Marsupials and the Coverage Provided by Protected Areas in Brazil

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Abstract

The United Nations Convention on Biological Diversity strategic plan to halt biodiversity loss through the achievement of 20 outcome-based targets failed at large. While some targets were partially met, most were not achieved. One of these targets (Aichi Target 11) states that 17% of terrestrial ecosystems should be preserved in situ. Brazil has met such target by means of its wide network of protected areas (PAs), but does this network really protect biodiversity? Here, the effectiveness of the Brazilian current network of PAs and Indigenous Lands (ILs) in representing all known marsupial species occurring in the country was assessed. The results show that species are relatively well covered by these areas, but the authors' estimates depended on the data type. On average, species were less represented in strict protection PAs (6.3% ± 4.6%), followed by

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sustainable use PAs (13% ± 8.4%) and ILs (14.4% ± 16.2%). Evaluating the effectiveness of PAs to biodiversity protection is a fundamental step toward understanding the impact of decision-making and conservation policy. Gap analysis such as the one reported here should be carried out elsewhere to support the establishment of PAs where they are most needed to guarantee the best allocation of scarce conservation resources available.

Keywords

Aichi targets · Brazilian mammals · Conservation policy · Gap analysis · Research-implementation spaces

Introduction

The increasing human occupation of the Earth's surface and its resulting impacts on natural ecosystems over the last century have accelerated human-induced species losses (IPBES 2019). Three-quarters of terrestrial environments and about 66% of the marine environment have been significantly altered by human actions (IPBES 2019), and between 1970 and 2014, there was an overall decline of 60% in population sizes of vertebrates (WWF 2018). To curb such threats, protected areas (PAs) still remain as the cornerstone strategy to protect biodiversity and guarantee the continuous provision of ecosystem services to people.

The Convention on Biological Diversity (CBD) defined a protected area as "a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives." CBD signatory parties had agreed to protect 17% of land and inland water and 10% of marine areas by 2020, part of Aichi Target 11 (CBD 2010). Accumulated evidence show that PAs has been effective in reducing deforestation (Andam et al. 2008; Brum et al. 2019) and buffering fire incidence (Nelson and Chomitz 2011), for example.

Although the PA coverage targets were not met uniformly around the globe, PAs now cover almost 20 million km^2 of terrestrial and inland waters area (UNEP-WCMC and IUCN 2020). Hence, considerable progress have been achieved over the last 10 years and new discussions are now underway on the post-2020 Global Biodiversity Framework (Visconti et al. 2019). Brazil, in particular, has one of the largest networks of PAs in the world (Vieira et al. 2019). The country holds 2446 PAs and > 2.5 million km^2 under protection, which represents 18.7% of its continental area and 25.5% of its marine territory (CNUC 2020). These figures account for PAs managed by the National System of Protected Areas (SNUC – acronym in Portuguese).

The SNUC was constituted in the year 2000 to unify and standardize management of PAs established with nature conservation as their main goal. In the system, there are two main categories of PAs following their management goals: those established for strict protection and those targeted for the sustainable use of natural resources. Currently, strict protection PAs represent 31.8% of reserves in SNUC, and they are equivalent to the International Union for Conservation of Nature (IUCN) categories Ia, II, and III. Sustainable use PAs represent 68.2% of the network and are equivalent to IUCN categories IV, V and VI. They are managed at the federal, state, and municipal levels.

In addition to SNUC PAs, Brazil has other categories of protected areas, such as indigenous lands and a mandatory minimum percentage of natural reserves inside rural private lands (Vieira et al. 2018). Indigenous lands (ILs) are those traditionally occupied by the indigenous peoples of Brazil and are essential for preserving the natural resources needed for their well-being according to their customs and traditions (FUNAI 2020). Brazil has 628 ILs covering an area of about 1.2 million km^2 (considering the different phases of the ILs demarcation procedure), which represents nearly 14% of the country's territory (FUNAI 2020). In the past, ILs were not accounted as areas for biodiversity conservation, however, indigenous peoples are increasingly recognized for contributing to nature conservation and their lands hold a great part of the world's biodiversity (Garnett et al. 2018; Leiper et al. 2018). Besides protecting their culture and heritage, ILs and other protected areas in the Brazilian Amazon are responsible for inhibiting fires and deforestation (Nepstad et al. 2006) and indigenous-managed lands were slightly richer in vertebrate species than other existing protected areas in Australia, Brazil, and Canada (Schuster et al. 2019), for example. The mechanism behind those results is an active enforcement of legal restrictions on natural resources exploitation, which varies according to the type of land management.

Previous studies have evaluated the role of Brazilian PAs in climate change mitigation (Soares-Filho et al. 2010), in avoiding deforestation in the Amazon and the Cerrado (Nolte et al. 2013; Brum et al. 2019) and the degree of biodiversity protection and knowledge within them (Oliveira et al. 2017; Ribeiro et al. 2018a, b). They provide several benefits for species conservation and ecosystem services provision; however, their potential could be even higher (Oliveira et al. 2017; Brum et al. 2019; Resende et al. 2019; Vieira et al. 2019). In Brazil, PA cover is highly heterogeneous across biomes and the vast majority of PAs are located in the Amazon (Vieira et al. 2019). The other five Brazilian biomes have a PA coverage gap and most of their remaining natural habitats are not under legal protection. Further, PAs are not representative for half of the Brazilian ecosystems, a likely outcome due to their establishment biases toward landscapes with least suitability for extractive uses, i.e., their residual nature (Vieira et al. 2019). Nevertheless, PAs will continue to be a key strategy for nature conservation, and the current gaps highlight the need to evaluate their effectiveness for different biodiversity groups and ecosystem services to improve the PAs network. Information on species representation in different PAs categories has been done sporadically (Oliveira et al. 2017; Ribeiro et al. 2018a, b), but it has not been done yet focusing on marsupials.

In Brazil, there are 15 genus and 65 species of Didelphidae marsupials, a group that occurs only in the Americas (Abreu-Jr et al. 2020b). They are distributed across all the Brazilian biomes, with the greatest diversity of species found in the dense forests of the Amazon and the Atlantic Forest, a pattern related to the adaptation of most species to arboreal habitats (Melo and Sponchiado 2012). Despite their wide distribution in Brazil, little is known about the details of the distribution of marsupials in non-forest biomes (Díaz-Nieto and Voss 2016). The lack of information regarding species geographic range still represents an important barrier in biogeographical studies, as well as to develop specific conservation strategies. Marsupials are among the most threatened species by habitat fragmentation, and there is not enough information about their responses and how to mitigate the impacts (Püttker et al. 2012). Other studies have also shown their vulnerability to climate change (Loyola et al. 2012), and, considering the rise of deforestation rates in Brazil, PAs become even more important for the conservation of these species.

In this chapter, the effectiveness of the Brazilian network of PAs (considering sustainable use, strict protection, and ILs as protected areas) in representing the marsupial species was evaluated. Information considering different types of species distribution data to assess biodiversity gaps in Brazil was compiled, to inform future targets and policies regarding marsupial species conservation.

Data on Marsupial Species Occurring in Brazil

To assess the coverage of marsupial species occurrence in the Brazilian network of PAs, both species occurrence records and species geographic distribution represented by their available range maps (see also Ribeiro et al. 2018a, b) were used. Both kinds of distribution data were used, given that they offer different, but complementary, information. Occurrence records offer more accurate information on the presence of a species at a specific point in space and time but are often biased toward localities of easy access (e.g., the vicinity of roads and biodiversity facilities; Oliveira et al. 2016). Range maps, on the other hand, provide a big picture of species distribution but are typically affected by the commission error (i.e., the inference about the presence of a species where it does not occur), which can overestimate the measure of species representativeness in PAs (Rodrigues et al. 2004).

Occurrence records of marsupial species occurring in Brazil (order Didelphimorphia) from the Global Biodiversity Information Facility (GBIF; www.gbif.org) and speciesLink (www.splink.org.br) databases were downloaded. Range maps were retrieved from the International Union for Conservation of Nature (IUCN; www.iucnredlist.org). To harmonize and adjust species taxonomy, the authors searched for species synonyms in several sources (e.g., Voss and Jansa 2009; Díaz-Nieto et al. 2016; Pavan and Voss 2016; Quintela et al. 2020; Voss et al. 2020) in order to find the valid name recognized in the most up-to-date list of marsupials in Brazil (Abreu-Jr et al. 2020).

For occurrence records, fossil records were removed, besides those that did not contain complete information on species taxonomy (i.e., species binomial) or geographical coordinates (i.e., latitude and longitude). Moreover, records with the same name and coordinates information, records in the ocean, assigned to country and state centroids, containing zero coordinates, with equal latitude and longitude information, and records in other countries were removed. The *clean.coordinates*

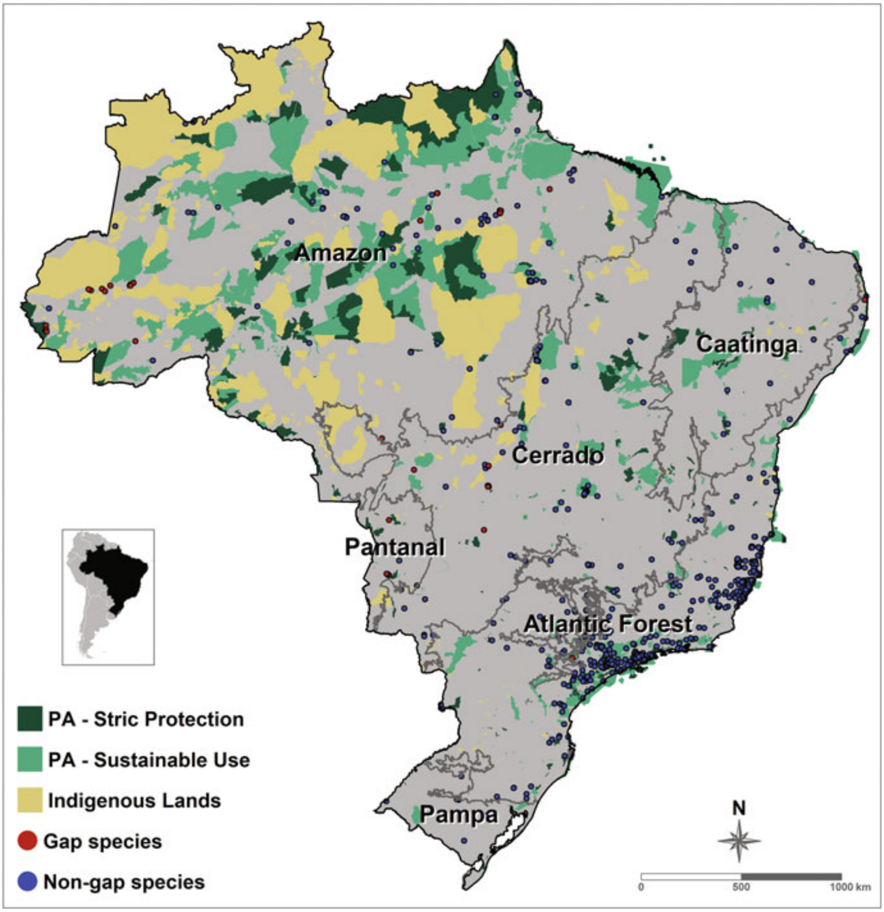

Fig. 1 Records of 51 species occurring in Brazil and the location of indigenous lands, strict protection, and sustainable use protected areas in the country. Gap species are those not represented in any protected area or indigenous lands. Records for all species are shown together with no discrimination

function of the CoordinateCleaner R package (Zizka et al. 2019) was used to do these procedures.

Overall, although 65 marsupial species occur in Brazil, only 51 of them have spatially explicit distribution data (Fig. 1). There are species rang maps for 45 species, and occurrence records were also compiled for 45 species, most of them sharing the two types of data (Table 1). Most occurrence records were concentrated in the Atlantic Forest with a lower number being found in other Brazilian biomes (Fig. 1).

Data on Location of Protected Areas in Brazil

Spatial data were gathered on federal, state, and municipal strict protection and sustainable use PAs (IUCN categories I–III and IV–VII, respectively) from the Brazilian Environmental Ministry website (mapas.mma.gov.br/i3geo/datadownload.htm). Spatial data on ILs from the National Indigenous Foundation (www.funai.gov.br/index.php/shape) were obtained and the Brazilian ILs were included in the list of currently established PAs (see Fig. 1).

Marsupial Species Representation in PAs

The representativeness of species distribution in PAs was assessed by overlapping species distribution data with the distribution of PAs using the function *st_intersection* of the *sf* package (Pebesma 2018). "Gap" was considered as those species not represented in any PA (Ribeiro et al. 2018a, b). The total number of occurrence records and the total area of range maps cropped to the limits of Brazil were also used to assess the proportion of each species distribution inside PAs. All analyses and figures were carried out in the software R (R Core Team 2020).

The number of species occurring inside PAs varied according to the type of data used in the analysis. When considering range maps, all species have at least part of their distribution in PAs (strict protection, sustainable use, and ILs – Fig. 2). On the other hand, when occurrence records were considered, the number of species drops to 27 in strict protection PAs, 30 in sustainable use PAs, and 10 in ILs (Fig. 3). No gap species were found when looking at species range, but there were 13 species with no record in any PA, most of them in the Amazon biome (Table 1, Fig. 1).

The percentage of occurrence records per species varied across the country (Fig. 2). Only 6 species had more than 50% of their records inside these areas, whereas 31 had more than 10% of their records in PAs. The percentage of records varied among species with some having no record at all and others, such as *Cryptonanus guahybae*, having all their records registered inside PAs (in this case, it is only one record; see Fig. 2, Table 1). The case of *C. guahybae* is interesting because although being found only in PAs, only ca. 5% of its range is covered by these areas, as shown below (Fig. 3). This situation highlights the importance of considering different types of data in analyses like the one used in this chapter.

There were eight species with only one record within strict protection PAs, seven within sustainable use PAs, and six species with only one record within ILs. In addition, there were only 9 species with 10 or more occurrence records within strict protection PAs, 12 within sustainable use Pas, and no species with more than 10 records within ILs.

Using species geographic range maps, it was found that, on average, species were less represented in strict protection PAs (6.3% ± 4.6%), followed by sustainable use PAs (13% ± 8.4%) and ILs (14.4% ± 16.2%). Percentage of coverage also varied considerably. For example, while *Didelphis imperfecta* had nearly all of its distribution represented in PAs, the species *C. guahybae* had only ca. 5% covered by these

Table 1 Marsupial species considered in this chapter along with their threat category, geographic distribution, and percentage of representation in indigenous lands, strict protection, and sustainable use protected areas in Brazil

			Species range					Occurrence records				
Species	Threat status	Brazilian Biomes	Area (km^2 x 1000)	% in strict protection	% in sustainable use	% in indigenous lands	% sum in protected areas	# of records	% in strict protection	% in sustainable use	% in indigenous lands	% sum in protected areas
Caluromys lanatus	LC	AM, AF, CE	2579.8	4.0	8.7	15.9	28.6	27	7.4	7.4	3.7	18.5
Caluromys philander	LC	AM, AF, CE	2834.2	5.2	10.1	14.2	29.5	62	4.8	19.4	0.0	24.2
Caluromysiops irrupta	CR		60.3	9.9	7.4	21.1	38.4	–	–	–	–	–
Chironectes minimus	DD	AM, AF, CA, CE	2390.7	3.9	10.0	11.1	25	17	17.6	5.9	5.9	29.4
Cryptonanus agricolai	LC	AF, CE	1144.1	2.2	7.4	0.4	10	19	0.0	0.0	0.0	0
Cryptonanus chacoensis	DD	CE	52.6	1.6	0.1	11.1	12.8	1	0.0	0.0	0.0	0
Cryptonanus guahybae	DD	AF	7.5	2.4	2.0	0.9	5.3	1	100.0	0.0	0.0	100
Didelphis albiventris	LC	AM, AF, CA, CE, PA	4101.2	2.2	4.7	2.8	9.7	170	5.9	22.4	2.9	31.2
Didelphis aurita	LC	AM, AF, CA, CE	1358.6	2.2	6.1	0.5	8.8	217	12.9	21.7	0.9	35.5
Didelphis imperfecta	LC		65.5	11.3	9.1	77.8	98.2	–	–	–	–	–
Didelphis marsupialis	LC	AM, AF, CE	3896.2	10.3	19.3	25.0	54.6	119	10.1	18.5	2.5	31.1
Glironia venusta	DD		1780.4	9.6	19.2	24.5	53.3	–	–	–	–	–

(continued)

Table 1 (continued)

Species	Threat status	Brazilian Biomes	Species range					Occurrence records				
			Area (km^2 x 1000)	% in strict protection	% in sustainable use	% in indigenous lands	% sum in protected areas	# of records	% in strict protection	% in sustainable use	% in indigenous lands	% sum in protected areas
Gracilinanus agilis	LC	AF, CA, CE, PT	2701.6	2.7	6.0	1.2	9.9	59	11.9	15.3	0.0	27.2
Gracilinanus emiliae	LC	AM	122.1	0.6	36.0	0.1	36.7	1	0.0	0.0	0.0	0
Gracilinanus microtarsus	LC	AF, CE	615.8	3.3	9.3	0.5	13.1	149	18.8	18.8	0.0	37.6
Hyladelphys kalinowskii	LC		1750.1	11.3	20.7	25.9	57.9	–	–	–	–	–
Lutreolina crassicaudata	LC	AF, CE, PA	1049.9	2.6	6.3	1.1	10	22	4.5	9.1	0.0	13.6
Marmosa (Marmosa) murina	LC	AM, AF, CA, CE, PA	4090.5	9.7	19.1	20.3	49.1	163	13.5	19.6	0.0	33.1
Marmosa (Micoureus) constantiae	DD	CE	335.8	5.2	2.0	7.6	14.8	1	0.0	0.0	0.0	0
Marmosa (Micoureus) demerarae	LC	AM, AF, CA, CE	6130.9	7.6	14.2	16.6	38.4	114	14.0	17.5	0.9	32.4
Marmosa (Micoureus) paraguayana	LC	AF, CE	814.7	3.1	7.9	0.6	11.6	58	10.3	17.2	1.7	29.2
Marmosa (Stegomarmosa) lepida	LC	AM	2026.2	11.5	19.8	32.1	63.4	6	0.0	0.0	0.0	0

Marmosops (Marmosops) incanus	LC	AM, AF, CA, CE	605.6	3.6	7.6	0.6	11.8	186	23.1	21.0	0.0	44.1
Marmosops (Marmosops) neblina	LC	AM	385.7	6.8	12.8	52.8	72.4	14	0.0	0.0	0.0	0
Marmosops (Marmosops) noctivagus	LC	AM, CE	1188.4	8.7	22.0	21.3	52	13	7.7	23.1	0.0	30.8
Marmosops (Marmosops) paulensis	VU	AF	74.0	9.7	27.9	0.7	38.3	11	36.4	54.5	0.0	90.9
Marmosops (Sciophanes) bishopi	LC	CE	1522.0	7.2	10.5	20.5	38.2	1	0.0	0.0	0.0	0
Marmosops (Sciophanes) parvidens	LC	AM	859.0	16.6	24.7	31.7	73	12	0.0	25.0	0.0	25
Marmosops (Sciophanes) pinheiroi	LC	AM	213.0	16.5	36.3	8.8	61.6	3	0.0	0.0	0.0	0
Metachirus myosuros	NE	AF, CE	–	–	–	–	–	29	13.8	10.3	0.0	24.1
Metachirus nudicaudatus	LC	AM, AF, CA, CE	6351.7	7.2	12.8	17.3	37.3	115	14.8	14.8	5.2	34.8
Monodelphis (Microdelphys) Americana	LC	AM, AF, CA, CE	1583.0	1.8	8.1	0.7	10.6	85	14.1	27.1	0.0	41.2
Monodelphis (Microdelphys) iheringi	NT	AF	679.1	3.6	8.4	0.5	12.5	20	0.0	45.0	0.0	45

(continued)

Table 1 (continued)

Species	Threat status	Brazilian Biomes	Species range					Occurrence records				
			Area (km^2 x 1000)	% in strict protection	% in sustainable use	% in indigenous lands	% sum in protected areas	# of records	% in strict protection	% in sustainable use	% in indigenous lands	% sum in protected areas
Monodelphis (Microdelphys) scalops	LC	AF, CA	344.6	4.6	13.3	0.6	18.5	24	20.8	20.8	4.2	45.8
Monodelphis (Monodelphiops) dimidiata	LC		1025.6	2.1	5.7	0.3	8.1	–	–	–	–	–
Monodelphis (Monodelphis) arlindoi	LC	AM	–	–	–	–	–	3	0.0	33.3	0.0	33.3
Monodelphis (Monodelphis) brevicaudata)	LC	AM	1041.2	16.9	24.3	28.5	69.7	7	0.0	14.3	0.0	14.3
Monodelphis (Monodelphis) domestica	LC	AF, CA, CE, PT	3385.9	2.4	4.5	4.2	11.1	23	4.3	4.3	0.0	8.6
Monodelphis (Monodelphis) glirina	LC	AM	1324.3	12.5	22.8	20.0	55.3	17	5.9	47.1	0.0	53
Monodelphis (Monodelphis) touan	LC	AM	–	–	–	–	–	3	33.3	33.3	0.0	66.6
Monodelphis (Mygalodelphys) kunsi	LC	AF, CE	410.7	1.2	4.5	1.2	6.9	5	0.0	20.0	0.0	20

Monodelphis (Pyrodelphys) emiliae	LC	AM	1055.2	3.9	18.3	20.6	42.8	9	0.0	0.0	0.0	0
Philander andersoni	LC	AM	445.6	14.2	27.2	43.3	84.7	1	0.0	0.0	0.0	0
Philander canus	NE	CE, PT	–	–	–	–	–	7	0.0	0.0	0.0	0
Philander mcilhennyi	LC	AM	409.5	3.3	13.2	33.7	50.2	9	0.0	0.0	0.0	0
Philander opossum	LC	AM, AF, CA, CE	3276.8	9.7	18.7	18.0	46.4	66	9.1	22.7	6.1	37.9
Philander pebas	NE	AM	–	–	–	–	–	4	25.0	0.0	0.0	25
Philander quica	NE	AF	–	–	–	–	–	6	50.0	16.7	0.0	66.7
Thylamys (Thylamys) macrurus	EN		62.1	1.3	0.4	6.3	8		–	–	–	–
Thylamys (Xerodelphys) karimii	LC	AM, CE	1431.4	3.6	7.6	7.0	18.2	3	0.0	0.0	0.0	0
Thylamys (Xerodelphys) velutinus	VU	CE	565.5	1.5	5.5	0.1	7.1	5	20.0	40.0	0.0	60

Results are shown for both geographic range and occurrence records. Threat status (ICMBio 2018): Critically endangered (CR), Endangered (EN), Vulnerable (VU), Near threatened (NT), Least concern (LC), Data deficient (DD), Not evaluated (NE). Brazilian biomes in which the species occur: Amazon (AM), Atlantic Forest (AF), Caatinga (CA), Pampa (PA), Pantanal (PT); blank spaces apply to species with no information on their biome occurrence. The following species were not analyzed because they do not have spatial data available for Brazil: *Marmosa (Marmosa) macrotarsus*, *M. (Micoureus) limae*, *M. (Micoureus) phaea*, *M. (Micoureus) rapposa*, *M. (Micoureus) rutteri*, *Monodelphis (Mygalodelphys) handleyi*, *M. (Mygalodelphys) pinocchio*, *M. (Mygalodelphys) saci*, *M. (Monodelphis) vossi*, *M. (Monodelphiops) unistriata*, *Cryptonanus unduaviensis*, *Gracilinanus peruanus*, *Marmosops (Marmosops) caucae*, and *M. (Marmosops) ocellatus*

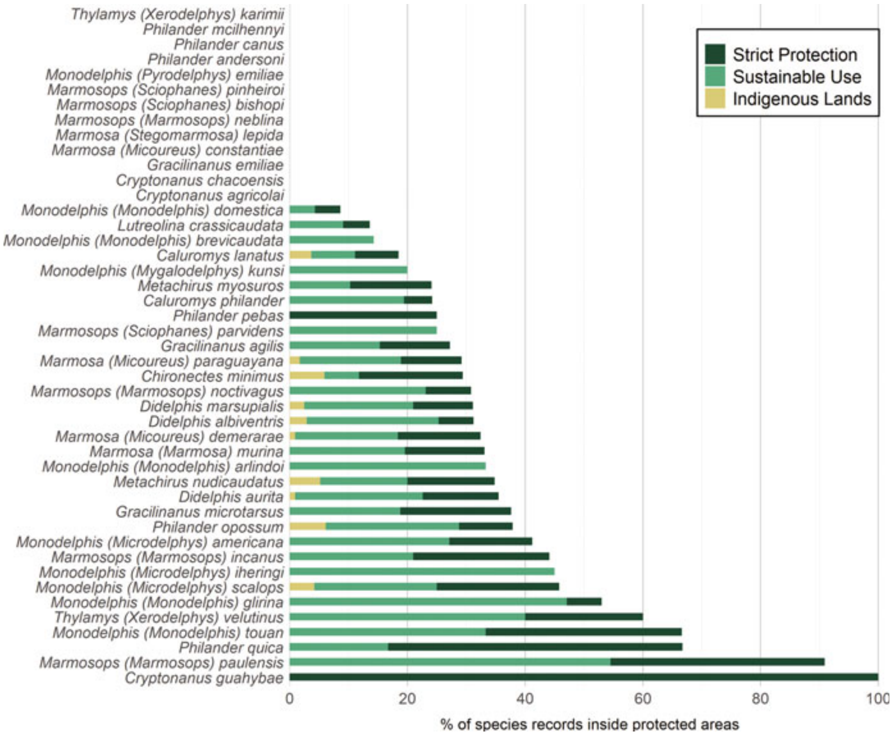

Fig. 2 Percentage of occurrence records for marsupial species occurring in indigenous lands, strict protection, and sustainable use protected areas in Brazil. The following species were not analyzed because they do not have spatial data available for Brazil: *Marmosa (Marmosa) macrotarsus*, *M. (Micoureus) limae, M. (Micoureus) phaea, M. (Micoureus) rapposa*, *M. (Micoureus) rutteri*, *Monodelphis (Mygalodelphys) handleyi*, *M. (Mygalodelphys) pinocchio*, *M. (Mygalodelphys) saci*, *M. (Monodelphis) vossi*, *M. (Monodelphiops) unistriata*, *Cryptonanus unduaviensis*, *Gracilinanus peruanus*, *Marmosops (Marmosops) caucae*, and *M. (Marmosops) ocellatus*

areas. Thirteen species had more than 50% of their distribution covered by PAs; most of them occurring in the Brazilian Amazon. For more details, see Fig. 3 and Table 1.

Evaluating the effectiveness of PAs to biodiversity protection is a fundamental step toward understanding the positive impact of environmental decision-making and conservation policy (Ferraro and Pressey 2015). In Brazil (Vieira et al. 2019) and in other parts of the world (Ferraro and Pressey 2015), PAs tend to be residual; that is, they have been consistently established on marginal lands that minimize costs and conflicts with extractive uses instead of focusing on places important to biodiversity.

It has been shown that Brazilian PAs do not do a good job in protecting plant species, given that 33% of all threated species still lie completely outside those areas (Ribeiro et al. 2018a, b), although they have been proven to be effective in refraining deforestation, at least in the Amazon (Nolte et al. 2013) and the Cerrado (Brum et al. 2019). As for whole ecosystems, nearly half of them are currently underrepresented in PAs (Vieira et al. 2019).

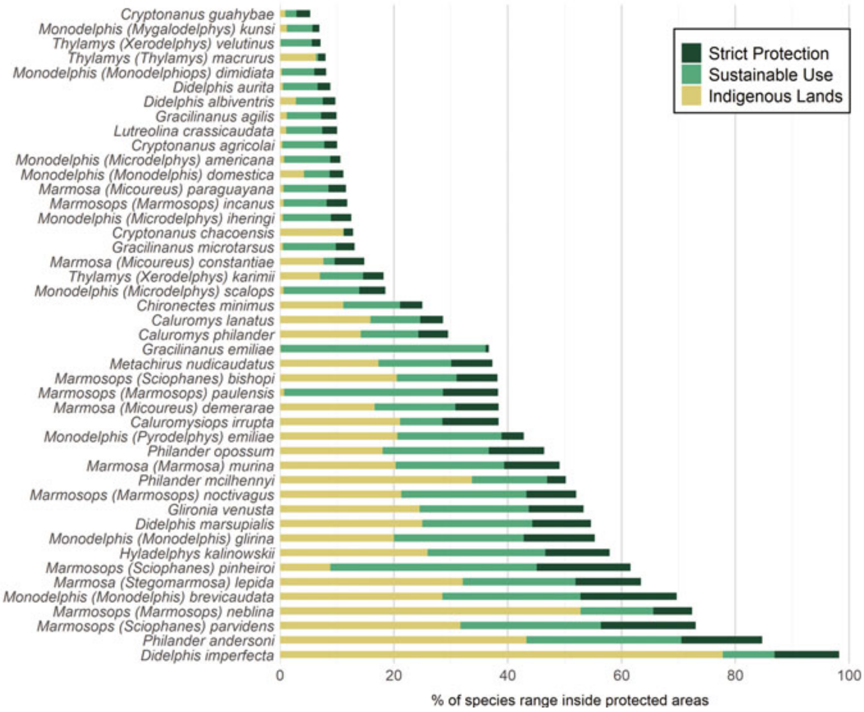

Fig. 3 Percentage of marsupial species geographic range overlapping with indigenous lands, strict protection, and sustainable use protected areas (PAs) in Brazil. Species with no bar had no records registered inside PAs. The following species were not analyzed because they do not have spatial data available for Brazil: *Marmosa (Marmosa) macrotarsus*, *M. (Micoureus) limae*, *M. (Micoureus) phaea*, *M. (Micoureus) rapposa*, *M. (Micoureus) rutteri*, *Monodelphis (Mygalodelphys) handleyi*, *M. (Mygalodelphys) pinocchio*, *M. (Mygalodelphys) saci*, *M. (Monodelphis) vossi*, *M. (Monodelphiops) unistriata*, *Cryptonanus unduaviensis*, *Gracilinanus peruanus*, *Marmosops (Marmosops) caucae*, *M.* and *(Marmosops) ocellatus*

Being the first investigation to analyze the formal protection of marsupial species, the current results suggest that PAs in Brazil do cover the distribution of marsupials reasonably well as the authors found few or none gap species (depending on the type of data being considered), although average coverage of species geographic range is still poor in strict protection PAs. However, the present analyses do not cover severe threats that menace marsupial species in Brazil, in particular climate change and deforestation.

The authors have previously alerted that marsupials in Brazil might lose considerable portions of their geographic range owing to climate change (Loyola et al. 2012). The case is particularly true for the Brazilian Atlantic forest (Vale et al. 2020), a biome that is already severely threatened by changes in its climatic regime and that might suffer more pressure with the climate crisis (Scarano 2019). The biome is also home for most marsupial species in Brazil, where patches of native vegetation can protect them and support their populations (Bovendorp et al. 2019). In this case, the role of native vegetation cover (Rezende et al. 2018), restoration (Strassburg et al. 2019), and areas formally protected are incommensurable, although studies suggest that PAs might not be able to counterbalance the effects of climate change for other vertebrates (Lemes et al. 2013) or even invertebrates (Ferro et al. 2014). In the Cerrado, conversion of native vegetation to agriculture is the biggest threat (Strassburg et al. 2017; Borges et al. 2019), and it applies to marsupial species (Loyola et al. 2012). In the Amazon, deforestation and climate change imperil marsupials as well as other mammals (Ribeiro et al. 2018a, b; Sales et al. 2019). Hence, climate change and deforestation, both inside and outside Pas, should be considered as a silent threat to marsupial species survival and might reduce the optimism found in the current results.

Brazil is home for 65 marsupial species (Abreu-Jr et al. 2020) ranging from small (ca. 10 g) to large species (ca. 3 kg) distributed mostly in forest areas such as the Amazon and the Atlantic Forest (Cáceres and Monteiro-Filho 2006). However, the scientific community still faces knowledge gaps about this group, which reinforces the importance of evaluating their taxonomy, distribution, threat status, and representation inside PAs, ILs, and also other formally protected areas in Brazil, such as the native vegetation protected within private lands (see Brancalion et al. 2016 and Vieira et al. 2018 for a discussion about these areas). To take the next step in decision-making for biodiversity conservation, it is fundamental to know how current actions and strategies are performing. Additional measures, such as habitat restoration, can complement PAs and achieve more impactful outcomes in marsupial conservation. Simultaneously, investments in the PA network and in biodiversity inventories in poorly sampled PAs and biomes need to be expanded. Gap analysis such as the one it is reported here should be carried out elsewhere to support the establishment of PAs where they are most needed the guarantee the best allocation of scarce conservation resources available.

Cross-References

- ▶ Conservation Biogeography of Living American Marsupials: Didelphimorphia, Microbiotheria, and Paucituberculata (by Gabriel Martin et al.)
- ▶ Effects of Habitat Loss and Fragmentation on Assemblages, Populations, and Individuals of American Marsupials (by Vieira, Barros, and Delciellos).
- ▶ Effects of interacting threats on Australasian terrestrial marsupials (by Tim Doherty).

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