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Distribution of Invasive Alien Species in Brazilian Ecoregions and Protected Areas

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2.1 Introduction

The transposition of biogeographical barriers associated with human activities leads to the intentional and accidental introduction of species, with no sign of saturation in the accumulation of species introductions at the global scale (Seebens et al. 2017). Some introduced species overcome environmental barriers and establish populations beyond the point of introduction, being therefore designated as invasive (Richardson et al. 2000). Biological invasions are one of the major threats to biological diversity and to human well-being (Vilà and Hulme 2017) and considered one of the main drivers of global environmental change in the Anthropocene (Steffen et al. 2011; Capinha et al. 2015).

Invasive alien species cause negative environmental impacts in natural ecosystems, with consequences to the conservation of biodiversity and human livelihoods in Brazil (Leão et al. 2011; Souza et al. 2018). Brazil is the fifth largest country and one of the five megabiodiverse countries in the world, housing the highest richness of freshwater, plant, and amphibian species (Mittermeier et al. 1997, 2004) as well as two of the world's biodiversity hotspots for conservation (Atlantic Forest and Cerrado) (Myers et al. 2000).

The main strategy for biodiversity conservation in Brazil is the establishment and management of protected areas (PA) (MMA 2012). There are 336 federal PA in the country, covering approximately 166 million hectares, equivalent to 19.5% of the Brazilian territory (ISA 2019). However, almost half of these PA (145; 43%) are located in the Legal Amazon Region, with only 57% of the area in other regions. Protected areas can also be established and managed at the state or municipal levels as well as by private owners (Rylands and Brandon 2005). The National Protected Area System includes PA of very limited use, such as Biological Reserves (Category Ia – Strict Nature Reserve of the IUCN Classification System) as well as PA where the sustainable management of natural resources is allowed

Invasive Alien Species: Observations and Issues from Around the World, Volume 4: Issues and Invasions in the Americas and the Caribbean, First Edition. Edited by T. Pullaiah and Michael R. Ielmini.

(Category VI Protected area with sustainable use of natural resources of the IUCN Classification System) (Rylands and Brandon 2005; MMA 2012). Many PA are designed to protect biodiversity by providing refugia to native species from the spread of invasive alien species (Gallardo et al. 2017). Thus, alien species occurring in these areas must be controlled and/or eliminated. Although the presence of invasive alien species and the need for management is acknowledged in most management plans of federal PA, a very limited number of management plans has been implemented (Dechoum et al. 2018). Protected areas may therefore offer refuge for invasive species spreading under climate change (Merino et al. 2009; Gallardo et al. 2017) in the lack of management actions.

The national database on invasive alien species in Brazil (www.bd.institutohorus.org.br) was established in 2005 by the Horus Institute for Environmental Conservation and Development, a Brazilian not-for-profit organization, to store data from national surveys on Invasive Alien Species conducted by the Ministry of Environment. The first national symposium on IAS held in 2005 by the Ministry of Environment became a milestone for raising awareness on the subject in Brazil (Zenni et al. 2016). The database includes invasive alien species of all biological groups. Species that are indigenous in some areas in Brazil but invasive in different parts of the country are also included in the National Database. The same species often generate economic or social impacts, as well as impacts on human or animal health, but the focus of this database is on species that impact biodiversity, natural habitats, and ecological functions (Instituto Hórus 2019).

The criteria for including species in the database are as follows: (i) the species is present in Brazil; (ii) it has a history of invasion in Brazil or elsewhere, usually in climatic conditions that favor adaptation to a climate type in the country; and (iii) there is reliable data on at least one place of occurrence outside its native range. Exceptions can be made for species which have many traits common to invasive alien species but still do not express invasiveness and are considered of high risk to Brazilian biodiversity, such as the lion fish (*Pterois volitans*), which is sold in the aquarium trade but has not established in natural areas.

Understanding the geographic distribution of invasive species in ecoregions and PA is important to develop and improve management programs. Ecoregions are biogeographic units defined as relatively large units of land or water containing a distinct assemblage of natural communities that share a large majority of species, dynamics, and environmental conditions (Olson et al. 2001). These biogeographic units can be useful in global and regional conservation priority-setting and planning efforts. We have therefore sought to answer the following question: How are IAS distributed in Brazil and in which ecoregions hold higher numbers?

2.2 Material and Methods

2.2.1 Data Collection

Data from the Brazil National Invasive Alien Species Database (http://bd.institutohorus.org.br) managed by the Horus Institute for Environmental Conservation and Development was used as a base for this assessment. The database comprehends records of species occurrences that include geographic information (coordinates of occurrence in the field or of the respective municipality) and ecological information (ecosystem, native range, dispersal syndrome, description, vectors, pathways, and more). Data available between 2005 and 2019 were used in this study, while Invertebrates, algae, and marine fishes were deliberately not included.

2.2.2 Geospatial Bases (Shapefiles)

The geospatial database of terrestrial ecoregions in Brazil (Olson et al. 2001) and the database of federal and state PA in Brazil available from Instituto Socioambiental (ISA – www.socioambiental.org) (map scale – 1 : 100 000 for the Legal Amazon and 1 : 250 000 for the rest of the country) were used in this study. Both databases contain geospatial vector data format (shapefiles) with information on the geographic limits of PA. Private reserves (RPPNs) were not included because information on their limits was not available.

2.2.3 Data Analyses

The geographic information from both databases was standardized using the format lat/long and WGS84 projection. The list of species occurrences was subjected to revision prior to the final calculations. The revision process consisted in calculating the distance from the point of occurrence of the individual to the centroid of the municipality. The centroid of Brazilian municipalities was calculated from the Digital Municipal Network of Brazil available from the Brazilian Institute for Geography and Statistics (IBGE 2019). All occurrences farther than 100 km from the municipality centroid were inspected for possible discrepancies (for example, invalid location and/or inverted geographic coordinates). Occurrence points that were wrong and could not be corrected and occurrences that did not specify geographic coordinates were discarded. Descriptive statistics were used to calculate the number of invasive alien species per ecoregion and per protected area by interpolation between the point of occurrence and the respective cartographic base (ecoregion and PA). The Quantum GIS (QGIS Development Team 2019) and R (R Core Team 2019) platforms were used for calculations and to produce maps.

2.3 Results

A total of 367 invasive alien species are registered for Brazil (excluding algae, invertebrates, and marine fishes) in the 35 Brazilian ecoregions. The highest numbers of IAS occur in Serra do Mar Coastal Forests, Alto Paraná Atlantic Forests and Araucaria Moist Forests, with more than 40% of all IAS recorded for Brazil (Figure 2.1, Table 2.1). Flowering plants (Magnoliophyta) and chordates (Chordata) accounted for more than

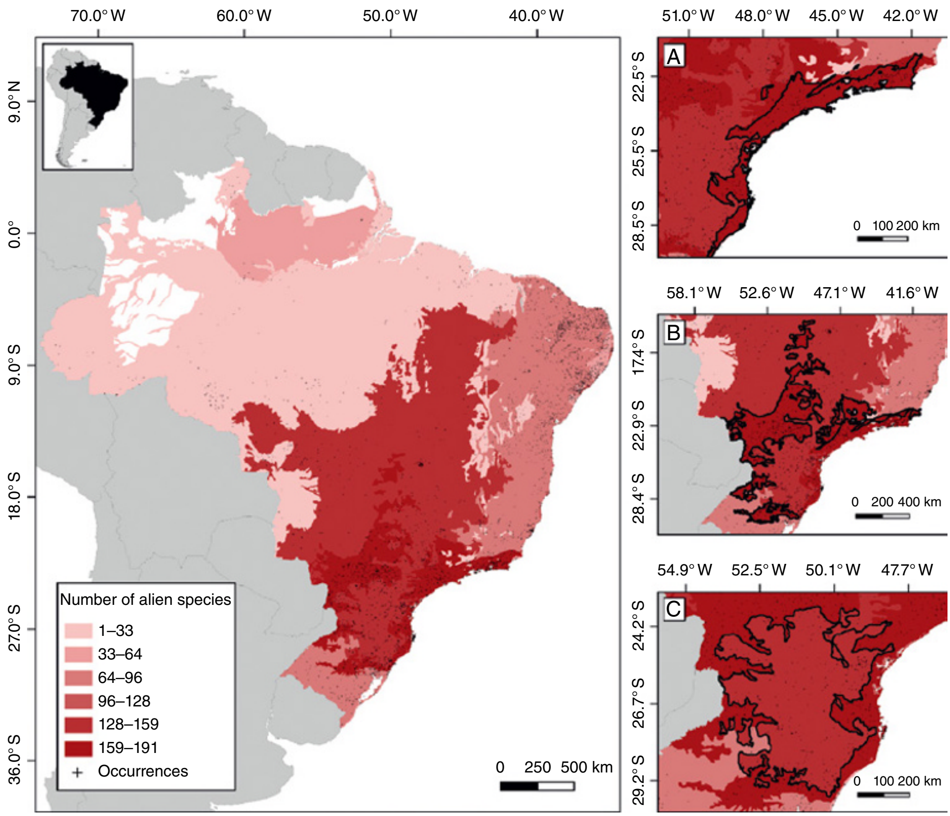

Figure 2.1 Distribution of invasive alien species (IAS) in Brazil and in ecoregions with the highest numbers of IAS (A–C). "+" represents reported occurrences and solid black lines the limits of ecoregions. (A) Serra do Mar Coastal Forests; (B) Alto Paraná Atlantic Forests; and (C) Araucaria Moist Forests.

96% of IAS, both with similar percentages: 49 and 47%, respectively. Dicotyledons (Magnoliopsida) hold the highest number of IAS among flowering plants, accounting for more than 30% of all IAS recorded in Brazil. Ray-finned fishes (Actinopterygii) accounted for more than 32% of all IAS recorded in Brazil among chordates. More information is available in Table 2.2.

Out of the 367 IAS recorded for Brazil, 215 (59%) are present in one or more of the 245 federal and state PA (Figure 2.2). The PA with the highest numbers of IAS were the Guaraqueçaba Environmental Protection Area, Escarpa Devoniana Environmental Protection Area and Tamoios Environmental Protection Area, each of them with more than 15% of all IAS in the PA in the country (Figure 2.2). State PA accounted for 87% of all IAS, while federal PA accounted for 73% of all IAS in Brazilian PA. More information is available in the supplementary material (Table 2.3).

Table 2.1 Numbers of invasive alien species (N IAS) and percentage of invasive alien species (% of IAS) identified for each Brazilian ecoregion in decreasing order.

Ecoregion	N IAS	% of IAS
Serra do Mar Coastal Forests	191	52.0
Alto Paraná Atlantic Forests	189	51.5
Araucaria Moist Forests	147	40.1
Cerrado	141	38.4
Southern Atlantic Mangroves	114	31.1
Uruguayan Savanna	94	25.6
Bahia Interior Forests	83	22.6
Caatinga	83	22.6
Bahia Coastal Forests	82	22.3
Atlantic Coast Restingas	59	16.1
Pernambuco Coastal Forests	45	12.3
Pernambuco Interior Forests	39	10.6
Uatuma-Trombetas Moist Forests	33	9.0
Japurá-Solimoes-Negro Moist Forests	32	8.7
Campos Rupestres Montane Savanna	23	6.3
Maranhão Babaçu Forests	22	6.0
Madeira-Tapajós Moist Forests	19	5.2
Pantanal	16	4.4
Tocantins/Pindare Moist Forests	16	4.4
Chiquitano Dry Forests	15	4.1
Southwest Amazon Moist Forests	14	3.8
Atlantic Dry Forests	12	3.3
Guianan Savanna	12	3.3
Northeastern Brazil Restingas	12	3.3
Monte Alegre Varzea	10	2.7
Amazon-Orinoco-Southern Caribbean Mangroves	8	2.2
Mato Grosso Seasonal Forests	8	2.2
Iquitos Varzeá	7	1.9
Xingu-Tocantins-Araguaia Moist Forests	7	1.9
Caatinga Enclaves Moist Forests	6	1.6
Purus Varzeá	5	1.4
Purus-Madeira Moist Forests	4	1.1
Marajó Varzeá	3	0.8
Humid Chaco	1	0.3
Tapajós-Xingu Moist Forests	1	0.3

Table 2.2 Percentage of invasive alien species (% of IAS) registered in Brazil per taxonomic group in decreasing order.

Kingdom	Phyllum/Division/Group	Class	% of IAS
Animalia	Chordata	Actinopterygii	32.4
		Mammalia	6.5
		Aves	3.5
		Ascidiacea	1.4
		Reptilia	1.4
		Amphibia	1.1
		Chondrichthyes	0.5
Plantae	Magnoliophyta	Magnoliopsida	30.8
		Liliopsida	18.5
	Coniferophyta	Pinopsida	2.2
	Pteridophyta	Polypodiopsida	1.4
		Lycopodiopsida	0.3

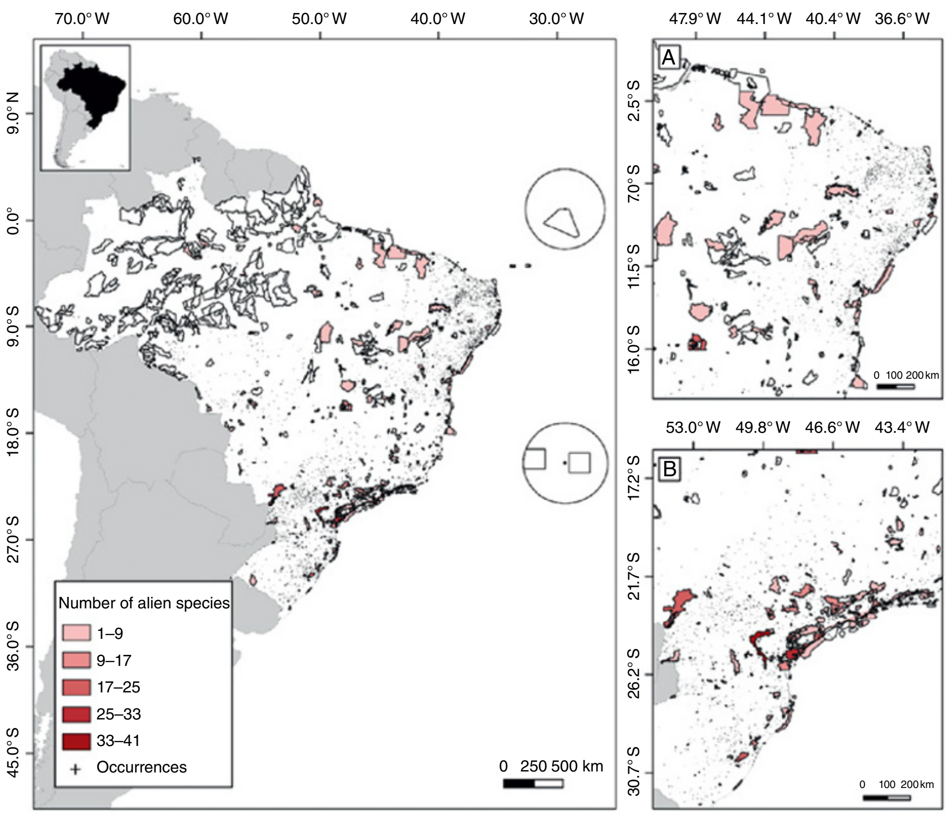

Figure 2.2 Distribution of invasive alien species (IAS) in Brazil and in Brazilian protected areas (PA). "+" represent reported occurrences and solid black lines the limits of protected areas. (A) Detailed view of PA located in northeastern, midwestern, and southeastern Brazil; (B) Detailed view of PA located in southeastern and southern Brazil.

2.4 Discussion

Invasive alien species occur in almost all ecoregions and in a large number of PA in Brazil – for instance, there are IAS in at least 26% of the total number of federal PA (87 out of 336). The majority of the IAS were registered in ecoregions and PA that are located in the Atlantic Forest hotspot, especially in southeastern and southern Brazil. The lack of data for certain regions tends to lead to underestimates of the number of invasive species, but actual species numbers are also higher because this study did not contemplate invertebrates, marine fishes, or algae. The data available on the distribution of invasive alien species in Brazil may include a certain bias because regions are not equally studied, there is more awareness in some states and more research has been done in certain areas. Environmental agencies in Parana, Santa Catarina, Rio Grande do Sul, Rio de Janeiro, and São Paulo have compiled species lists in the past with the aim of publishing official reference lists of invasive species. Although not all states succeeded in this endeavor, inquiries on species were made to protected area managers, field practitioners and the scientific community, generating a large amount of data that was incorporated in the National IAS Database used in this study (Instituto Hórus 2019).

While this may help explain why the three ecoregions (Serra do Mar Coastal Forests, Alto Paraná Atlantic Forests and Araucaria Moist Forests) with more invasive species are located in the south and southeast of Brazil, these ecoregions also cover some of the most populated areas in the country (MMA 2013) and have therefore been highly altered (Ribeiro et al. 2009). The Serra do Mar Coastal Forests ecoregion is especially densely populated, with a high level of degradation and fragmentation of natural areas, which may explain the high number of invasive species (Hobbs 2000; Gavier-Pizarro et al. 2010; Zenni and Dechoum 2013; González-Moreno et al. 2017), in this case more plants than animals. The Alto Paraná Atlantic Forests ecoregion was intensely deforested in the 1950s for timber and conversion to agriculture – the forest cover decreased around 50% between 1973 and 2000 (Huang et al. 2007), and only 10% of its original cover remains (Hutchison and Aquino 2011). Similarly, the Araucaria Moist Forests ecoregion was also highly deforested for timber, especially of Brazilian pine (*Araucaria angustifolia*), the tree species that characterizes the ecosystem (Vibrans et al. 2011). In this particular ecoregion, remnants of primary forests are estimated at slightly less than 1% of the original cover, while remnants of primary and secondary forests add to approximately 12% of the ecosystem (Ribeiro et al. 2009).

Although our results are focused on numbers of invasive alien species, the fact that fewer species occur in a certain area does not imply lower impact. Some invasive species are characteristically aggressive in specific ecosystems: mesquite (*Prosopis juliflora*, *P. pallida*) and neem (*Azadirachta indica*) in the northeastern Caatinga, African grasses such as brachiaria (*Urochloa* spp.), jaragua grass (*Hyparrhenia rufa*), and gamba grass (*Andropogon gayanus*) in the Savanna (Cerrado), Grasslands and deforested areas, trees such as the Japanese raisin tree (*Hovenia dulcis*), privet (*Ligustrum* spp.), Australian chesewood (*Pittosporum undulatum*), jackfruit (*Artocarpus heterophyllus*), plums (*Syzygium* spp.), and African oil palm (*Elaeis guineensis*) in the Atlantic Forest, pines (*Pinus elliottii*, *P. taeda*) in Grasslands, coastal scrub (restinga) and deforested areas; aquaculture fishes such as tilapia (*Oreochromis niloticus*), carp (*Cyprinus carpio*), African catfish (*Clarias gariepinus*), and rainbow trout (*Onchorhynchus* *mykiss*) are widespread in river systems, many of which have been translocated within Brazil (peacock bass *Cichla* spp., black-finned pacu *Colossoma macropomum* and spotted sorubim *Pseudoplatystoma corruscans*), while ornamental fishes are increasingly more common (common pandora *Erythrinus erythrinus*, serape tetra *Hyphessobrycon eques*, Araguaia cichlid *Laetacara araguaie* and ornate pim *Pimelodus ornatus*). Pets, especially dogs (*Canis familiaris*) and cats (*Felis catus*), are commonly observed in PA (Sampaio and Schmidt 2013; Ziller and Dechoum 2013), while other animals such as sliders (*Trachemys* spp.) are often abandoned and others have spread due to illegal animal trafficking, such as marmosets (*Callithrix* spp.), or result from illegal introductions for hunting or breeding, such as with Feral swine (*Sus scrofa)* or American bullfrog (*Lithobates catesbeianus*).

The high number of invasive vertebrates is due to freshwater fishes introduced for aquaculture, sport fishing, the aquarium trade, or use as live bait (Lima et al. 2018). The number of species is especially high in the Alto Paraná Atlantic Forests and Araucaria Moist Forests ecoregions, where construction of the Itaipu Hydroelectric plant eliminated the barrier between the Upper and Lower Paraná River, allowing fishes to migrate upstream. This leads to the homogenization of these two assemblages between the adjacent aquatic regions (Vitule et al. 2011). As a consequence, the class of freshwater fishes (Actinoperygii) is the only one with more invasive species (119) than vascular plants (Magnoliopsida, 113) in the National Database (Instituto Hórus 2019).

Protected areas are divided in two classes in Brazil. Sustainable use areas are intended to restrict the development of activities that may impact the environment, but much of the land is private property in use for production. Such activities are not allowed in strict protection areas, established for the conservation of biodiversity, often also involving the protection of valued landscapes. The highest numbers of invasive species were registered in four PA in the sustainable use class, which may be due to the higher fragility of such areas to biological invasions because restrictions on the use of species are rare or nonexistent. As a consequence, propagule pressure, a major factor in triggering biological invasions, is increased when invasive species are under cultivation or breeding (Lockwood et al. 2005). At the same time, five of the areas in the strict protection class with more species (Vila Velha State Park in Paraná, Brasília National Park in Goiás, Ilha Grande State Park and Tijuca National Park in Rio de Janeiro, and Saltinho Biological Reserve in Pernambuco) have been thoroughly assessed for invasive species, which shows that the number of species tends to be correlated with field surveys. Buffer zones around strict protection areas are subject to similar effects from cultivation and breeding of invasive species, as boundaries are permeable and there are few PA with invasive species management programs in place. Better regulations to avoid the use of invasive species in such areas, including reference lists of invasive species, are needed to increase the level of protection and help prevent invasions. Research on alternatives to replace or safely manage invasive species is also a relevant gap.

Threats posed by invasive alien species involve multiple environmental effects that change community composition, biotic interactions and ecosystem processes (Vilà et al. 2011; Pyšek et al. 2012; Ricciardi et al. 2013; Gallardo et al. 2016; Schirmel et al. 2016; David et al. 2017; Vilà and Hulme 2017). These effects can be aggravated by climate change and habitat fragmentation (Cardinale et al. 2012; Segan et al. 2016), which is especially high along the Atlantic Coast and in southwestern Brazil. National plans for endangered species currently identify invasive species as one of the major threats of species extinctions (MMA 2019). The lack of specific regulations on the use of invasive species further aggravate the threats to biodiversity. Although the federal government is currently developing risk assessment protocols for new introductions, unauthorized introductions have not been prevented. Such is the case of the panga fish (*Pangasianodon hypophthalmus*), invasive in Asia but nevertheless recently introduced and promoted for aquaculture despite the lack of legal authorization by the federal authority.

Given the continental dimensions of the country, the translocation of species inside country borders may have catastrophic consequences to regional biodiversity, as species that are indigenous in some regions can become invasive in others. For instance, the marmosets *Callithrix jacchus* and *C. penicillata*, indigenous to northeastern Brazil, were taken to southeastern Brazil, where they co-occur and have been impacting populations of the endangered golden-lion-tamarin (*Leontopithecus rosalia*) and the vulnerable buffy-tufted-ear-marmoset (*Callithrix aurita*) in the state of Rio de Janeiro (MMA 2011).

There are less invasive species in the Amazon region (Figure 2.1). Although this tends to be accurate given that there are more pristine areas and many areas are difficult to access, this is also the region for which less data has been gathered, as there are fewer people working on biological invasions or even aware of the problems posed by invasive species. The integrity of ecosystems in the Amazon region and consequent fewer occurrences of invasive species indicate an important opportunity for the states in the region to prevent the introduction of species already known to be invasive. Important work to develop awareness, beginning with government agencies, academia and not-for-profit organizations will greatly benefit the region in the future. The establishment of prevention and early detection measures, as well as the development of consistent regulations to avoid introductions of invasive species and carefully regulate the use of alien species, can still be attained in the region, one of the few areas in the world where invasions are not yet widespread. According to the MapBiomas Project (Projeto MapBiomas 2019), between 1985 and 2018 the liquid loss of indigenous vegetation in Brazil was approximately 89 million hectares. The contribution of pastures increased from 127 to 174 million hectares, and agriculture increased from 24 to 60 million hectares, or 37 and 250%, respectively. The highest conversion rate to pasture refers to the Amazon region, with an increase in the order of almost 380%, from 14 to 53 million hectares. This scenario implies that there are many new opportunities for invasion due to species introductions, increased fragmentation, and increasing access to new areas. Therefore, the inclusion of invasive species as a priority issue in conservation planning is an urgent need. The same level of urgency applies to PA and other natural areas of importance for the conservation of biodiversity and ecosystem services, as well as for resilience against climate change.

A reviewed National Strategy on Invasive Species was published by the Ministry of Environment in 2018 (MMA 2018a) along with a program of work (MMA 2018b). The program is organized in five components: legislation, intersectorial integration and international cooperation; prevention, early detection and rapid response; eradication, control and impact mitigation; scientific research; capacity building; and communications. The program of work was developed by a large number of government agencies, research, and not-for-profit institutions and is overseen by the Ministry of Environment. While this is a positive step forward, legal instruments are lacking to ensure implementation of practical measures and to provide reference on which species are considered invasive in the different ecoregions in Brazil. The main environmental laws that mention invasive alien species only refer to them in one or two articles (Law on Crimes to the Environment, 1998, and Law on the National System of Protected Areas, 2000). Regulations on the control of nuisance species included invasive species in 2006 (IBAMA Normative Instruction no. 141, 2006). Still, the main gaps in national terms may be the lack of official reference on invasive species, as only three states have published official lists, and lack of awareness and capacity for implementation of practical measures.

Acknowledgements

To Instituto Socioambiental for providing the cartographic base of protected areas in Brazil. To Alexandre Marcel S. Machado and Eduardo L. H. Giehl for their useful suggestions on the maps.

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Table 2.3 Numbers of invasive alien species (N IAS) and percentage of invasive alien species (% of IAS) identified in Brazilian state and federal (Management) protected areas in decreasing order.

Protected area	N IAS	% of IAS	Management	Class
APA Guaraqueçaba	41	19.1	State	Sustainable Use
APA Estadual da Escarpa Devoniana	40	18.6	State	Sustainable Use
APA de Tamoios	34	15.8	State	Sustainable Use
APA de Guaraqueçaba	31	14.4	Federal	Sustainable Use
PES de Vila Velha	31	14.4	State	Strict Protection
PARNA de Brasília	29	13.5	Federal	Strict Protection
APA de Guadalupe	25	11.6	State	Sustainable Use
PES da Ilha Grande	25	11.6	State	Strict Protection
PARNA da Tijuca	24	11.2	Federal	Strict Protection
REBIO de Saltinho	22	10.2	Federal	Strict Protection
APA das Ilhas e Várzeas do Rio Paraná	21	9.8	Federal	Sustainable Use
APA do Banhado Grande	21	9.8	State	Sustainable Use
PES Turístico do Alto Ribeira – PETAR	21	9.8	State	Strict Protection
APA do Planalto Central	20	9.3	Federal	Sustainable Use
PES Sumaúma	19	8.8	State	Strict Protection
APA Cananéia – Iguape – Peruíbe	18	8.4	Federal	Sustainable Use
APA Guaratuba	17	7.9	State	Sustainable Use
APA do Litoral Norte do Estado da Bahia	16	7.4	State	Sustainable Use
APA Estadual do Iraí	15	7.0	State	Sustainable Use
PES do Juquery	15	7.0	State	Strict Protection
PES do Rio Vermelho	15	7.0	State	Strict Protection
APA Rota do Sol	13	6.0	State	Sustainable Use
PES da Fonte Grande	13	6.0	State	Strict Protection
APA Bonfim/Guaraíra	12	5.6	State	Sustainable Use
APA das Setiba	12	5.6	State	Sustainable Use
APA dos Quilombos do Médio Ribeira	12	5.6	State	Sustainable Use
PARNA da Serra da Bocaina	12	5.6	Federal	Strict Protection
PARNA de Itatiaia	12	5.6	Federal	Strict Protection
PARNA do Superagui	12	5.6	Federal	Strict Protection
PES da Pedra Branca	12	5.6	State	Strict Protection
APA Corumbatai, Botucatu e Tejupá	11	5.1	State	Sustainable Use
APA dos Rios Piracicaba e Juqueri-Mirim	11	5.1	State	Sustainable Use
APA Petrópolis	11	5.1	Federal	Sustainable Use
PES da Cachoeira da Fumaça	11	5.1	State	Strict Protection
PES da Serra da Tiririca	11	5.1	State	Strict Protection
APA Sistema Cantareira	10	4.7	State	Sustainable Use
ESEC Estadual de Guaxindiba	10	4.7	State	Strict Protection

Table 2.3 (Continued)

Protected area	N IAS	% of IAS	Management	Class
PARNA de Aparados da Serra	10	4.7	Federal	Strict Protection
REBIO de Poço das Antas	10	4.7	Federal	Strict Protection
APA da Bacia do Rio São João/ Mico-Leão-Dourado	9	4.2	Federal	Sustainable Use
PARNA Cavernas do Peruaçu	9	4.2	Federal	Strict Protection
PARNA da Serra Geral	9	4.2	Federal	Strict Protection
APA Cavernas do Peruaçu	8	3.7	Federal	Sustainable Use
PARNA da Restinga de Jurubatiba	8	3.7	Federal	Strict Protection
PES das Araucárias	8	3.7	State	Strict Protection
APA de Massambaba	7	3.3	State	Sustainable Use
APA Ituparanga	7	3.3	State	Sustainable Use
APA Mananciais da Bacia do Rio Paraíba do Sul	7	3.3	Federal	Sustainable Use
PARNA da Serra dos Órgãos	7	3.3	Federal	Strict Protection
PARNA de Saint-Hilaire/Lange	7	3.3	Federal	Strict Protection
PES da Serra do Tabuleiro	7	3.3	State	Strict Protection
REBIO da Serra Geral	7	3.3	State	Strict Protection
REBIO de Duas Bocas	7	3.3	State	Strict Protection
REBIO de Praia do Sul	7	3.3	State	Strict Protection
RVS Banhado dos Pachecos	7	3.3	State	Strict Protection
APA de Conceição da Barra	6	2.8	State	Sustainable Use
APA de Murici	6	2.8	State	Sustainable Use
APA do Lago de Sobradinho	6	2.8	State	Sustainable Use
APA do Rio Guandu	6	2.8	State	Sustainable Use
APA Ibitinga	6	2.8	State	Sustainable Use
PARNA da Serra da Canastra	6	2.8	Federal	Strict Protection
PARNA dos Lençóis Maranhenses	6	2.8	Federal	Strict Protection
PES de Itapeva	6	2.8	State	Strict Protection
PES Paulo Cesar Vinha	6	2.8	State	Strict Protection
APA da Baleia Franca	5	2.3	Federal	Sustainable Use
APA da Chapada dos Guimarães	5	2.3	State	Sustainable Use
APA da Serra da Mantiqueira	5	2.3	Federal	Sustainable Use
APA do Catolé e de Fernão Velho	5	2.3	State	Sustainable Use
APA do Passaúna	5	2.3	State	Sustainable Use
APA do Pau Brasil	5	2.3	State	Sustainable Use
APA Litoral Sul do Estado de Sergipe	5	2.3	State	Sustainable Use
APA Morro da Pedreira	5	2.3	Federal	Sustainable Use
APA Upaon-Açu/Miritiba/Alto Preguiças	5	2.3	State	Sustainable Use

(*Continued*)

Table 2.3 (Continued)

Protected area	N IAS	% of IAS	Management	Class
ESEC de Aracuri-Esmeralda	5	2.3	Federal	Strict Protection
FLONA de Canela	5	2.3	Federal	Sustainable Use
FLONA Passo Fundo	5	2.3	Federal	Sustainable Use
PARNA do Caparaó	5	2.3	Federal	Strict Protection
PARNA do Catimbau	5	2.3	Federal	Strict Protection
PES do Mendanha	5	2.3	State	Strict Protection
PES do Rio Doce	5	2.3	State	Strict Protection
PES Itacolomi	5	2.3	State	Strict Protection
REBIO do Mato Grande	5	2.3	State	Strict Protection
REBIO União	5	2.3	Federal	Strict Protection
APA Baixada Maranhense	4	1.9	State	Sustainable Use
APA Campos do Jordão	4	1.9	State	Sustainable Use
APA da Serra do Mar	4	1.9	State	Sustainable Use
APA de Mangaratiba	4	1.9	State	Sustainable Use
APA de Piaçabuçu	4	1.9	Federal	Sustainable Use
APA de Santa Cruz	4	1.9	State	Sustainable Use
APA de Santa Rita	4	1.9	State	Sustainable Use
APA do Lago de Pedra do Cavalo	4	1.9	State	Sustainable Use
APA Jundiaí	4	1.9	State	Sustainable Use
APA Serra da Ibiapaba	4	1.9	Federal	Sustainable Use
ESEC de Carijós	4	1.9	Federal	Strict Protection
FLONA de Carajás	4	1.9	Federal	Sustainable Use
FLONA de Ibirama	4	1.9	Federal	Sustainable Use
FLONA São Francisco de Paula	4	1.9	Federal	Sustainable Use
PARNA da Chapada Diamantina	4	1.9	Federal	Strict Protection
PARNA de São Joaquim	4	1.9	Federal	Strict Protection
PES Alberto Lofgren (Horto)	4	1.9	State	Strict Protection
PES Carlos Botelho	4	1.9	State	Strict Protection
PES da Costa do Sol	4	1.9	State	Strict Protection
PES dos Três Picos	4	1.9	State	Strict Protection
REBIO Marinha do Arvoredo	4	1.9	Federal	Strict Protection
APA da Ponta da Baleia/Abrolhos	3	1.4	State	Sustainable Use
APA da Serra de Baturité	3	1.4	State	Sustainable Use
APA das Bacias dos Córregos Gama e Cabeça de Veado	3	1.4	State	Sustainable Use
APA de Guapimirim	3	1.4	Federal	Sustainable Use
APA de Santo Antônio	3	1.4	State	Sustainable Use

Table 2.3 (Continued)

Protected area	N IAS	% of IAS	Management	Class
APA Delta do Parnaíba	3	1.4	Federal	Sustainable Use
APA do Ibirapuitã	3	1.4	Federal	Sustainable Use
APA Estadual da Serra da Esperança	3	1.4	State	Sustainable Use
APA Marinha do Litoral Norte	3	1.4	State	Sustainable Use
APA Pouso Alto	3	1.4	State	Sustainable Use
APA Sul RMBH	3	1.4	State	Sustainable Use
ESEC Aratinga	3	1.4	State	Strict Protection
ESEC da Guanabara	3	1.4	Federal	Strict Protection
ESEC do Caiuá	3	1.4	State	Strict Protection
ESEC Juréia-Itatins	3	1.4	State	Strict Protection
FLONA de Ipanema	3	1.4	Federal	Sustainable Use
FLONA Rio Preto	3	1.4	Federal	Sustainable Use
PARNA da Lagoa do Peixe	3	1.4	Federal	Strict Protection
PES Cunhambebe	3	1.4	State	Strict Protection
PES da Ilha Anchieta	3	1.4	State	Strict Protection
PES da Serra do Mar	3	1.4	State	Strict Protection
PES de Vassununga	3	1.4	State	Strict Protection
PES Fritz Plaumann	3	1.4	State	Strict Protection
PES Pico do Marumbi	3	1.4	State	Strict Protection
REBIO do Gurupi	3	1.4	Federal	Strict Protection
REBIO Mata Paludosa	3	1.4	State	Strict Protection
APA Anhatomirim	2	0.9	Federal	Sustainable Use
APA Área Estuarina do Canal de Santa Cruz	2	0.9	State	Sustainable Use
APA Chapada do Araripe	2	0.9	Federal	Sustainable Use
APA Costa de Itacaré/ Serra Grande	2	0.9	State	Sustainable Use
APA da Baía de Todos os Santos	2	0.9	State	Sustainable Use
APA da Serra da Sapiatiba	2	0.9	State	Sustainable Use
APA de Cafuringa	2	0.9	State	Sustainable Use
APA de Goiapaba-Açu	2	0.9	State	Sustainable Use
APA de Macaé de Cima	2	0.9	State	Sustainable Use
APA do Alto Iguaçu	2	0.9	State	Sustainable Use
APA do Delta do Rio Parnaíba	2	0.9	State	Sustainable Use
APA do Igarapé Gelado	2	0.9	Federal	Sustainable Use
APA do Lago Paranoá	2	0.9	State	Sustainable Use
APA Leandro (Ilha do Bananal/Cantão)	2	0.9	State	Sustainable Use
APA Nascentes do Rio Paraguai	2	0.9	State	Sustainable Use

(*Continued*)

Table 2.3 (Continued)

Protected area	N IAS	% of IAS	Management	Class
APA Rio Batalha	2	0.9	State	Sustainable Use
ARIE Cerrado Pé-de-Gigante	2	0.9	Federal	Sustainable Use
ESEC de Itirapina	2	0.9	State	Strict Protection
ESEC do Paraíso	2	0.9	State	Strict Protection
FES do Palmito	2	0.9	State	Sustainable Use
PARNA Boqueirão da onça	2	0.9	Federal	Strict Protection
PARNA da Chapada dos Guimarães	2	0.9	Federal	Strict Protection
PARNA das Araucárias	2	0.9	Federal	Strict Protection
PARNA do Descobrimento	2	0.9	Federal	Strict Protection
PARNA do Iguaçu	2	0.9	Federal	Strict Protection
PARNA do Serra do Itajaí	2	0.9	Federal	Strict Protection
PARNA Grande Sertão Veredas	2	0.9	Federal	Strict Protection
PARNA Serra de Itabaiana	2	0.9	Federal	Strict Protection
PES das Fontes do Ipiranga	2	0.9	State	Strict Protection
PES de Ilhabela	2	0.9	State	Strict Protection
PES de Porto Ferreira	2	0.9	State	Strict Protection
REBIO de Sooretama	2	0.9	Federal	Strict Protection
RESEX do Batoque	2	0.9	Federal	Sustainable Use
APA Aldeia-Beberibe	1	0.5	State	Sustainable Use
APA Algodoal-Maiandeua	1	0.5	State	Sustainable Use
APA Área Estuarina dos Rios Goiana e Megaó	1	0.5	State	Sustainable Use
APA Caminhos Ecológicos da Boa Esperança	1	0.5	State	Sustainable Use
APA Carste de Lagoa Santa	1	0.5	Federal	Sustainable Use
APA Caverna do Maroaga (Presidente Figueiredo)	1	0.5	State	Sustainable Use
APA da Bacia do Rio Descoberto	1	0.5	Federal	Sustainable Use
APA da Baía de Camamu	1	0.5	State	Sustainable Use
APA da Foz do Rio das Preguiças	1	0.5	State	Sustainable Use
APA da Ilha Comprida	1	0.5	State	Sustainable Use
APA da Lagoa de Jijoca	1	0.5	State	Sustainable Use
APA da Plataforma Continental do Litoral Norte	1	0.5	State	Sustainable Use
APA das Ilhas de Tinharé e Boipeba	1	0.5	State	Sustainable Use
APA de Guaibim	1	0.5	State	Sustainable Use
APA de Maricá	1	0.5	State	Sustainable Use
APA do Pratigi	1	0.5	State	Sustainable Use
APA do Rio Pacoti	1	0.5	State	Sustainable Use

Table 2.3 (Continued)

Protected area	N IAS	% of IAS	Management	Class
APA Dunas e Veredas do Baixo Médio São Francisco	1	0.5	State	Sustainable Use
APA Estadual do Rio Verde	1	0.5	State	Sustainable Use
APA Jalapão	1	0.5	State	Sustainable Use
APA Margem Direita do Rio Negro	1	0.5	State	Sustainable Use
APA Marimbus/Iraquara	1	0.5	State	Sustainable Use
APA Marinha do Litoral Sul	1	0.5	State	Sustainable Use
APA Marituba do Peixe	1	0.5	State	Sustainable Use
APA São Francisco Xavier	1	0.5	State	Sustainable Use
APA Sapucaí-Mirim	1	0.5	State	Sustainable Use
APA Serra da Meruoca	1	0.5	Federal	Sustainable Use
ARIE Parque Juscelino Kubitschek	1	0.5	State	Sustainable Use
ESEC de Águas Emendadas	1	0.5	State	Strict Protection
ESEC de Fechos	1	0.5	State	Strict Protection
ESEC de Jataí	1	0.5	State	Strict Protection
ESEC de Pirapitinga	1	0.5	Federal	Strict Protection
ESEC de Tamoios	1	0.5	Federal	Strict Protection
ESEC dos Caetetus	1	0.5	State	Strict Protection
ESEC Sebastião Aleixo da Silva (Bauru)	1	0.5	State	Strict Protection
ESEC Tripuí	1	0.5	State	Strict Protection
FLONA Araripe-Apodi	1	0.5	Federal	Sustainable Use
FLONA Chapecó	1	0.5	Federal	Sustainable Use
FLONA de Capão Bonito	1	0.5	Federal	Sustainable Use
FLONA de Goytacazes	1	0.5	Federal	Sustainable Use
FLONA de Pacotuba	1	0.5	Federal	Sustainable Use
FLONA de Silvânia	1	0.5	Federal	Sustainable Use
FLONA Passa Quatro	1	0.5	Federal	Sustainable Use
PARNA da Amazônia	1	0.5	Federal	Strict Protection
PARNA da Serra da Bodoquena	1	0.5	Federal	Strict Protection
PARNA da Serra das Confusões	1	0.5	Federal	Strict Protection
PARNA de Ilha Grande	1	0.5	Federal	Strict Protection
PARNA do Pantanal Mato-Grossense	1	0.5	Federal	Strict Protection
PES da Ilha do Cardoso	1	0.5	State	Strict Protection
PES da Serra do Brigadeiro	1	0.5	State	Strict Protection
PES de Campos do Jordão	1	0.5	State	Strict Protection
PES de Forno Grande	1	0.5	State	Strict Protection
PES de Itapuã	1	0.5	State	Strict Protection

(*Continued*)

Table 2.3 (Continued)

Protected area	N IAS	% of IAS	Management	Class
PES de Pedra Azul	1	0.5	State	Strict Protection
PES do Cerrado	1	0.5	State	Strict Protection
PES do Cocó	1	0.5	State	Strict Protection
PES do Delta do Jacuí	1	0.5	State	Strict Protection
PES do Grajaú	1	0.5	State	Strict Protection
PES do Lago Azul	1	0.5	State	Strict Protection
PES do Morro do Diabo	1	0.5	State	Strict Protection
PES do Rio Ivinhema	1	0.5	State	Strict Protection
PES do Sumidouro	1	0.5	State	Strict Protection
PES do Tainhas	1	0.5	State	Strict Protection
PES Ibitipoca	1	0.5	State	Strict Protection
PES Mata dos Godoy	1	0.5	State	Strict Protection
PES Pico do Jabre	1	0.5	State	Strict Protection
PES Serra de Santa Bárbara	1	0.5	State	Strict Protection
PES Vila Rica do Espírito Santo	1	0.5	State	Strict Protection
REBIO de São Donato	1	0.5	State	Strict Protection
REBIO de Una	1	0.5	Federal	Strict Protection
REBIO do Aguaí	1	0.5	State	Strict Protection
REBIO do Ibirapuitã	1	0.5	State	Strict Protection
REBIO do Lago de Piratuba	1	0.5	Federal	Strict Protection
REBIO do Tinguá	1	0.5	Federal	Strict Protection
RESEC de Jacarenema	1	0.5	State	Strict Protection
RESEC de Jacarepiá	1	0.5	State	Strict Protection
RESEX do Rio Cajari	1	0.5	Federal	Sustainable Use
RESEX Marinha da Lagoa do Jequiá	1	0.5	Federal	Sustainable Use
RESEX Marinha de Caeté-Taperaçu	1	0.5	Federal	Sustainable Use
RESEX Marinha do Delta do Parnaíba	1	0.5	Federal	Sustainable Use
RVS Mata da Usina São José	1	0.5	State	Strict Protection
RVS Mata do Curado	1	0.5	State	Strict Protection

The protected areas were classified in two classes: Sustainable Use and Strict Protection (last column). Strict protection areas are more restrictive: The direct use of natural resources is prohibited, and management is focused on research, conservation, and education; whereas in the Sustainable Use class, the sustainable use of natural resources is allowed as well as some other activities that aim to harmonize human settlement with income generation and land use. There are different categories in each of these management classes (Sustainable Use – APA: Environmental Protection Area [*Área de proteção ambiental*], ARIE: Area of Relevant Ecological Interest [*Área de Relevante Interesse Ecológico*], FLONA: National Forest [*Floresta Nacional*], FES: State Forest [*Floresta Estadual*], and RESEX: Extractive Reserve [*Reserva Extrativista*]; and Strict Protection – PARNA: National Park [*Parque Nacional*], PES: State Park [*Parque Estadual*], ESEC: Ecological Station [*Estação Ecológica*], REBIO: Biological Reserve [*Reserva Biológica*], ESEC: Ecological Reserve [*Reserva Ecológica*], and RVS: Wildlife refuge [*Refúgio de Vida Silvestre*]).