



The financial needs vs. the realities of *in situ* conservation: an analysis of federal funding for protected areas in Brazil's Caatinga

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ABSTRACT

In situ conservation is an effective strategy to protect biodiversity, and Brazil has one of the largest protected area (PA) systems in the world. However, the distribution of Brazilian PAs is uneven and the Caatinga drylands are poorly protected. As financial resources are essential for effectively managing PAs, we analyzed the Brazilian Government's budget allocated to 20 federal PAs in the Caatinga between 2008 and 2014, which ranged from 231,575 USD in 2008 to 13.5 Mi USD in 2011. Neither expenses, nor the availability of funds, were homogeneous among PAs or throughout the years. Land acquisition in a single PA consumed ~75% of the budget, and the two smallest PAs received proportionally the most money. Excluding land acquisition, the 20 PAs received 0.50 USD/ha/year. Funds were allocated not to biodiversity conservation *per se* but mainly to securing offices, cars, and equipment. From 2012 onwards, the PA budget was reduced. Even including salaries, the budget allocated for these PAs is ~13 times lower than what the Ministry of the Environment declared necessary for the basic operation of protected areas in Brazil, 1.5 times lower than values spent worldwide, up to 5 times lower than spent in Latin American and African parks, and up to 72 times lower than spent in the European Union, exposing one cause of the precarious situation of the Caatinga PAs.

Abstract in Portuguese is available with online material.

Key words: conservation budget; funding shortfall; parks and reserves; protected area systems.

THE SIX TERRESTRIAL BIOMES OF BRAZIL (AMAZON, CERRADO, CAATINGA, ATLANTIC FOREST, PANTANAL, AND PAMPAS) are among the richest and most diverse in the world, harboring much of the biodiversity known to science (Brooks *et al.* 2006, ICMBio, 2017). As part of the strategy to protect this biodiversity, Brazil established one of the largest systems of protected areas (hereafter PAs) in the world, with *ca.* 2.2 million km² (WDPA 2016). Excluding indigenous lands, *quilombos* (areas owned by traditional slave-descendants), and military PAs, Brazil currently has 954 federal, 795 state, and 230 municipal parks and reserves (locally known as *unidades de conservação*), which cover *ca.* 1.55 million km² (Brasil, 2000; MMA 2016). The Chico Mendes Institute for Biodiversity Conservation (ICMBio), an autarchy under the Ministry for the Environment, manages the federal PAs. Despite their large extent, coverage by PAs is heterogeneous. Amazonia has the largest percentage of protected territory (~27%), whereas this percentage varies from 2.7% to 9.9% in other terrestrial biomes (MMA 2016).

The Caatinga drylands of Northeastern Brazil comprise 844,453 km², representing ~10% of the Brazilian territory (IBGE 2016), and are among the least protected biomes in the country. The Caatinga was long seen as a biologically poor area due to its water scarcity (Castelletti *et al.* 2003). However, recent studies have changed this view. In the Caatinga, 4846 angiosperm, over

240 fish, 160 reptile, 515 bird, and 148 mammal species have been recognized (Leal *et al.* 2003, Santos *et al.* 2011, Flora do Brasil 2015). Currently, the Caatinga is considered to have high biodiversity and endemism (Leal *et al.* 2003, Hauff 2010) and is among the richest dry forests in the world (Portillo-Quintero & Sánchez-Azofeifa 2010, Portillo-Quintero *et al.* 2015).

In the Caatinga, 157 federal, state, and municipal PAs cover ~7.5% of the biome (MMA 2016). However, only ~1.2% of the Caatinga has full protection. Together, the 24 federal PAs of the Caatinga cover 4,146,696.32 ha (MMA 2016), but most are under the least restrictive conservation category in Brazil (IUCN category V). Despite its biological importance, the Caatinga experiences strong pressure from humans and ~46% of its area has been deforested (MMA 2015). Among the main threats are deforestation for livestock farming (mostly caprine), logging for firewood, agriculture, hunting, and fragmentation by roads or misuse of fire (Castelletti *et al.* 2003, Leal *et al.* 2005). In addition, the Caatinga is one of the poorest regions in Brazil, has areas under advanced desertification, and may face intensive transformation from climate change (Seddon *et al.* 2016).

Funding is essential for the management of PAs (Leverington *et al.* 2010, Watson *et al.* 2014). The proportion of investment in PAs varies greatly among countries (Balmford *et al.* 2003), and developed countries tend to invest more than developing countries (Bruner *et al.* 2004). There has been a recent increase in worldwide PAs (WDPA 2016) and an effort to consolidate them, yet funding has not kept apace (Watson *et al.* 2014). This

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situation is no better in Brazil (Chiaravalloti *et al.* 2015), where the main income source for the maintenance of PAs is the public budget (Geluda & Serrão 2014). Successive cuts in the budget of the Ministry for the Environment have recently exacerbated the financial situation (Bragança 2013, Pegurier 2015).

Considering the biological richness of the Caatinga, its concerning conservation status, and the potential detrimental effect of climate change on the region, extant PAs in the Caatinga will only become more important for *in situ* protection of biodiversity. However, will the PAs be prepared for these challenges? We analyzed an essential element for the effective management of any PA: the availability of financial resources. Here, we (1) present data on funding given by the Brazilian government for the management of 20 federal PAs in the Caatinga during seven years; (2) identify the PAs that received the most resources; (3) report in detail how those resources were spent; and (4) assess the total spent in relation to the areas protected. The choice of the Caatinga aimed to fill an information gap, as this biome is poorly studied in terms of PA management (Hauff 2010), especially with respect to funding. This type of budgetary research can support decision makers and help them improve management planning, through actions that solve funding shortfalls and their consequences for biodiversity conservation.

METHODS

We analyzed the budget of a set of 24 federal PAs in the Caatinga biome, identified according to the list provided by ICMBio (<http://www.icmbio.gov.br/portal/biodiversidade/unidades-de-conservacao/biomas-brasileiros/caatinga/unidades-de-conservacao-caatinga>). Through Law 12,527/2011, popularly known as the 'law on access to public information' (Brasil, 2011), we requested a list of expenses of all federal PAs in the Caatinga between January 2004 and December 2014 from the Ministry of Environment.

We received a table containing the expenses from 2008 to 2014 for 20 out of the 24 PAs, but lacking data for 2004 to 2007, and lacking the Protected Area of Serra da Ibiapaba, the Areas of Relevant Ecological Interest of Cocorobó and Vale dos Dinossauros, and the National Park of Furna Feia. We excluded these PAs from our analysis, which was therefore restricted to 20 federal PAs that together comprise an area of 2,356,490.63 ha (Table 1).

One caveat is that we did not include in our analyses expenses related to personnel, *i.e.*, the wages and bonuses paid to ICMBio's environmental analysts working in our focal PAs. ICMBio does not maintain a public data base with the number and identity of employees at each PA, and our phone calls requesting this information were unsuccessful. The official ICMBio source for data on the 20 PAs we analyzed (CNUC 2017) had no information on staffing. Furthermore, the publicly available information about staff is of questionable quality; we know of at least one PA for which CNUC states there is an on-site manager, but in fact there has been no staff on site for at least two years. Even with data on staffing levels, estimates of personnel expenses would be fraught with the potential for error. Wages can vary for

the same position depending on the level of education or post-employment changes in responsibilities. Commissioned Positions (*Direção e Assessoramento Superiores* – D.A.S.), which may include higher management activities, can vary more than two-fold in salary, based on their salary ranking on a 6-level scale. Because we felt these shortcomings would lead to major errors in estimating the amount spent by the federal government in these parks, we did not include them.

For each PA, we kept track of expense discrimination, values spent per expense item in each year, management category (following the Brazilian National System of Protected Areas), type of use (Full Protection or Sustainable Use), and area (in hectares), all of which were obtained from the website of the ICMBio (<http://www.icmbio.gov.br/portal/>). All values were converted at a rate of 1.00 USD = 3.98 BRL, as in December 2015. We classified expenses in two groups: 'Capital Assets' for the expenses converted into assets of the organ or entity that generated those expenses (*e.g.*, goods, equipment, or vehicles); and 'Costs' for the set of expenses related to the maintenance of basic items (*e.g.*, property security costs, telecommunication costs, and costs related to the maintenance of goods and vehicles) (Table S1).

We summed the respective values for each PA per year to obtain total annual expenses. To obtain a budget variance index, we divided the result of each year by that of the previous year. We calculated the mean of these values per year, and the general mean of PAs. For the analysis of the budgetary performance of a PA, we compared its annual budget with the mean budget of the 20 PAs. To identify budget particularities, such as higher expenses, and proportion among expenses and among PAs, we analyzed expenses on 'Capital Assets' and 'Costs' separately or focused on specific items.

We organized the cost of each item in decreasing order and calculated their percentages in the total budget for all PAs in that period. We identified the item 'Lands' on only two occasions, *i.e.*, funds allocated to pay private owners for their lands to be added to the PA. To obtain the value spent per hectare per year in the 20 PAs, we divided the total budget by the sum of the total area (2,356,490.63 ha) and by 7 years (2008–2014). We made this calculation for 'Costs' and 'Capital Assets' individually, in two scenarios, including and excluding the costs of land acquisition ('Lands'), as this latter used a substantial amount of the funds. We tested two possible correlations (both excluding resources for land acquisition): total budget received and the area of each PA; and USD/ha/yr and area of each PA.

RESULTS

The budget allocated for the 20 PAs varied from 231,575 USD in 2008 to 13.5 Mi USD in 2011 (Table 1). We identified expenses distributed among 122 items: 11 in the category 'Capital Assets' and 111 in the category 'Costs'. These items showed broad variability, from maintenance and conservation of equipment, journal subscriptions and annual fees, to fuels and automotive lubricants and worker's compensation (Table S1). The

TABLE 1. Budgets of 20 Federal Protected Areas in the Caatinga of Northeastern Brazil from 2008 to 2014. The area is expressed in hectares (ha). APA: Área de Proteção Ambiental (Protected Area); ESEC: Estação Ecológica (Ecological Station); FLONA: Floresta Nacional (National Forest); PARN: Parque Nacional (National Park); MN: Monumento Natural (Natural Monument); REBIO: Reserva Biológica (Biological Reserve).

Protected Area	Area (ha)	Total budget (in USD) per year								USD/ha/yr
		2008	2009	2010	2011	2012	2013	2014	Total	
APA Chapada do Araripe	972590.45	2579.65	51524.14	36544.85	31343.58	46129.29	36114.47	57979.41	262215.39	0.04
APA Serra do Meruoca	29361.27	0.00	0.00	0.00	0.00	45.63	4573.26	7734.13	12353.02	0.06
ESEC Aluaba	11746.60	2736.18	59142.20	65952.76	78917.13	80556.52	71010.59	81601.23	439916.60	5.35
ESEC Castanhão	12574.44	1153.02	146.46	1617.95	26.45	0.00	100.41	110.45	3154.75	0.04
ESEC Raso da Catarina	104842.84	25150.75	19311.02	28501.49	50561.14	126136.03	138435.62	225136.46	613232.51	0.84
ESEC Seridó	1123.59	3266.33	36921.63	65671.71	80433.42	80810.89	59825.41	128360.44	455289.84	57.89
FLONA Açú	218.46	5013.41	27841.31	33711.49	36325.36	44372.59	33086.47	66597.39	246948.03	161.49
FLONA Araripe-Apodi	38919.47	2306.96	57,096.97	60469.53	77341.23	72041.25	67352.15	91189.77	427797.87	1.57
FLONA Contendas do Sincorá	11215.78	9094.08	21545.86	27360.57	30,308.11	47467.82	49089.34	52589.20	237454.97	3.02
FLONA Negreiros	3004.52	0.00	988.62	1961.46	1438.17	7221.03	3754.52	864.19	16227.99	0.77
FLONA Palmares	168.21	19532.60	46494.60	41729.28	50705.27	56535.32	60294.38	79579.46	354870.90	301.38
FLONA Sobral	661.01	2010.05	18584.31	17554.69	34305.22	25894.72	36545.63	56661.24	191555.87	41.40
PARN Catimbau	62294.14	3894.22	7355.06	2576.18	31045.31	34737.94	28098.16	49260.25	156967.13	0.36
PARN Chapada Diamantina	152141.87	134515.64	105178.65	39075.29	58648.49	419003.47	67123.67	80220.97	903766.18	0.85
PARN Serra da Capivara	91848.88	2261.31	189608.52	187726.96	295879.97	329237.70	256873.64	643747.63	1905335.72	2.96
PARN Serra das Confusões	823843.08	2512.56	80083.06	12617939.56	12411109.48	110877.02	100455.65	186700.04	25509677.38	4.42
PARN Sete Cidades	6303.64	1155.78	78794.17	81949.39	114174.61	112998.45	90581.43	171250.08	650903.92	14.75
PARN Ubajara	6271.23	11229.09	106759.93	100362.42	108617.08	135820.87	153166.96	184971.15	800927.49	18.24
MN Rio São Francisco	26736.30	0.00	0.00	104.27	17288.03	339.20	0.00	0.00	17731.49	0.09
REBIO Serra Negra	624.85	3163.07	2318.12	3195.64	8660.87	11634.70	8094.16	14084.16	51150.72	11.69
Total	2356490.63	231574.70	909694.64	13414005.49	13517128.94	1741860.43	1264575.91	2178637.67	33257477.77	2.02

budgets with the largest number of items belonged to Ubajara and Chapada Diamantina National Parks and Raso da Catarina Ecological Station (with 59, 57, and 53 items, respectively), whereas the Natural Monument of the São Francisco River showed only three items. The budgets showed a mean of 36 items per PA. The frequency at which those items appeared per PA varied substantially: 43 items appeared only once, and five appeared 18 times each. No item was common to all PAs.

No PA showed a constant budget throughout the years analyzed (Table 1) and the case-by-case analysis revealed extreme variations (up to 165.8 times) in the difference between values designated to a PA, like in Natural Monument of the São Francisco River. On average, interannual budgets varied 7.9-fold. The analysis of annual budgets showed two patterns: in five PAs the general budget decreased over the seven years analyzed (Cantanhão Ecological Station, Negreiros National Forest, Chapada Diamantina and Serra das Confusões National Parks, and Natural Monument of the São Francisco River); while in the other 15 PAs, the budget increased. The total budget of the 20 PAs also showed two patterns: an annual increase from 2008 to 2011, and decrease since 2012.

The sum of all the expenses of the 20 PAs was 33.2 Mi USD (Table 1). Of this, ~24.8 Mi USD was used for land acquisition in Serra das Confusões National Park in 2010 and 2011 (Table S1). The second highest expense of ~5.1 Mi USD was used for ostensible property security in 15 of 20 PAs (Table S1). The amount spent on security increased throughout the study period, from 15,526 USD in 2008 to ~1.2 Mi USD in 2014. In 2008, this item appeared in only two PAs (Contendas do Sincorá and Palmares National Forests), whereas in 2014, 15 PAs included expenses with ostensible security. Of the ~5.1 Mi USD spent on this item, 39.5% was used in only two PAs (Serra da Capivara and Ubajara National Parks).

By dividing the budget spent by the 20 PAs throughout the seven years analyzed and by the total area, we obtained a mean cost of 2.01 USD/ha/yr. After excluding the values spent on land acquisition, the total expenses summed ~8.3 Mi USD, resulting in 0.50 USD/ha/yr (99.6% spent in 'Costs' and 0.4% in 'Capital Assets'). There was no correlation between total budget received and the area of each PA ($P = 0.6959$), or between USD/ha/yr and area of each PA ($P = 0.4419$) (Fig. 1).

DISCUSSION

The present study showed that in spite of the significant value (>33 Mi USD), the budget of the 20 federal PAs in the Brazil's Caatinga was unevenly and disproportionally spent in terms of both the size of the total area considered (>2.3 Mi ha) and the distribution of values among PAs. The values effectively spent per hectare were very low (0.50 USD/ha/yr). Basically, the budgets available for the same PA varied substantially among years, and since 2012 the tendency to provide the PAs with increasing budgets was interrupted and reverted, making the financial outlook of PAs even more unstable.

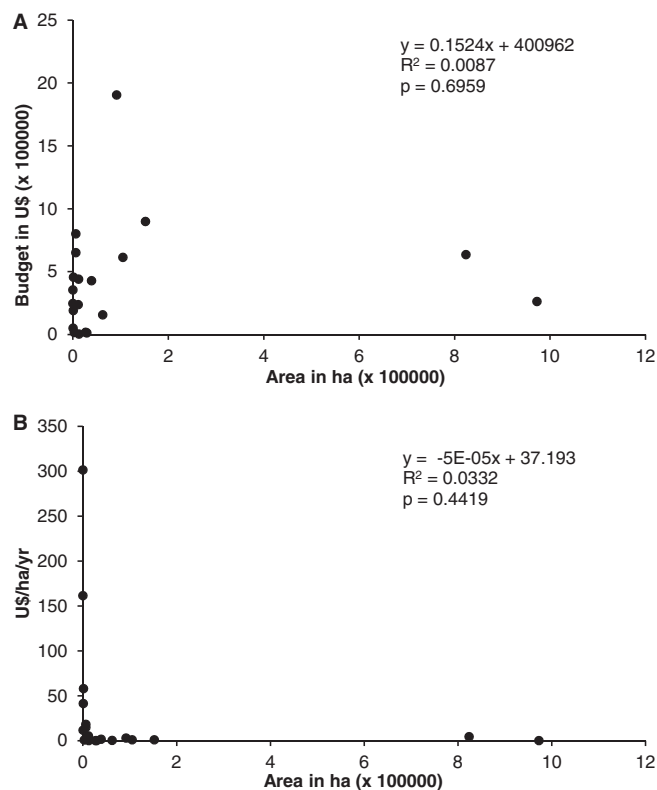


FIGURE 1. Cents per hectares: Correlations between (A) total budget received between 2008 and 2014 and area (in hectares), and (B) USD/ha/yr and area for 20 federal protected areas in Brazil's Caatinga.

The effective management of an area in the PA system is only possible with the regular availability of financial resources (Bruner *et al.* 2001, Leverington *et al.* 2010, Geluda & Serrão 2014). However, for PAs in the Caatinga, budget varied a lot, not only compared to other PAs, but also over time, which hinders planning. The greatest variation occurred in the budget of Monumento Natural do Rio São Francisco: in 2010, total expenses were 104.27 USD and in the following year, ~17,290 USD. Despite the 165-fold variation, the largest budget is not very high for the management of a PA with ~26,700 ha. Such a large variation indicates a lack of budget standardization and planning by the Brazilian federal government. The Brazilian Ministry for the Environment has faced budget cuts in the past years and, consequently, so has the ICMBio, the agency responsible for the management of federal PAs (Bragança 2013). In 2015, the planned resource transfer was the lowest in history (Pegurier 2015), and expenses were curtailed, so that the actual budget was lower than the planned budget. That variation can be explained by recent changes in the political importance given to PAs and the PA system in Brazil (see Bernard *et al.* 2014) as well as by a severe change in the Brazilian economy since 2014.

Ultimately, this lack of standardization compromises the capacity of PAs to effectively protect their biodiversity. Lack of resources is one of the strongest causes of inefficient

management (Watson *et al.* 2014), as without money it is not possible to hire skilled staff or buy equipment (James *et al.* 2001, Bruner *et al.* 2004). Furthermore, essential activities such as controlling, elaboration/execution of management plans, or area demarcation cease, and the area becomes vulnerable.

In addition to year-to-year variation in budget, we detected a recent tendency toward reduced general budgets for the PAs in the Caatinga. However, this is not exclusive to PAs in this biome or Brazil. PAs throughout the world have been receiving fewer investments and developing countries generally have fewer resources for maintaining their parks and reserves (James *et al.* 2001, Bruner *et al.* 2004, Watson *et al.* 2014). Paradoxically, studies show that the cost/benefit relationship in those countries is favorable; *i.e.*, the cost of investments needed to maintain PAs is low relative to the conservation gain they provide (Balmford *et al.* 2003). Reversing this scenario would secure biodiversity conservation for current and future generations and maintain natural resources and ecosystem services such as carbon sequestration, water sources, and pollination. These resources and services are crucial for the future of planetary biodiversity in times of climate change (Malhi *et al.* 2008, Watson *et al.* 2014, Portillo-Quintero *et al.* 2015).

Increasing investment in PAs is an urgent challenge if the benefits they provide are to be maintained. Several countries made this commitment through international agreements (CBD 1992, 2010), some of which include not only maintaining but also expanding national systems of PAs (*e.g.*, Aichi Target 11 – CBD 2010). Despite the worldwide increase in PAs over the past century, their effectiveness is still very low (Watson *et al.* 2014) and they face new threats (Mascia & Pailler 2011, Bernard *et al.* 2014, Mascia *et al.* 2014, Pack *et al.* 2016, WWF 2017). Although Brazil has one of the largest systems of PAs in the world (WDPA 2016), funding remained almost unchanged in the last 10 years, and the value invested per hectare decreased by approximately 40% (Chiaravalloti *et al.* 2015). The investment deficit compromises the maintenance of extant PAs and the creation of new ones (Bruner *et al.* 2004). Besides, the expansion of a system of PAs without its respective implementation does not assure its effective protection (Salmona *et al.* 2014). In the scenario analyzed, some PAs in the Caatinga appear to be working as ‘paper parks’. Indeed, according to the *Cadastro Nacional de Unidades de Conservação* (National Data base of Protected Areas), out of the 20 PAs analyzed in the present study, 12 do not have a management council, 11 do not have a management plan, 10 do not have basic infrastructure, and only seven receive visitors. This scenario puts at risk the effectiveness and integrity of these PAs.

BUDGET PRIORITIES.—Land acquisition in a single PA consumed ~75% of the total budget analyzed. In the set of PAs studied, only two areas were provided with the purchase of lands. This fact shows the discrepancies in the land tenure scenario of parks and reserves in Brazil (Rocha *et al.* 2010, Ferreira 2014, Geluda & Serrão 2014). Indeed, Chapada Diamantina and Serra das Confusões National Parks are among the largest PAs in the

Caatinga, and together represent approximately 42% of the total area of the PAs analyzed. However, as almost all PAs in the Caatinga have problems with land tenure and acquisition (MMA 2015), the distribution of the budget meant to solve this problem should be more egalitarian. The inconclusiveness of the land acquisition process of areas intended to become protected is among the problems faced by PAs in Brazil (Ferreira 2014; MMA 2015). Rocha *et al.* (2010) noticed that 66% of the Brazilian national parks created before 2000 had problems with land tenure. Estimates by ICMBio indicated that three out of 10 ha of federal PAs in Brazil included lands that were not legally transferred to the government, and at least 188 PAs had private properties within their boundaries. The estimated value to expropriate these areas is 3 billion USD (Bragança 2013). The resource transfer to the Ministry for the Environment is insufficient to solve this issue, especially when it faces successive budget cuts.

The second most budget-consuming item was ostensive property security, *i.e.*, the surveillance and security of the offices and their contents within PAs. The ostensive property security must not be confused with controlling activities, which are carried out by skilled environmental analysts settled or not in the PA. Hence, we conclude that the protection of properties (*e.g.*, buildings, equipment, and cars) has been given priority over the protection of biodiversity. Given that some PAs in the Caatinga span vast areas, comprising thousands of hectares, money spent on ostensive property security may do little to conserve their physical integrity (*e.g.*, prevent deforestation or hunting within their boundaries). Indeed, the security expenses in the smallest area studied (Palmares National Forest, 168 ha, ~303,400 USD) were almost twice those of much larger PAs, such as Chapada Diamantina National Park (152,141 ha, ~168,000 USD) or Chapada do Araripe (972,590 ha, ~161,000 USD).

Interestingly, some of the PAs that included ostensive property security in their budgets do not have physical headquarters, such as Catimbau and Serra das Confusões National Parks (MMA 2015). In face of this finding, it is very likely that the people hired for the security guard positions are actually performing other functions in those PAs. This may represent a planning failure by the management agency, reducing the available budget for protecting biodiversity in the Caatinga PAs.

SCARCE AND UNEVEN BUDGETS.—Properly estimating the costs for implementing and managing a PA is fundamental for proposing a more realistic budget (Geluda & Serrão 2014). Balmford *et al.* (2003) affirmed that the investment levels in PAs vary greatly among countries (from 0.001 USD to 10,000.00 USD/ha). The values available for the PAs we analyzed are far below the ideal, but this issue is not exclusive to the Caatinga or Brazil. Many countries spend less than is needed to achieve their objectives of *in situ* conservation in PAs. In 2001, James *et al.* affirmed that the suitable cost for managing all PAs in developing countries was 2.3 billion USD/yr, whereas the value effectively spent was 0.69 billion USD/yr or 93.00 USD/km² (~0.93 USD/ha). On the other hand, developed countries spent 5.27 billion USD/yr in

PAs, or 929.00 USD/km² (~9.29 USD/ha). A study from 2001 estimated that African nations, excluding South Africa, spent about 0.65 USD/ha on PAs (Wilkie *et al.* 2001). Bruner *et al.* (2004) concluded that there was a funding deficit of nearly 1.7 billion USD/yr to manage all PAs that existed then. However, according to Bruner *et al.* (2004), some African and Latin American countries spend from 0.05 USD to 3.00 USD per ha/yr, whereas the ideal would be from 0.90 USD to 9.00 USD. Based on data from 20 Latin American and Caribbean countries, a study published in 2010 estimated 1.95 USD/ha as the total annual available funds for PAs in those countries, with values varying from 0.20 USD/ha in Paraguay up to 39.95 USD/ha in El Salvador (Bovarnick *et al.* 2010). Data from other regions in the world varied from 5.40 USD/ha/yr in the Middle East, to 11.20 USD/ha/year in Eastern Europe and 43.00 USD/ha/year in the European Union (López & Jiménez 2006). In an estimate of management costs of PAs in the Eastern Arc Mountains in Tanzania, the median total expenditure was 2.30 USD/ha/yr, while the median amount reported as necessary for a PA to achieve all its objectives was 8.30 USD/ha/yr (Green *et al.* 2012). In a recent study on investments on PAs in the Brazilian state of Amapá, Dias *et al.* (2016) estimated that the annual costs per hectare for nine areas covering 9.18 Mi ha ranged from 3.1 USD to 10.0 USD, and were inversely correlated with the size of the protected area.

Obtaining data on the PA staff's salaries proved to be the most difficult part of our research. There is a clear need for an updated, unified, and transparent databank on this subject in Brazil, as such data are crucial for better and more accurate estimates on how much money actually goes to *in situ* conservation. In the absence of such a databank, anyone interested in this topic has to use proxies. In 2009, the Brazilian Ministry of the Environment published a study estimating that approximately 1.12 billion USD would be needed for 1,641 national PAs covering 1.47 million km² to be fully functional (MMA 2009). The projected cost was 7.61 USD/ha/yr. Salaries accounted for 21.16% of that total (MMA 2009; p. 34). Therefore, even correcting our calculations for salaries, *i.e.*, adding 21.16% to our estimates, the values spent in the PAs in the Caatinga (~0.50 USD/ha/yr + 0.10 USD/ha/yr) were approximately 13 times lower than the values determined by their own Ministry of the Environment as necessary for the basic operation of a PA in Brazil, 1.5 times lower than those found in the study by James *et al.* 2001, up to 5 times lower than the values spent in Latin American and African parks (Bruner *et al.* 2004, Green *et al.* 2012), and up to 72 times lower than values spent in PAs in the European Union (López & Jiménez 2006). This scenario shows that, in terms of investments necessary for maintenance, the PAs in the Caatinga are operating far below the minimum values of other countries similar to Brazil.

There is an urgent need for funding for the maintenance of PAs worldwide (Watson *et al.* 2014). Although they may seem costly, they are much less so when compared with other expenses made (or even diverted) by governments, and certainly bring greater benefits (*e.g.*, Melo *et al.* 2014). To attract resources for

management of PAs, decision makers must be persuaded that when PAs work well they offer more benefits than they require investments. Suggestions have been made on how to increase budget revenues of PAs around the world: correct destination of environmental compensation, permission and expansion of visitation, payment for environmental services, forest concessions, partnerships in the management of common areas in an integrated way, and payment of ecological fees and taxes (Balmford & Whitten 2003, MMA 2009; Muanis *et al.* 2009, Watson *et al.* 2014, Chiaravalloti *et al.* 2015). Specific studies to identify the best opportunities for the PAs in the Caatinga need to be made, but, if put into practice, some of these alternatives could alter the budget framework dramatically. The current situation must be amended, or the protection of biodiversity, and the maintenance of their resources and ecosystem services, will become even more difficult in the only fully Brazilian biome.

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DATA AVAILABILITY

Data available in the Dryad Repository: <https://doi.org/10.5061/dryad.v74t1> (de Carneiro Oliveira & Bernard 2017).

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