836	1	1	-	NT	Afr.
	<i>Tragelaphus imberbis</i> Blyth, 1869	1	-	1	NT	Afr.
	<i>Tragelaphus spekii</i> Speke, 1863	6	4	2	LC	Afr.
Camelidae	<i>Camelus bactrianus</i> Linnaeus, 1758	14	8	6	-	Pal.
	<i>Camelus dromedarius</i> Linnaeus, 1758	3	1	2	-	Pal.
	<i>Lama glama</i> Linnaeus, 1758	8	2	6	-	Neot.
	<i>Lama guanicoe</i> Müller, 1776	4	1	3	LC	Neot.
	<i>Vicugna pacos</i> Linnaeus, 1758	10	4	6	-	Neot.
	<i>Vicugna vicugna</i> Molina, 1782	2	1	1	LC	Neot.
Cervidae	<i>Axis axis</i> Erxleben, 1777	7	2	5	LC	Ind.
	<i>Axis porcinus</i> Zimmermann, 1780	1	1	-	EN	Ind.
	<i>Capreolus capreolus</i> Linnaeus, 1758	2	-	2	LC	Pal.
	<i>Cervus elaphus</i> Linnaeus, 1758	6	1	5	LC	Pal.
	<i>Cervus nippon</i> Temminck, 1838	2	1	1	LC	Pal.
	<i>Dama dama</i> Linnaeus, 1758	9	2	7	LC	Pal.
	<i>Muntiacus reevesi</i> Ogilby, 1838	6	4	2	LC	Pal. Ind.
	<i>Rangifer tarandus</i> Linnaeus, 1758	2	2	-	VU	Near. Pal.
	<i>Rusa alfredi</i> P.L. Sclater, 1870	1	1	-	EN	Ind.
Giraffidae	<i>Giraffa camelopardalis</i> Linnaeus, 1758	14	9	5	VU	Afr.
	<i>Okapia johnstoni</i> P.L. Sclater, 1901	1	1	-	EN	Afr.
Hippopotamidae	<i>Choeropsis liberiensis</i> Morton, 1849	4	3	1	EN	Afr.
	<i>Hippopotamus amphibius</i> Linnaeus, 1758	13	7	6	VU	Afr.
Suidae	<i>Potamochoerus porcus</i> Linnaeus, 1758	3	3	-	LC	Afr.
	<i>Sus scrofa</i> Linnaeus, 1758	2	-	2	LC	Pal. Ind.
Carnivora						
Ailuridae	<i>Ailurus fulgens</i> F.G. Cuvier, 1825	6	6	-	EN	Pal.
Canidae	<i>Alopex lagopus</i> Linnaeus, 1758	1	-	1	LC	Near. Pal.
	<i>Canis lupus</i> Linnaeus, 1758	7	4	3	LC	Pal. Near.
	<i>Chrysocyon brachyurus</i> Illiger, 1815	4	3	1	NT	Neot.
	<i>Lycaon pictus</i> Temminck, 1820	1	1	-	EN	Afr.
	<i>Nyctereutes procyonoides</i> Gray, 1834	4	2	2	LC	Pal.

Ord. and Fam.	Species	Zoo	Eaza	n-Eaza	IUCN	Realms
	<i>Otocyon megalotis</i> Desmarest, 1822	1	1	-	LC	Afr.
	<i>Vulpes vulpes</i> Linnaeus, 1758	4	-	4	LC	Pal.
	<i>Vulpes zerda</i> Zimmermann, 1780	2	1	1	LC	Afr.
Eupleridae	<i>Cryptoprocta ferox</i> Bennett, 1833	2	1	1	VU	Afr.
Felidae	<i>Acinonyx jubatus</i> Schreber, 1775	6	5	1	VU	Afr.
	<i>Caracal caracal</i> Schreber, 1776	4	2	2	LC	Afr. Pal.
	<i>Felis chaus</i> Schreber, 1777	1	-	1	LC	Afr. Pal. Ind.
	<i>Felis silvestris</i> Schreber, 1777	2	1	1	LC	Pal.
	<i>Herpailurus yagouaroundi</i> Saint-Hilaire, 1803	1	-	1	LC	Neot.
	<i>Leopardus geoffroyi</i> d'Orbigny & Gervais, 1844	1	1	-	LC	Neot.
	<i>Leopardus pardalis</i> Linnaeus, 1758	4	3	1	LC	Neot.
	<i>Leptailurus serval</i> Schreber, 1776	4	1	3	LC	Afr.
	<i>Lynx lynx</i> Linnaeus, 1758	9	4	5	LC	Pal.
	<i>Lynx rufus</i> Schreber, 1777	1	-	1	LC	Near.
	<i>Neofelis nebulosa</i> Griffith, 1821	2	2	-	VU	Ind.
	<i>Otocolobus manul</i> Pallas, 1776	1	1	-	LC	Pal.
	<i>Panthera leo</i> Linnaeus, 1758	14	8	6	VU	Afr. Ind.
	<i>Panthera onca</i> Linnaeus, 1758	2	-	2	NT	Neot.
	<i>Panthera pardus</i> Linnaeus, 1758	8	6	2	VU	Afr. Ind. Pal.
	<i>Panthera tigris</i> Linnaeus, 1758	13	8	5	EN	Ind. Pal.
	<i>Panthera uncia</i> Schreber, 1775	4	4	-	VU	Pal.
	<i>Prionailurus bengalensis</i> Kerr, 1792	1	1	-	LC	Pal. Ind.
	<i>Prionailurus viverrinus</i> Bennett, 1833	1	1	-	VU	Ind.
	<i>Puma concolor</i> Linnaeus, 1771	4	4	-	LC	Near. Neot.
Herpestidae	<i>Cynictis penicillata</i> G. Cuvier, 1829	4	1	3	LC	Afr.
	<i>Helogale parvula</i> Sundevall, 1846	1	-	1	LC	Afr.
	<i>Herpestes ichneumon</i> Linnaeus, 1758	1	-	1	LC	Afr. Pal.
	<i>Mungos mungo</i> Gmelin, 1788	1	-	1	LC	Afr.
	<i>Suricata suricatta</i> Schreber, 1776	13	8	5	LC	Afr.
Hyaenidae	<i>Crocuta crocuta</i> Erxleben, 1777	1	1	-	LC	Afr.
	<i>Hyaena hyaena</i> Linnaeus, 1758	2	2	-	NT	Afr. Pal. Ind.
Mephitidae	<i>Mephitis mephitis</i> Schreber, 1776	2	-	2	LC	Near.
Mustelidae	<i>Aonyx cinereus</i> Illiger, 1815	9	6	3	VU	Ind.
	<i>Lutra lutra</i> Linnaeus, 1758	3	1	2	NT	Pal. Ind.
	<i>Martes flavigula</i> Boddaert, 1785	1	1	-	LC	Pal. Ind.
	<i>Martes foina</i> Erxleben, 1777	1	-	1	LC	Pal. Ind.
	<i>Meles meles</i> Linnaeus, 1758	2	-	2	LC	Pal.
	<i>Mustela sibirica</i> Pallas, 1773	1	1	-	LC	Pal.
	<i>Neogale vison</i> Schreber, 1777	1	-	1	LC	Near.
	<i>Pteronura brasiliensis</i> Gmelin, 1788	1	1	-	EN	Neot.

Ord. and Fam.	Species	Zoo	Eaza	n-Eaza	IUCN	Realms
Otariidae	<i>Arctocephalus pusillus</i> Schreber, 1775	4	2	2	LC	Afr. Aust.
	<i>Callorhinus ursinus</i> Linnaeus, 1758	1	-	1	VU	Pal. Near.
	<i>Otaria flavescens</i> Shaw, 1800	3	1	2	LC	Neot.
	<i>Zalophus californianus</i> Lesson, 1828	3	2	1	LC	Near.
Phocidae	<i>Halichoerus grypus</i> Fabricius, 1791	2	2	-	LC	Pal.
	<i>Phoca vitulina</i> Linnaeus, 1758	4	2	2	LC	Pal.
Procyonidae	<i>Nasua nasua</i> Linnaeus, 1766	7	3	4	LC	Neot.
	<i>Procyon lotor</i> Linnaeus, 1758	5	1	4	LC	Near.
Ursidae	<i>Tremarctos ornatus</i> F.G. Cuvier, 1825	1	1	-	VU	Neot.
	<i>Ursus arctos</i> Linnaeus, 1758	7	3	4	LC	Pal. Near.
	<i>Ursus maritimus</i> Phipps, 1774	1	-	1	VU	Pal. Near.
	<i>Ursus thibetanus</i> G. Cuvier, 1823	1	-	1	VU	Pal. Ind.
Viverridae	<i>Arctictis binturong</i> Raffles, 1822	4	3	1	VU	Ind.
	<i>Genetta genetta</i> Linnaeus, 1758	2	-	2	LC	Pal. Afr.
	<i>Paguma larvata</i> C.H. Smith, 1827	1	-	1	LC	Pal. Ind.
	<i>Paradoxurus hermaphroditus</i> Pallas, 1777	3	1	2	LC	Ind.
Cetacea						
Delphinidae	<i>Tursiops truncatus</i> Montagu, 1821	3	2	1	LC	-
Cingulata						
Chlamyphoridae	<i>Chaetophractus villosus</i> Desmarest, 1804	2	2	-	LC	Neot.
	<i>Tolypeutes matacus</i> Desmarest, 1804	2	2	-	NT	Neot.
Chiroptera						
Pteropodidae	<i>Pteropus giganteus</i> Brünnich, 1782	1	1	-	LC	Ind.
	<i>Pteropus vampyrus</i> Linnaeus, 1758	3	-	3	NT	Ind.
	<i>Rousettus aegyptiacus</i> É. Geoffroy Saint-Hilaire 1810	1	-	1	LC	Afr. Pal.
Dioproctodonta						
Macropodidae	<i>Macropus giganteus</i> Shaw, 1790	2	1	1	LC	Aust..
	<i>Macropus rufogriseus</i> Desmarest, 1817	15	6	9	LC	Aust.
	<i>Macropus rufus</i> Desmarest, 1822	3	1	2	LC	Aust.
	<i>Wallabia bicolor</i> Desmarest, 1804	2	2	-	LC	Aust.
Erinaceomorpha						
Erinaceidae	<i>Atelerix albiventris</i> A. Smith, 1831	1	1	-	LC	Afr.
Hyracoidea						
Procaviidae	<i>Procavia capensis</i> Pallas, 1766	1	1	-	LC	Afr.
Lagomorpha						
Leporidae	<i>Lepus corsicanus</i> de Winton, 1898	1	-	1	VU	Pal.
	<i>Oryctolagus cuniculus</i> Linnaeus, 1758	1	-	1	EN	Pal.
Perissodactyla						
Equidae	<i>Equus africanus</i> von Heuglin&Fitzinger, 1866	4	2	2	CR	Afr.
	<i>Equus przewalskii</i> Poliakov, 1881	1	1	-	EN	Pal.
	<i>Equus grevyi</i> Oustalet, 1882	2	2	-	EN	Afr.
	<i>Equus hemionus</i> Pallas, 1775	1	1	-	NT	Pal.
	<i>Equus quagga</i> Boddaert, 1785	15	6	8	NT	Afr.
Rhinocerotidae	<i>Ceratotherium simum</i> Burchell, 1817	7	4	3	NT	Afr.

Ord. and Fam.	Species	Zoo	Eaza	n-Eaza	IUCN	Realms
Tapiridae	<i>Tapirus terrestris</i> Linnaeus, 1758	9	7	2	VU	Neot.
Pilosa						
Choloepodidae	<i>Choloepus didactylus</i> Linnaeus, 1758	3	2	1	LC	Neot.
Primates						
Atelidae	<i>Alouatta caraya</i> Humboldt, 1812	1	1	-	NT	Neot.
	<i>Ateles fusciceps</i> Gray, 1865	1	1	-	EN	Neot.
	<i>Ateles paniscus</i> Linnaeus, 1758	1	-	1	VU	Neot.
Callitrichidae	<i>Callimico goeldii</i> Thomas, 1904	1	1	-	VU	Neot.
	<i>Callithrix argentata</i> Linnaeus, 1771	1	1	-	LC	Neot.
	<i>Callithrix geoffroyi</i> Homboldt, 1812	3	1	2	LC	Neot.
	<i>Callithrix jacchus</i> Linnaeus, 1758	5	1	4	LC	Neot.
	<i>Callithrix penicillata</i> É. Geoffroy Saint-Hilaire, 1812	2	1	1	LC	Neot.
	<i>Cebuella pygmaea</i> Spix, 1823	2	1	1	VU	Neot.
	<i>Leontopithecus chrysomelas</i> Kuhl, 1820	1	1	-	EN	Neot.
	<i>Leontopithecus rosalia</i> Linnaeus, 1766	1	1	-	EN	Neot.
	<i>Saguinus imperator</i> Goeldi, 1907	3	3	-	LC	Neot.
	<i>Saguinus labiatus</i> É. Geoffroy Saint-Hilaire, 1812	2	1	1	LC	Neot.
	<i>Saguinus midas</i> Linnaeus, 1758	2	1	1	LC	Neot.
	<i>Saguinus oedipus</i> Linnaeus, 1758	7	5	2	CR	Neot.
Cebidae	<i>Saimiri boliviensis</i> I. Geoffroy Saint Hilaire & de Blainville, 1834	1	1	-	LC	Neot.
	<i>Saimiri sciureus</i> Linnaeus, 1758	3	2	1	LC	Neot.
	<i>Sapajus apella</i> Linnaeus, 1758	9	4	5	LC	Neot.
	<i>Sapajus libidinosus</i> Spix, 1823	1	-	1	NT	Neot.
Cercopithecidae	<i>Allochrocebus lhoesti</i> P.L. Sclater, 1898	1	1	-	VU	Afr.
	<i>Cercocebus lunulatus</i> Temminck, 1853	1	1	-	EN	Afr.
	<i>Cercopithecus mona</i> Schreber, 1774	1	1	-	NT	Afr.
	<i>Cercopithecus neglectus</i> Schlegel, 1876	1	-	1	LC	Afr.
	<i>Chlorocebus aethiops</i> Linnaeus, 1758	1	1	-	LC	Afr.
	<i>Colobus guereza</i> Rüppell, 1835	3	2	1	LC	Afr.
	<i>Macaca fascicularis</i> Raffles, 1821	1	-	1	VU	Ind.
	<i>Macaca fuscata</i> Blyth, 1875	5	1	4	LC	Pal.
	<i>Macaca mulatta</i> Zimmermann, 1780	1	-	1	LC	Ind.
	<i>Macaca nemestrina</i> Linnaeus, 1766	2	1	1	VU	Ind.
	<i>Macaca sylvanus</i> Linnaeus, 1758	4	1	3	EN	Pal.
	<i>Mandrillus sphinx</i> Linnaeus, 1758	2	2	-	VU	Afr.
	<i>Papio hamadryas</i> Linnaeus, 1758	3	-	3	LC	Afr.
	<i>Semnopithecus entellus</i> Dufresne, 1797	1	1	-	LC	Ind.
	<i>Theropithecus gelada</i> Rüppell, 1835	1	1	-	LC	Afr.
Cheirogaleidae	<i>Microcebus murinus</i> J.F. Miller, 1777	2	2	-	LC	Afr.
Hominidae	<i>Gorilla gorilla</i> Savage, 1847	1	-	1	CR	Afr.
	<i>Pan troglodytes</i> Blumenbach, 1775	5	2	3	EN	Afr.
	<i>Pongo</i> sp.	1	1	-	-	Ind.
Hylobatidae	<i>Hylobates lar</i> Linnaeus, 1771	8	4	4	EN	Ind.

Ord. and Fam.	Species	Zoo	Eaza	n-Eaza	IUCN	Realms
	<i>Nomascus concolor</i> Harlan, 1826	2	1	1	CR	Ind.
	<i>Nomascus gabriellae</i> Thomas, 1909	2	2	-	EN	Ind.
	<i>Symphalangus syndactylus</i> Raffles, 1821	4	2	2	EN	Ind.
Lemuridae	<i>Eulemur albifrons</i> É. Geoffroy Saint-Hilaire, 1796	2	-	2	VU	Afr.
	<i>Eulemur macaco</i> Linnaeus, 1766	2	2	-	EN	Afr.
	<i>Eulemur mongoz</i> Linnaeus, 1766	1	1	-	CR	Afr.
	<i>Eulemur rubriventer</i> É. Geoffroy Saint-Hilaire, 1850	2	2	-	VU	Afr.
	<i>Hapalemur alaotrensis</i> Rumpler, 1975	1	1	-	CR	Afr.
	<i>Lemur catta</i> Linnaeus, 1758	17	10	7	EN	Afr.
	<i>Varecia rubra</i> É. Geoffroy Saint-Hilaire, 1812	6	3	3	CR	Afr.
	<i>Varecia variegata</i> Kerr, 1792	10	8	2	CR	Afr.
Pitheciidae	<i>Pithecia pithecia</i> Linnaeus, 1766	2	2	-	LC	Neot.
Proboscidea						
Elephantidae	<i>Elephas maximus</i> Linnaeus, 1758	8	3	5	EN	Ind.
	<i>Loxodonta africana</i> Blumenbach, 1797	2	-	2	EN	Afr.
Rodentia						
Bathyergidae	<i>Heterocephalus glaber</i> Rüppell, 1842	1	-	1	LC	Afr.
Castoridae	<i>Castor fiber</i> Linnaeus, 1758	1	-	1	LC	Pal.
Caviidae	<i>Dolichotis patagonum</i> Zimmermann, 1780	10	4	6	NT	Neot.
	<i>Dolichotis salinicola</i> Burmeister, 1875	1	-	1	LC	Neot.
	<i>Hydrochoerus hydrochaeris</i> Linnaeus, 1766	10	6	4	LC	Neot.
Chinchillidae	<i>Lagostomus maximus</i> Desmarest, 1817	1	1	-	LC	Neot.
Dasyproctidae	<i>Dasyprocta azarae</i> Lichtenstein, 1823	1	-	1	DD	Neot.
	<i>Dasyprocta leporina</i> Linnaeus, 1758	1	-	1	LC	Neot.
Hystriidae	<i>Hystrix africaeustralis</i> Peters, 1852	2	1	1	LC	Afr.
	<i>Hystrix cristata</i> Linnaeus, 1758	8	2	6	LC	Afr. Pal.
	<i>Hystrix indica</i> Kerr, 1792	4	1	3	LC	Ind. Pal.
Muridae	<i>Acomys cahirinus</i> É. Geoffroy Saint-Hilaire, 1803	1	-	1	LC	Pal.
	<i>Lemniscomys barbarus</i> Linnaeus, 1766	2	1	1	LC	Pal.
	<i>Meriones unguiculatus</i> Milne-Edwards, 1867	1	-	1	LC	Pal.
	<i>Mus minutoides</i> A. Smith, 1834	1	-	1	LC	Afr.
	<i>Mus musculus</i> Linnaeus, 1758	1	-	1	LC	Pal. Ind.
	<i>Pachyuromys duprasi</i> Lataste, 1880	1	-	1	LC	Pal.
	<i>Phloeomys pallidus</i> Nehring, 1890	1	-	1	LC	Ind.
Myocastoridae	<i>Myocastor coypus</i> Molina, 1782	2	1	1	LC	Neot.
Octodontidae	<i>Octodon degus</i> Molina, 1782	1	-	1	LC	Neot.
Sciuridae	<i>Cynomys ludovicianus</i> Ord, 1815	5	1	4	LC	Near.
	<i>Marmota marmota</i> Linnaeus, 1758	1	-	1	LC	Pal.
	<i>Sciurus carolinensis</i> Gmelin, 1788	1	-	1	LC	Near.
	<i>Sciurus vulgaris</i> Linnaeus, 1758	2	-	2	LC	Pal.
Sirenia						
Manatidae	<i>Trichechus manatus</i> Linnaeus, 1758	1	1	-	VU	-
Soricorpha						
Soricidae	<i>Suncus etruscus</i> Savi, 1822	1	-	1	LC	Pal.

Tab. III reports how species kept in Italian zoos are broken down by their respective orders, Red List Categories, and biogeographical realms.

When considering all zoological gardens, nearly three quarters of the species are represented by three orders: Carnivora, Primates, and Artiodactyla. Rodentia represent nearly 11% of the species while Perissodactyla represent 3.17%. The other nine taxa range between 1.81% and 0.45% and together make up only 8.57% of species. When taking into account EAZA membership,

Tab. III. Percentages of species kept in Italian zoos according to their respective orders. Distinction in EAZA membership was taken into account.

Order	All Zoos	EAZA	Non-EAZA
Artiodactyla	26.24%	27.04%	27.27%
Carnivora	28.05%	27.67%	29.22%
Cetacea	0.45%	0.63%	0.65%
Chiroptera	1.36%	0.63%	1.30%
Cingulata	0.90%	1.26%	-
Diprotodonta	1.81%	2.52%	1.95%
Erinaceomorpha	0.45%	0.63%	-
Hyracoidea	0.45%	0.63%	-
Lagomorpha	0.90%	-	1.30%
Perissodactyla	3.17%	4.40%	2.60%
Pilosa	0.45%	0.63%	0.65%
Primates	23.08%	27.04%	18.18%
Proboscidea	0.90%	0.63%	1.30%
Rodentia	10.86%	5.66%	14.94%
Sirenia	0.45%	0.63%	-
Soricomorpha	0.45%	-	0.65%
Red List Category			
LC	57.75%	53.79%	63.95%
NT	9.86%	9.80%	8.16%
VU	14.55%	14.38%	13.61%
EN	12.21%	15.69%	7.48%
CR	4.69%	5.88%	5.44%
EW	0.47%	0.65%	0.68%
DD	0.47%	-	0.68%
Biogeographical Realms			
Afrotropical	31.10%	34.27%	29.05%
Australasian	1.97%	2.81%	2.23%
Indomalayan	16.93%	16.85%	16.20%
Nearctic	5.91%	3.93%	7.26%
Neotropical	18.11%	21.35%	16.76%
Palaearctic	25.98%	20.79%	28.49%

Carnivora and Artiodactyla are represented by similar percentages. On the other hand, Primates are more represented in zoos with EAZA membership than in zoos without EAZA membership (27.04% vs 18.18%). On the contrary Rodentia are more represented in non-EAZA zoos (14.94% vs 5.66%). The other orders are represented by broadly similar percentages in both groups of zoos. No species belonging to Lagomorpha and Soricomorpha is kept in EAZA zoos while non-EAZA zoos are devoid of species belonging to Hyracoidea, Cingulata, Erinaceomorpha, and Sirenia.

Regarding the Red List Categories, 67.61% of the species kept in Italian Zoos belong to a non-threatened Category (Least Concern or Vulnerable) while 31.45% belongs to a threatened Category (Vulnerable, Endangered, Critically Endangered, or Extinct in the Wild). The Data Deficient species are 0.47%. When zoos are broken down for their EAZA membership status, it can be seen that non-EAZA zoos are richer in non-threatened species than EAZA ones (72.11% vs 63.39%) while EAZA zoos are richer in threatened species (36.60% vs 27.21%).

The most represented biogeographical realm in Italian zoos is the Afrotropical one as it is represented by circa 31% of species. It is followed by the Palaearctic, Neotropical, and Indomalayan realms whose representation ranges between 16.93 and 25.98%. Nearctic and Australasian realms are the least represented as they are respectively represented by 5.91% and 1.97% of species. When considering EAZA membership, it can be seen that the Afrotropical, and Neotropical realms are more represented in zoos with EAZA membership while the Palaearctic and Nearctic ones are better represented by zoos without EAZA membership. Indomalayan and Australasian realms have similar representations in both types of zoos.

All the chi-squared tests (Tab. IV) have a p-value higher than 0.05 which makes us accept the null hypothesis. Thus, the frequency of species in Italian zoos per respective orders, Red List Categories and biogeographical realms is independent from their EAZA membership status.

Fig. 1 shows the percentages of zoological gardens which keep at least one species of the different orders, also accounting for EAZA membership. Six taxa are kept

Tab. IV. Results of the chi-squared analyses on frequencies of species relative to orders, Red List Categories and biogeographical realms according to EAZA membership. "D.o.f." stands for degrees of freedom.

	chi-squared	D.o.f.	p-value
Orders	18.87	15	0.2197
Red List Categories	7.017	6	0.3193
Biogeographical Realms	5.8106	5	0.3251

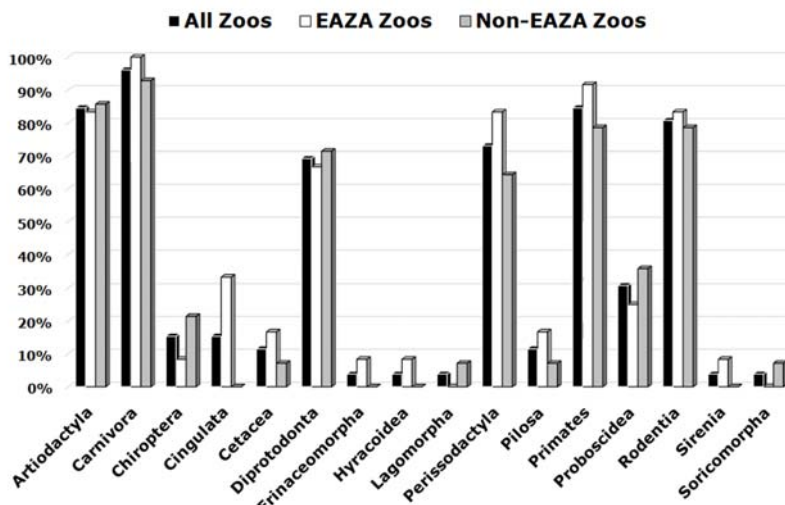


Fig. 1. Bar-plot showing the percentages of Italian zoos which keep at least one species of the different mammalian orders.

by more than 70% of zoos (also considering EAZA Membership), namely Artiodactyla, Carnivora, Diprotodonta, Perissodactyla, Primates, and Rodentia. Among these, Carnivora are kept by more than 90% of Italian zoos; and by all EAZA zoos. While Artiodactyla, Primates, and Rodentia are respectively kept by more than 80%, albeit slightly more in EAZA zoos. Furthermore, Perissodactyla and Diprotodonta, whose species represent only a small number of the ones kept in Italian zoos, are present in several zoos (both 86.60% of all zoos), with the first being kept in all EAZA zoos. Proboscidea are kept by more than 30% of Italian zoos. Interestingly, the percentage of non-EAZA zoos that keeps this taxon is higher than that of EAZA zoos (41.67% vs 30%). The other nine taxa are kept by less than 20% of Italian zoos. Among these Chiroptera are kept by a higher fraction of non-EAZA zoos and 40% of EAZA zoos keep at least one species belonging to Cingulata.

Orders

59 species belonging to 6 families of Artiodactyla out of 10 are kept in Italian zoos (Tab. V). Bovidae is the one with the highest number of species (37) kept in Italian zoos while the other families range between 2 to 9 species. When looking at the complete list of species, families with few species such as Camelidae, Giraffidae and Hippopotamidae all have species represented in Italian zoos. The representativeness of the other taxa ranges from 10.53% to 25.87%. Except for the Bovidae, all families are represented either by an equal or higher number of species in zoos with EAZA membership rather than non-EAZA membership.

Regarding the distribution (Fig. 2), species belonging to Bovidae, Camelidae and Cervidae are present in a rather high share of Italian zoos (between 69% and 74%). Also, Giraffidae and Hippopotamidae are

rather frequent in Italian zoos, respectively in 53.85% and 61.54% while Suidae are kept in only 19.23% of zoos. Camelidae, Giraffidae, Hippopotamidae, and Suidae are present in a higher share of EAZA zoos. Among these the discrepancies of Giraffidae and Hippopotamidae are rather high: respectively 74% vs 37.71% and 75% vs 50%. On the other hand, we find Bovidae and Cervidae in a higher share of non-EAZA zoos: respectively 78.57% vs 66.67% and 78.57% vs 58.33%.

62 species of Carnivora belonging to 13 families out of 15 are kept in Italian zoos (Tab. VI). The Felidae is the taxon which is represented by the highest number of species. All the other families are represented by less than 10 species; among these the most numerous are the Canidae and the Mustelidae. If the complete number of species is considered (excluding monospecific families such as Ailuridae), 7 taxa (Eupleridae, Herpestidae, Mephitidae, Mustelidae, Phocidae, Procyonidae, and Viverridae) are represented by 8% to 20% of their total species diversity. Otariidae, Canidae, and Hyenidae are represented by 25% to 40% of their total species diversity while Felidae and Ursidae are the most represented taxa (respectively 48.78% and

Tab. V. Percentages of species belonging to Artiodactyla families kept in Italian zoos. Wilson and Reeder (2005) was used as a benchmark.

Artiodactyla	All Zoos	EAZA zoos	Non-EAZA zoos
Bovidae	25.87%	16.78%	18.18%
Camelidae	100%	100%	100%
Cervidae	17.65%	15.69%	9.80%
Giraffidae	100%	100%	50%
Hippopotamidae	100%	100%	100%
Suidae	10.53%	5.26%	5.26%

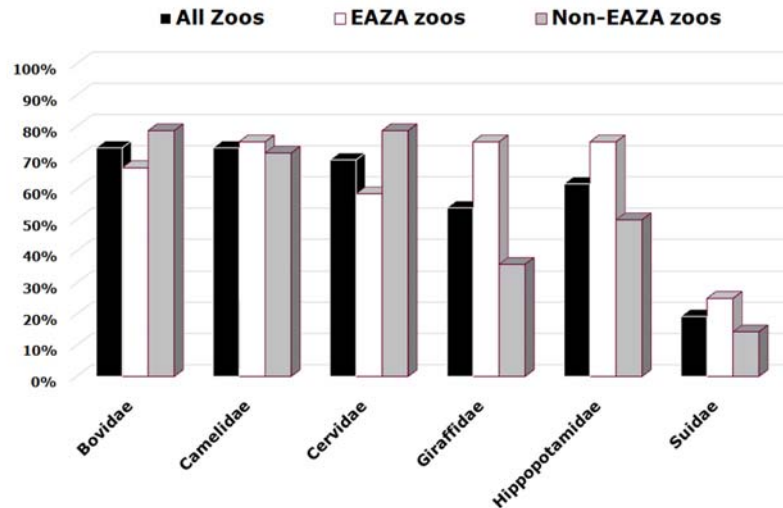


Fig. 2. Bar-plot showing the percentages of Italian zoos which keep at least one species of the different Artiodactyla families.

50%). Species belonging to Ailuridae and Hyenidae are kept only in EAZA zoos while no Mephitidae can be found in EAZA zoos. Interestingly, taxa such as Herpestidae, Mustelidae, Otariidae, Ursidae, and Viverridae are represented by a higher species number in non-EAZA zoos.

When looking at the family distribution among zoos (Fig. 3), a high disparity between the various taxa can be noticed. Only three taxa are present in 50% or more of Italian zoos: Felidae, Herpestidae, and Mustelidae. Among these, Felidae and Herpestidae are present in a higher share of zoos (76.92% and 61.54% respectively) than Mustelidae (50%) respectively. Regarding the other taxa, 20 to 50% of Italian zoos keep Ailuridae, Canidae, Otariidae, Procyonidae, Ursidae, and Viverridae. Eupleridae, Hyenidae, and Mephitidae are the rarest Carnivora families in Italian zoos, ranging between 7 to 12% of Italian zoos. When

Tab. VI. Percentages of species belonging to Carnivora kept in Italian zoos. Wilson and Reeder (2005) was used as a benchmark.

Carnivora	All Zoos	EAZA zoos	Non-EAZA zoos
Ailuridae	100%	100%	-
Canidae	33.33%	25.00%	25.00%
Eupleridae	12.50%	12.50%	12.50%
Felidae	48.78%	39.02%	31.71%
Herpestidae	15.15%	6.06%	15.15%
Hyaenidae	50.00%	50.00%	-
Mephitidae	8.33%	-	8.33%
Mustelidae	13.56%	8.47%	10.17%
Otariidae	25.00%	12.50%	25.00%
Phocidae	10.53%	10.53%	5.26%
Procyonidae	14.29%	14.29%	14.29%
Ursidae	50%	25.00%	50%
Viverridae	11.43%	5.71%	11.43%

accounting for the EAZA membership, eight taxa (Canidae, Eupleridae, Felidae, Herpestidae, Mustelidae, Otariidae, Phocidae, and Ursidae) are present in a higher share of EAZA zoos than Procyonidae, and Viverridae which are found more frequently in non-EAZA zoos. Among these taxa, the ones with higher discrepancies are Canidae, Felidae, Herpestidae, and Mustelidae for EAZA zoos.

51 species of Primates belonging to 9 families out of 16 are kept in Italian zoos (Tab. VII). The families with the highest number of species are Callitrichidae, Cercopithecidae and Lemuridae. Species belonging to Pitheciidae and Cheirogaleidae are only kept in EAZA zoos. When the complete number of species is taken into account, it can be seen that three families (Cebidae, Hominidae, and Lemuridae) are represented by more than 30% of their species, four range between 10 to 30% of their species and two by less than 5%. Interestingly, Cercopithecidae, the family with the highest number of species in Italian zoos, is represented by 11.36% of its total species number. All taxa except for the Cebidae

Tab. VII. Percentages of species belonging to Primates families kept in Italian zoos. Wilson and Reeder (2005) was used as a benchmark.

Primates	All Zoos	EAZA zoos	Non-EAZA zoos
Atelidae	12.50%	8.33%	4.17%
Callitrichidae	27.91%	27.91%	16.30%
Cebidae	30.77%	23.08%	23.98%
Cercopithecidae	11.36%	8.33%	5.30%
Cheirogaleidae	4.76%	4.76%	-
Hominidae	50.00%	33.33%	33.33%
Hylobatidae	28.57%	28.57%	21.43%
Lemuridae	42.10%	36.84%	21.05%
Pitheciidae	2.50%	2.50%	-

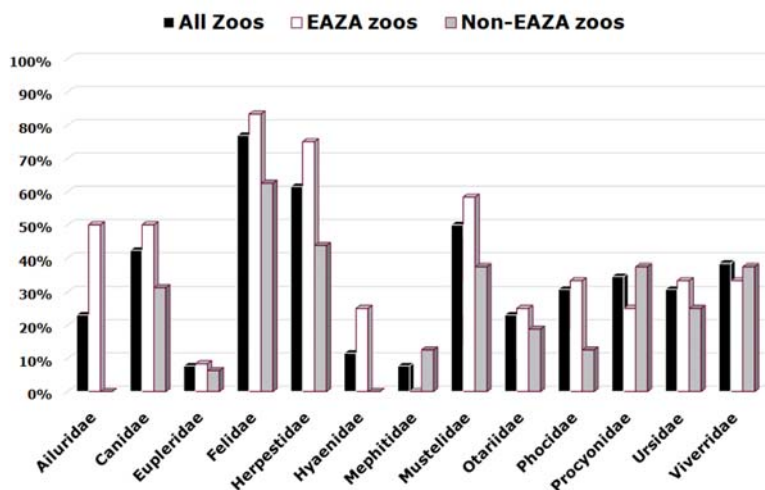


Fig. 3. Bar-plot showing the percentages of Italian zoos which keep at least one species of the different Carnivora families.

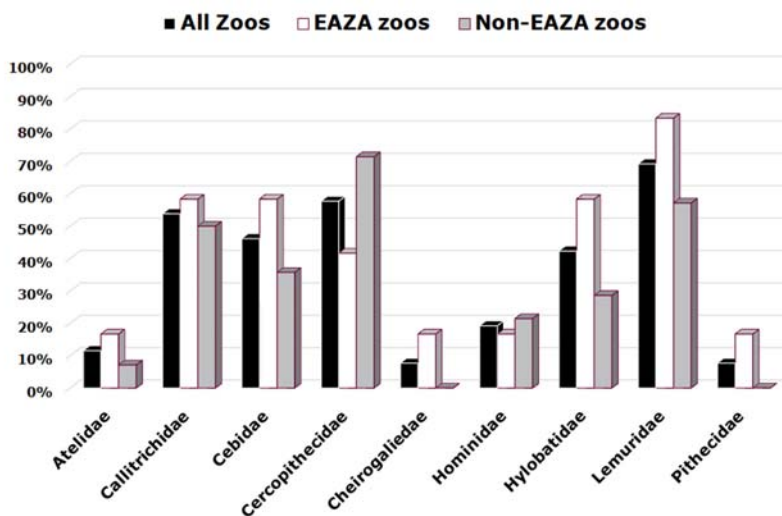


Fig. 4. Bar-plot showing the percentages of Italian zoos which keep at least one species of the different Primates families.

and the Hominidae are kept in higher species numbers in zoos with EAZA membership.

When looking at the families distribution among zoos (Fig. 4), three taxa are present in 50% or more of Italian zoos. Lemuridae is the family present in the highest share of Italian zoos (69.23%), followed by Cercopithecidae (57.69%) and Callitrichidae (53.85%). Cebidae and Hylobatidae are respectively kept in 46.15% and 42.31% of zoos. On the other hand, Atelidae, Cheirogaleidae, Hominidae, and Pitheciidae are present in less than 20% of zoos. When breaking down zoos according to EAZA membership, it can be seen that the majority of taxa are distributed in a higher share in zoos with EAZA membership. Although, this is not true for Cercopithecidae and Hominidae which are present in a higher share in zoos without EAZA membership: respectively 71.43% vs 41.67% and

21.43% vs 16.67%.

All the chi-squared tests (Tab. VIII) have a p-value higher than 0.05 which makes us accept the null hypothesis. Thus, the frequency of species per family of the three most represented orders in Italian zoos is independent from the EAZA membership status.

Tab. VIII. Results of the chi-squared analyses on frequencies of species per family of Artiodactyla, Carnivora, and Primates according to EAZA membership. “D.o.f.” stands for degrees of freedom.

	Chi-squared	D.o.f.	p-value
Artiodactyla	1.0586	5	0.9577
Carnivora	7.858	12	0.7961
Primates	7.1731	8	0.5181

DISCUSSION

According to current data, approximately an equal number of species of mammals is held in Italian zoos outside international databases such as ZIMS (Zoological Information Management Software), which is mandatory for EAZA members. According to the limited available historical data, the number of species per zoological garden has declined in the last forty years, sometimes by 50% or more (cf. Finotello & Castaldo, 1985; Cignini & D'Alessandro, 1991; Cignini *et al.*, 1991), a trend that is also known internationally (Brereton & Brereton, 2020). This is interpreted as a positive trend, given the relatively small size of Italian zoological gardens, suggesting a greater attention given to the quality of facilities in which the animals are kept and a better staging for the public. Regarding the biogeographical realms of species, the only noteworthy result is that non-EAZA zoos seem more interested in Palearctic species, indicating little interest by major zoos toward native or European species.

The majority of species belongs to Primates, Artiodactyla, and Carnivora, which are also present in the majority of Italian zoos. In Primates species diversity is increasing in some taxonomic groups. Previous data showed the presence of five families and 14 genera (Gandini & Rocca, 1988). Although the increase in families (9) is partly due to systematic changes, there is a genuine increase of diversity with 31 genera now represented. Callithrichidae, now one of the commonest families, was totally absent in 1986. While members of Artiodactyla are among the commonest species in Italian zoos, there is a marked difference among families (and tribes). While Hippopotamidae, Giraffidae, and Camelidae are well-represented, others (Tragulidae, Tayassuidae, Moschidae) are completely absent, while tribes such as Cephalophini (duikers) or Caprini (goats and sheep) are totally absent or represented in a negligible way.

Carnivora are also popular in Italian zoos with Felidae, Herpestidae, and Mustelidae as the most common families. However, there are some differences between families in number of species held, as only Canidae, Felidae, Hyaenidae, and Ursidae are represented by more than 30% of their total species diversity. On the other hand, Herpestidae and Mustelidae, while present in several zoos, are represented by a small fraction of their species' diversity.

Taxa such as Diprotodonta, Perissodactyla, and Rodentia represent a small part of the Italian zoos collection, yet they are present in several zoos. The first two taxa are represented by charismatic animals such as kangaroos and odd-toed ungulates (i.e., zebras, rhinoceros, and tapirs). In the case of Perissodactyla, the species diversity of the families is rather low today (Wilson and Reeder, 2005), thus a low contribution to species

number is expected. On the other hand, Diprotodonta and Rodentia have a far higher species diversity (the latter represent more than half total mammal diversity). Furthermore, many species belonging to Rodentia are present in a single Italian zoo only, while large-sized species such as *Dolichotis patagonum* (Zimmermann, 1780), *Hydrochoerus hydrochaeris* (Linnaeus, 1766) and those belonging to the genera *Hystrix* and *Dasyprocta* are present in several zoos. This is not surprising as zoos usually tend to skew their collections towards attractive species and species with high body mass (Balmford *et al.*, 1996; Ward *et al.*, 1998; Frynta *et al.*, 2013) and Italian zoos are no exception to this. As no Italian zoo currently features a 'night house', species that are active at daylight hours are much preferred over nocturnal ones. Thus, it is not surprising to find that small-sized species belonging to Carnivora and Primates are more represented than small-sized species belonging to taxa such as Rodentia, Soricomorpha, Pilosa, and Chiroptera.

The fact that circa 31.50% of species belong to a threatened Red List Category is a positive datum, considering also that we did not investigate below the species level (zoos may hold some threatened subspecies of non-threatened ones). In an analysis of world data on ISIS (now ZIMS) zoos, Conde *et al.* (2013) find that 27% of mammal species held are threatened. The discrepancy between the share of threatened species in EAZA and non-EAZA zoo is not surprising as the first have an easier access to European 'ex situ' conservation programs. Regarding biogeographical realms, the Nearctic and the Australasian are the least represented ones.

However, the chi-squared tests indicate that there is no significant association between frequencies of species per respective order, Red List Category, and biogeographical realms and the zoos' EAZA membership status. Thus, the differences among species between EAZA and non-EAZA zoos appear statistically non-significant.

We argue that the scarcity of small-sized taxa in Italian zoos is also a consequence of the geography of present-day Italian zoos. Very few urban zoos exist in Italy (i.e. Zoo di Napoli and Bioparco di Roma), therefore several Italian zoos are found in the countryside and are closed during the wintertime. Thus, as visitors have fewer chances of visiting the zoos in the wintertime, the number of indoor facilities, which often feature small mammals (i.e. nocturnal houses), is almost non-existent in Italian zoos. However, as zoos also have an educational role regarding younger visitors (Randler *et al.*, 2012; Jensen, 2014), we fear that the under-representation of small-sized mammalian taxa in Italian zoos may result in what is considered a biased representation of mammal diversity to the public.

CONCLUSIONS

It is already known that wild animals exhibited in zoological gardens are biased toward some groups that are deemed highly attractive by the public (Frynta *et al.*, 2013) and that about a quarter only belong to threatened taxa (Conde *et al.*, 2013). As almost all Italian zoos depend exclusively on ticket sales for their existence and maintenance, it is unlikely that such a situation will change soon. As it is acknowledged that zoological gardens play a fundamental role as biodiversity embassies (Gippoliti, 2012; Robovský *et al.*, 2020), it is desirable that in the future a greater differentiation of collection planning among zoos should allow specific story-telling to emphasize little-known biodiversity hotspots or

species, including native ones that are currently over-neglected. However, in the meantime, we consider the priority to be that the educational and scientific potential of zoo collections should be ‘exploited’ to a greater extent as possible, while these institutions maintain their popularity as a means to fight the increased dependency on electronic media by new generations.

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