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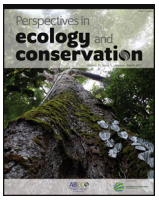

Research Letters

A systematization of information on Brazilian Federal protected areas with management actions for Animal Invasive Alien Species

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ABSTRACT

Invasive alien species (IAS) threaten the stability of natural ecosystems and the persistence of several native species. Despite the known occurrence of animal IAS in Brazilian Protected Areas, the lack of systematized information impairs the planning, implementation and improvement of control actions. We identified, listed and evaluated animal invasive alien species control/management actions in federal Brazilian protected areas by reviewing protected areas management plans and applying online questionnaires to protected areas managers. The majority (85%) of the 68 Management Plans that identified the occurrence animal invasive alien species inside the protected areas had only very generic control recommendations. Among 116 respondent managers, 48% declared to perform some invasive alien species management/control actions, which are mainly physical control efforts, due convenience and not necessarily effectiveness of such actions. We point out the need for better integrated management planning and actions in order to control animal IAS in federal Brazilian protected areas.

Invasive alien species (IAS) in protected areas (PA)

The creation and maintenance of PA is a well-established and proven effective strategy for the conservation of biodiversity worldwide, since it mainly prevents habitat loss and fragmentation – the main threats to biodiversity (Rodrigues et al., 2004; Bensusan, 2006). In Brazil, PA have a fundamental role in conservation and the sustainable use of biodiversity. There are two main PA groups: (i) Integral Protection, where only indirect uses of natural resources are accepted and (ii) Sustainable Use, which aim to harmonize conservation with sustainable use of natural resources (Federal Law n° 9.985/2000).

However, PA are not immune to IAS, which are known to occur and cause damage in PA worldwide, including Brazil (Merino et al., 2009; Spear et al., 2011; Sampaio and Schmidt, 2013; Spear et al., 2013; Ziller and Dechoum, 2013) and may threaten PA's conservation and sustainable use goals. Biological invasions are multistage processes which vary widely according to the alien species and the invaded ecosystem (Nentwing, 2007). However, once the invasion is established, the impact is huge and may be irreversible, since effective control actions might be too complex and/or too expensive (Mack et al., 2000; Pimentel, 2011). Thus, from a PA management perspective, as a precaution, species known to be potential invaders should be managed or controlled as soon as their presence is detected. The earlier control actions are undertaken in the invasion process, the higher their chances of success and the lower the costs will be (Mack et al., 2000; Beale et al., 2013).

Rapid responses to prevent and control biological invasions depend directly on managers' knowledge and the perception of risks associated with IAS. In many tropical countries, where deforestation is a growing threat to biodiversity and financial resources for conservation are scarce, it is very common that IAS are not perceived as major threats. As a consequence, information on IAS risks, impacts and control efforts are usually limited. This is the case in Brazil, where lack of systematized information on IAS impacts and control actions impairs the integration and strengthening IAS management efforts, as well as the definition of priorities regarding IAS (Ziller, 2005). In fact, in Brazil, research on biological invasions focused on management and control are still very limited (Zenni et al., 2016).

To date, there is little information on IAS occurrence inside PA in Brazil (Ziller, 2005; Sampaio and Schmidt, 2013; Ziller and Dechoum, 2013), and they are all focused on plant species. The federal system of PA encompasses 327 PA, distributed throughout

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all the Brazilian territory, in all 27 Brazilian states, representing the countries' PA reality. Therefore, identifying actions planned and/or performed with the aim to control animal IAS in Brazilian federal PA can catalyze interest for more research applied to the management of biological invasions in all PA, increase awareness about this threat and help improve management efforts.

To identify planned management actions regarding animal IAS in federal PA, we analyzed all PA Management Plans (MP) available on the website of the governmental agency responsible for federal PA management (www.icmbio.gov.br. until December 2013). This is the official website for federal PA, where all published management plans for federal PA are available. To identify management actions carried out by PA staff, we sent a questionnaire to managers of all 313 federal PA (existing at the time) managed by ICMBio (Chico Mendes Institute for Biodiversity Conservation), in July 2014 using Google Forms (see S2).

IAS management actions indicated in the management plans

Of the 90 existing MP for federal PA, 68 recorded animal IAS occurrence (48 Integral Protection PA and 20 Sustainable Use PA), of which 58 (85%) recommended some IAS control action (43 of Integral Protection and 15 Sustainable Use, Table 1). However, most of these recommendations were very generic (Figure S1), and the development of studies on animal IAS was the most commonly recommended action. Only three MP pointed out specific recommendations regarding animal IAS control, and none had a specific IAS control program.

It is important to note that part of these MP are outdated, for example, the MP for Amazonia National Park was published in 1978 and has not been reviewed since. This may explain the poor information or even lack of interest in the subject of IAS. However, 48.8% of the MP were published in the last ten years and also mostly lack information on IAS and possible actions for detecting and managing biological invasions.

The Management Plan is an important instrument for PA implementation worldwide (MacKinnon et al., 1990). In Brazilian PA, MP should establish zoning and standards that should regulate the use and management of PA (Federal Law n° 9.985/2000). Much of the management carried out in Brazil is based on the MP, which is why it is essential they include specific actions on IAS prevention and control. This is especially key in PA where IAS occurrence has been identified. The absence of specific controlling recommendations may lead staff to conclude that the presence of IAS is not a threat to biological conservation. Currently methodological guidelines for the drafting of MP do not request the planning of actions related to IAS management. The revision of such guidelines and inclusion of a specific program centered on the prevention of the introduction and control of IAS is urgent.

It is essential to point out that the lack of MP or its inaccuracy should not impair IAS control efforts within PA. The need to protect natural resources within PA is independent of any MP (Federal Law n° 9.985/2000), and IAS are legally recognized as an environmental threat that should be avoided (National Biodiversity Commission Resolution n° 05/2009). Early detection and rapid response are known to be the best strategies to control and eradicate IAS worldwide (Mack et al., 2000; Simberloff, 2003; Pluess et al., 2012; Ziller and Dechoum, 2013). In this context, deciding not to manage and/or failing to make a management decision regarding the control of animal IAS may represent losing the sole opportunity to effectively control IAS and promote conservation within PA (Oliveira and Pereira, 2010).

IAS management actions performed in federal PA

Managers from 116 Brazilian federal PA (36% of federal PA; Fig. 1) answered our questionnaire about the occurrence of IAS (Figure S2). Of these PA, 95.6% (111) have registered the presence of IAS, and control actions have been performed in 50 PA (45.0% of the PA with IAS; Table 1). No IAS control actions have been carried out in the other 61 PA where the existence of IAS is known. For five PAs, the managers declared that there are no IAS in the PA. This low proportion of PA with prevention or control actions can result from lack of structure, money and/or staff to carry out management activities, which is quite common in Brazilian PA. However, this may also reflect a perception that IAS do not represent an actual threat to biodiversity, which might be a mistake with severe consequences for PA effectiveness in conserving native biodiversity and ecosystems.

Although the MP of 58 PA included some recommendations regarding IAS control, in 58.6% of these cases (34 PA) no IAS control actions seem to be carried out. Whereas in 19 PA managers reported performing control actions that did not reflect the MP recommendations, mostly because the MP indicated mostly very generic actions. In only five PA we identified the implementation of IAS control actions that followed the MP recommendations. There were PA's managers that reported to perform IAS control actions in PA which the MP did not indicate the need for IAS control (10) or in PA with no MP (16).

These results indicate that most federal PA have registered the presence of IAS but no control actions are performed. In addition, when control actions are performed, they are carried out independently from the PA long-term planning outlined in the MP. The limited efficiency of the MP in promoting controlling of IAS may be related to recent invasions (IAS were not present when MP was written) and especially to the lack of objectivity in the MP recommendations, reinforcing the idea that MP may be negligent toward biological invasions.

The species most commonly managed are the wild boar (*Sus scrofa*) and sun coral (*Tubastraea coccinea* and *Tubastraea tagusensis*). Presently, the Brazilian government, through the Ministry of the Environment, is drafting National Control Plans precisely for these three species (MMA, 2016). With exception of sun coral and golden mussel, aquatic animals are in general not perceived as a problem and the invasive fish species are the least managed invasive species in PA.

The main animal IAS control techniques reported were mechanical removal of individuals by trapping, hunting or fishing, that is killing the individuals directly or euthanasia after capture ($n = 32$; Figure S3) (Wittenberg and Cock, 2001; Clout and Williams, 2009). The reasons to use mechanical methods can be associated with the low cost compared to other techniques such as translocations and castration, but also with the aims of maximizing the effect on the target species, avoiding adverse consequences to ecosystems and/or other species (Mack et al., 2000; Wittenberg and Cock, 2001).

Another common response was to 'capture and move to another destination' ($n = 7$), mainly performed due to inadequate legislation and/or public opposition to animal euthanasia. In these cases, specialized institutions such as Wild Animal Triage Center (in Brazil, CETAS), commonly refuse to receive large animals and/or large quantities of individuals ($n = 4$), decreasing the effectiveness of such a strategy. Managers declared that reintroducing individuals into their species original range was impossible due to logistics, costs and unknown possible effects of such translocations ($n = 7$).

Our results indicated that the main reasons for the choice of control methods in Brazilian PA were the feasibility, low cost and/or low staff demand, and not necessarily the effectiveness of the method. This is quite hazardous, since adequate funding and the adoption of scientific-based actions are known to be the

Table 1
Number and percentage of PA with records of animal IAS that have management plan (MP) and number of implemented actions (regardless of the existence of a MP) by category and group.

Group	Category	Number of PA with IAS in the MP	Number of PA with IAS with recommendations on MP	% Of PA with IAS with recommendations on MP	PA with control action implemented
Integral protection	PARNA	29	25	86%	14
	ESEC	10	9	90%	9
	REBIO	9	9	100%	8
	REVIS	0	0	0%	0
	MONA	0	0	0%	0
		48	43	90%	31
Sustainable use	FLONA	11	8	73%	14
	RESEX	1	1	100%	1
	APA	6	5	83%	4
	ARIE	2	1	50%	0
	RDS	0	0	0%	0
		20	15	75%	19
	Total	68	58	85%	50

The abbreviations of PA categories are in Portuguese: PARNA, National Park; ESEC, Ecological Station; REBIO, Biological Reserve; REVIS, Wildlife Refuge; MONA, Natural Monument; FLONA, National Forest; RESEX, Extractive Reserve; APA, Environmental Protection Area; ARIE, Relevant Ecological Interest Area; RDS, Sustainable Development Reserve.

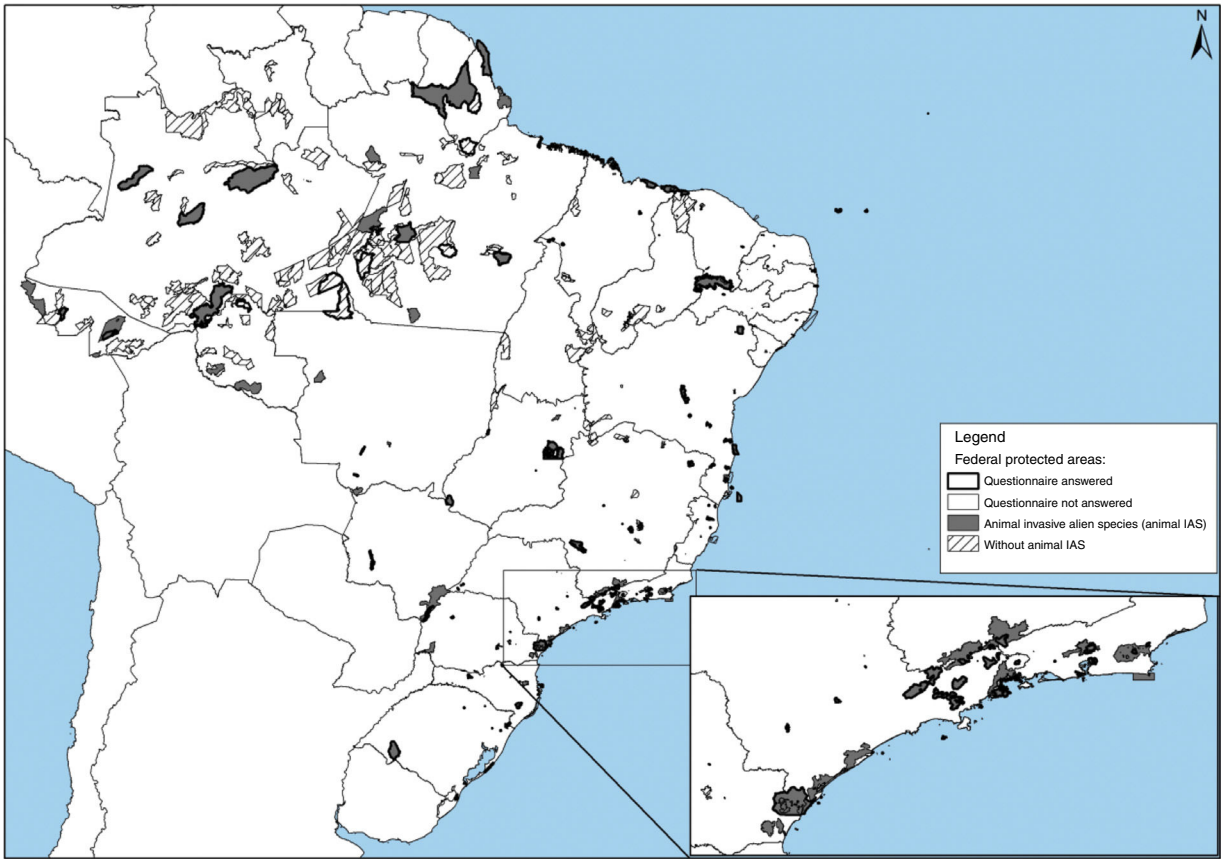

Fig. 1. Map with federal PA, indicating the PA whose managers answered the questionnaires and in which there are animal IAS records.

major reasons for IAS successful eradications (Genovesi, 2005). In fact, satisfactory financing is usually required for successful actions, given the need for continuity (Mack et al., 2000; Simberloff, 2003; Genovesi, 2005). However, sufficient resources are generally available only when the IAS cause economic impact, whereas usually, ecological impact is ignored (Manchester and Bullock, 2000).

Management programs conducted in partnership can save financial resources and provide social benefits, enhancing the sustainability of IAS control actions (Sharp and Saunders, 2012). Mechanical control methods can be performed by trained volunteers, reducing costs and increasing the viability and success of IAS management (Wittenberg and Cock, 2001). Unfortunately, in Brazil, volunteers are still rarely involved in controlling IAS, especially animals.

Aside from money and staff limitations, precarious infrastructure, logistics and legal framework also impair animal IAS in Brazilian PA. For example, animal destination and euthanasia are not regulated; hunting in Brazil is mainly prohibited (except for subsistence by traditional communities), which has been reported

to impair animal IAS control in other countries (Genovesi, 2005; Manchester and Bullock, 2000; Clout and Williams, 2009). Legal restrictions can be even more problematic for IAS management inside PA.

Public opposition is also an important challenge to control animal IAS (Mack et al., 2000; Simberloff, 2003; Genovesi, 2005), especially for charismatic species (Oliveira and Pereira, 2010). This opposition is based on the lack of perception of the impact of IAS on native species and ecosystems, and on the fact that the main forms of management imply the death of IAS individuals. Public opposition can be decreased by general public outreach and information spreading on IAS impacts (Mack et al., 2000; Genovesi, 2005; Oliveira and Pereira, 2010), which is nearly non-existent in Brazil.

Only the boar can be legally hunted in order to control invasive populations in Brazil (Brazilian Institute of Environment and Renewable Natural Resources – IBAMA Normative Instruction n° 03/2013). Even in the case of this non-charismatic species, with specific regulations, public opposition to control is quite frequent (Castro, 2016; Giovanini, 2016). For animal IAS control actions to be more effective in Brazil, regulating feral animal euthanasia is essential. For that, public participation and outreach campaigns to expose IAS control importance are crucial. Finally, there is no specific department responsible for biological invasion management in federal agencies in Brazil, not even within the Environmental Ministry. The lack of such instances is an identified barrier to implement the control and monitoring of IAS in PA. It is essential that several public institutions can articulate collaborative actions regarding IAS control, since these species do not recognize state, country or PA limits. In Brazil, at the federal level, there is a need for complementary actions among the environmental agencies, since ICMBio manages federal PA, IBAMA regulates and enforces environmental use rules (including authorization of introduction and control of alien fauna throughout the national territory, and the use of hunting and chemical products in rural and natural areas) and the Ministry for Environment (MMA) coordinates public policy creation. If public policies and actions regarding IAS management and control are not clearly coordinated at the federal level, it will be hard for state level agencies to collaborate on IAS across state limits.

Recommendations

Biological invasions are a main threat to biodiversity. Contrastingly, our results indicate that the management agencies of PA in the species richest country in the world mostly ignore their threat. Below we have listed some urgent recommendations aiming to change this scenario:

1. A specific program regarding the prevention and control of IAS should be required in all PA MP, especially those where IAS occurrence has been identified. For that, the methodological guide for MP development needs to be reviewed.
2. Euthanasia of feral individuals should be regulated. This process needs to be combined with outreach and education about the need to control IAS due to their impact, in order to build public support.
3. Volunteer training Programs in PA should consider IAS management and outreach to help compensate for limitations in staff and to build public support.
4. PA should establish as many partnerships as possible with NGOs and research institutions in order to plan and implement IAS control and monitoring actions as well as research programs to help develop and test adequate IAS control practices.
5. The Brazilian government should consider creating a national fund and/or specific grant programs to induce applied research, monitoring and control of IAS.
6. Federal institutions need to define institutional divisions or departments to define guidelines; coordinate management actions regarding IAS prevention and control and to establish monitoring networks to improve institution abilities to deal with this important threat that until now has been nearly ignored in Brazil.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.pecon.2017.06.005.

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