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Measuring what matters – Identifying indicators of success for Brazilian marine protected areas

José Gilmar C. Oliveira Júnior[a,*], Richard J. Ladle[a,b], Ricardo Correia[a,b], Vandick S. Batista[a]

[a] Institute of Biological and Health Sciences (ICBS), Federal University of Alagoas, Maceió, AL, Brazil
[b] School of Geography and the Environment, University of Oxford, Oxford, United Kingdom

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ABSTRACT

The large increase in number and extent of Marine Protected Areas (MPAs) over the last few decades has been an important step towards the conservation of marine environments. However, it is not clear whether these important conservation tools are effectively managed, especially in the developing world where resources are limited and there are frequent conflicts with traditional resource users. An innovative approach was used to identify the most important governance, socioeconomic and biophysical variables that are associated with the management effectiveness of Brazilian MPAs. Management effectiveness data was extracted from Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM), applied by World Wildlife Fund-Brazil in 2005 and 2010. This comprehensive dataset was summarized in a single management effectiveness metric and related to a set of 15 explanatory variables using generalized linear models (GLMs). An innovative multi-model averaging approach was employed to identify the most important variables relating to management effectiveness. As a result, five main indicators showed high influence on management effectiveness: 1) higher levels of monitoring/research; 2) higher investment; 3) greater human resources; 4) greater social participation, and; 5) lower levels of conflicts between users and managers. managerial effectiveness of Brazilian MPAs could be significantly improved by adopting an indicator based approach to management prioritization. Specifically, MPA managers should dedicate special attention to the highlighted factors when choosing how to allocate available resources in order to boost the overall effectiveness of their protected area.

1. Introduction

The creation of Protected Areas (PAs) for conserving nature was a defining feature of the 20th century [1]. Indeed, the percentage of Earth's terrestrial land under some form of protection rose from < 2% in 1900 to 12.5% by 2014 [2]. One of the main drivers of the rapid expansion of protected lands was the obligation of the signatories of the Convention in Biological Diversity (CBD) [3] to create a system of PAs that covers at least 10% of the total area of each main biome. These ambitious goals have subsequently been revised, with current targets of at least 17% of terrestrial land and 10% of coastal and marine areas under protection by 2020 [4]. Moreover, Target 11 of the Aichi Biodiversity Targets states that protected area networks should be “equitably managed, ecologically representative and well connected”.

The global conservation community has clearly had remarkable success gazetting land for the protection of nature. Perhaps inevitably, given the rapid rate of expansion, the management effectiveness of many PAs – especially those in the developing world – has been questioned [5–7]. Indeed, successful management of PAs is becoming increasingly complex and difficult due to factors such as urban expansion, overexploitation of natural resources and pollution threatening nature inside and outside of reserves [8,9]. Moreover, PAs in developing countries often suffer from weak governance, lack of enforcement and numerous social conflicts between resource users and park management [10,11]. Moreover, PAs around the world are coming under increasing political pressure to justify their role in competition with other land uses [2]. In response to these multiple and interconnected challenges, many PAs have modified their objectives, adopting a more explicit ecosystem approach that protects of all the system components and processes rather than the more traditional focus on single species or resources [12].

Multiple management objectives and complex governance are now characteristics of many Marine Protected Areas (MPAs) [13], which frequently have an auxiliary role in protecting valuable fishery resources [14]. Like their terrestrial counterparts, many MPAs in the developing world countries such as Brazil are perceived as being ineffectively managed [15] and frequently in conflict with local communities [16,17]. These problems have, in turn, caused the general

* Corresponding author.
E-mail address: gilmaroliveirajunior@gmail.com (J.G.C. Oliveira Júnior).

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public and policy makers to increasingly question their value for society [18,19].

An important step in increasing the social acceptability and long-term viability of MPAs is to create a simple, cost effective system to monitor management effectiveness. Such a system needs to be sufficiently flexible to encompass the diverse objectives, plans, and strategies of modern MPA networks [20,21]. Ideally, it should also bring rapid and low cost answers, while being sufficiently detailed to identify the main sources of variability in MPAs effectiveness [22]. The best known and most widely used example of such a system for MPAs is WWF's Rapid Assessment and Prioritization of Protected Areas Management or RAPPAM [21]. RAPPAM is delivered through a questionnaire applied to MPA managers containing over 100 indicator statements (e.g. 9a. “The level of staffing is sufficient to effectively manage the area”) grouped into a number of thematic categories [21].

Assessments such as RAPPAM provide opportunities to identify the key factors influencing MPA management effectiveness. These factors are likely to be diverse and interacting, and include: i) enforcement and investment [23]; ii) conflicts of users and management [24]; iii) social participation [25], and; iv) physical characteristics such as MPA size and age [26]. An analytical framework that allows the full consideration of relevant variables and their relevance for PA management is therefore needed in order to identify the most relevant variables for conservation success. Using an innovative multi-modeling approach, this article aims to investigate the relative influence of managerial, social and physical characteristics on MPA effectiveness. Trends on the temporal evolution of manager perceptions are also accessed. Such analyses have immense potential benefits for the future development of the MPA network in Brazil, including improvements on budget planning, inclusion of economical valuation and social benefits of conservation in management development, as well as to better design protected area mosaics considering socio-political inclusion of the supporters on the defence of the protection systems. This is a requirement to increase the still limited MPA network in Brazil, which currently only covers 0.35% of the Brazilian Exclusive Economic Zone (EEZ) [27,28].

2. Materials and methods

2.1. MPA network

This analysis assessed a set of 54 marine protected areas (MPAs) of the total 59 federal Brazilian MPAs in the coastal and marine biome, as at the time of the last RAPPAM evaluated, only these 54 MPAs existed and had their effectiveness assessed (Fig. 1). A total of 32 MPAs considered for this study were classified as sustainable use areas (SUA); these included 10 Environmental Protection Areas (EPAs), 3 Areas of Relevant Ecological Interest (AREIs) and 19 Extractive Reserves (ERs). Additionally, another 21 full protection MPAs were considered, consisting of 8 National Parks (NPs), 5 Biological Reserves (BRs), 8 Ecological Stations (ESs), and Wildlife Refuge (WRs).

2.2. Explanatory variables

The identification of 15 explanatory variables was made based on their potential to explain variations in management effectiveness. These variables were allocated to three groups of indicators following Pomeroy [20] to better distinguish their form of influence on management effectiveness: Group I - Governance indicators: 1) *Financial investment* (external sources were also considered); 2) *Legal support* (extent to which laws are integrated into MPA policies); 3) *Human resources* (Number and qualification); 4) *IUCN category;* 5) *Monitoring/Research;* 6) *RAPPAM Evaluation;* 7) *Management plan age*. Group II - Socioeconomic indicators: 8) *Social participation*; 9) *Conflicts of users and management*; 10) *Socioeconomic importance*; *Economic development level*; 11) *Human population*; Group III – Biophysical indicators: 12) *MPA age*; 13) *MPA size*; 14) *Distance of center of protection to coast*; 15) *Biological importance*. (definitions and sources in Table 1). These variables were selected based on the literature and our understanding of the main drivers of MPA effectiveness in Brazil.

The World Wildlife Fund (WWF) and Brazilian Institute of Environment and Natural Resources (IBAMA) evaluated the management effectiveness through RAPPAM method in 2005 and 2010 – no similar evaluations have been completed since this date. The results of this database was analysed and published in two reports and at the web page Protected Areas Observatory (PA Observatory) [29]. The first eight explanatory variables were calculated using data from WWF's RAPPAM analysis of Brazilian MPAs, collected in 2005 and 2010 and available in the web page Protected Areas Observatory (PA Observatory). Six of the analysed MPAs were designated after the 2005 evaluation and are therefore only evaluated in 2010. The *Manguezais da Foz do Rio Mamanguape* MPA was only evaluated in 2005. Each variable was a compound measure derived from responses to related indicators on the RAPPAM questionnaire. There are four levels of possible response for each indicator, ranging from ‘yes’, ‘mostly yes’, ‘mostly no’ and ‘no’ [21]. For the purposes of statistical analysis, each of these responses were converted into numbers from zero to three, where zero corresponded to the worst scenario (complete failure to achieve indicator) and three is the optimal scenario (complete success to achieve indicator) and their results were averaged to obtain the final scores. There was no upper limit to the number of indicators to form each variable (See supplementary materials Table 1).

Data on *MPA age*, *age of management plan*, *MPA size* and *distance* (from the center of the MPA) *to coast* were obtained from the Brazilian Ministry of the Environment's database (http://www.mma.gov.br/areas-protegidas/). *MPA age* was defined the difference between the year of creation of the MPA and the year of each RAPPAM evaluation. *Management plan age* is the difference between the year of creation of the management plan and the year of each RAPPAM evaluation. *MPA size* is the total area (km^2) of each MPA. *Distance to coast* was generated by downloading the shape file of each MPA from the ICMBio web page. Using “Google Maps” (https://www.google.com.br/maps/), The distance of center of protection to coast was calculated using the average between the nearest distance of the MPA border to the coast and the maximum far distance of the border of the MPA to the coast line. This measure was named as the distance from center of protection to coast, and represents an approximation of the real distance that resources are located and more difficult to be exploited for human populations.

Data on human population and economic development was collected from Brazilian Institute of Geography and Statistics (IBGE) (http://www.ibge.gov.br). Specifically, population and Gross National Product (GNP) per capita for the closest city to each MPA were used to build these indicators (see Table S2 for more details). To get IBGE data series for the same period as the RAPPAM evaluation, data from the 2010 census was used. As there was no census in 2005, an estimate for this year created by the IBGE was used.

2.3. Response variable

Overall management effectiveness of each MPA was quantified using data from the ‘outcomes’ section from the RAPPAM surveys (2005 and 2010). This section contains 13 questions on the RAPPAM questionnaire assessing the effectiveness of the MPA over the previous 2 years in relation to the specific threats and pressures, MPA objectives and annual work-plan. As with the previous variables from RAPPAM, the responses to these statements (‘yes’, ‘mostly yes’, ‘mostly no’, ‘no’) were converted into numbers from zero to three, where zero corresponded to the worst scenario (complete failure to achieve indicator) and three is the optimal scenario (complete success to achieve indicator) and the overall management effectiveness for each MPA

Fig. 1. Map of Brazilian MPAs under federal jurisdiction. The name of each MPA is followed by the acronyms of the category According to SNUC and to IUCN in parenthesis. Acronyms: EPA: Environmental Protection Area; RIEA: Relevant Interest Ecological Area; ER: Extractive Reserve; NP: National Park; BR: Biological Reserve; ES: Ecological Stations; W*R*: Wildlife Refuge.

was obtained by an average of the scores of the 13 questions related to management outcomes which is seen here as a measure of management effectiveness.

2.4. Statistical analysis

Initially, this study compared how the views of MPA managers regarding different managerial dimensions changed between the two RAPPAM assessments in 2005 and 2010 for the subset of 47 MPAs evaluated. To perform this comparison a Wilcoxon's Rank Sum test was used. However, the primary objective of this study is to assess which MPA characteristics were more strongly associated with positive views of management outcomes (management effectiveness). Generalized linear models (GLMs) with Gaussian distribution were selected to test the association between management outcomes and MPA characteristics but, due to the large number of potentially relevant explanatory variables, it is unlikely that a single model could accurately represent the importance of a given variable. In such cases, an information theoretic ('IT') approach allows the simultaneous examination of several competing hypotheses and the identification of the best set of models using information criteria, such as the Akaike Information Criterion (AIC) [30]. This metric provides a quantitative measure of relative support for each competing hypothesis; lower AIC scores indicate lower information loss in relation to reality, and thus the better models can identified by the lowest AIC scores [26]. Furthermore, the comparison between AIC scores of different models allows the computation of the Akaike's weights (ωAIC), indicating the probability with which a given model in our set best explains reality

Table 1
Predictor variables, their sources and expected relationship with management effectiveness.

Variable	Source	Expected Relationship	Conceptual basis for expected association
1-Investment (INV)	RAPPAM: Questions 12a to 12f.	Positive	More investment from government or external sources allows applying actions and planning more effectively [2].
2-Legal support (LEGSUP)	RAPPAM: Questions 7a to 7e.	Positive	The legal instruments and major law applicability that allows management body apply effectively their MPA politics [30].
3-Human resources (HUMRES)	RAPPAM: Questions 9a to 9e.	Positive	Staff in adequate number and capacity are responsible for executing actions and meeting objectives [31].
4-IUCN Category (IUCNCAT)	ICMBio	[a]	As the different categories have specific management measures, it should influence the management effectiveness.
5-RAPPAM evaluation (EVALUA)	RAPPAM realization	[a]	The information made available for management at the first evaluation, would influence the values of management effectiveness
6-Social participation (SOCPART)	RAPPAM: Questions 10a, 10d to 10f and 14a to 14h.	Positive	The local acceptance of a MPA and the participation of social actors in the management facilitate the meeting of objectives [30,32].
7-Conflicts between users and management (CONFL)	RAPPAM: Questions 4b, 4c and 5d to 5h.	Negative	Management in disaccording with local actors difficult the acceptance and accomplishment of local policies of natural resources use [30].
8-Socio economic importance (SOCIMP)	RAPPAM: Questions 4a to 4j.	Positive	Higher levels of importance lead to more concern, improving the enforcement and the effectiveness [30,33].
9-Management plan age (PLAGE)	ICMBio	Positive	Planning is necessary to trace objectives and strategies to reach the expected goals [33].
10-Economic development (GNP)	IBGE censos: Municipal GNP per capita	Positive	The economic development of a region leads to better education, development of technologies and alternatives to use the natural resources [34]. But, also could bring more fishing demand for market and the development of predatory fishing methods [35]
11-MPA age (MPAGE)	ICMBio	Positive	As long as a MPA is properly managed, the experience grows affecting positively the effectiveness. There are also positive ecological effects of MPA age in sedentary fishing resources, when effective protection is applied [36]
12-MPA size (MPASIZE)	ICMBio	Positive or negative	Larger MPA are more difficult to protect and monitor reducing their effectiveness [37]. In other hand, Larger MPAs could protect more habitats and organisms more effectively [38].
13-Distance from center of protection to coast (DIST)	ICMBio and google maps.	Positive or negative	Resources located at higher distances from human populations are more difficult to be exploited in Marine ecosystems [39] or freshwater ecosystems [40]. In other hand, management body, has more difficulties with continental communication, supplies and transport.
14-Human population (POPUL)	IBGE census: municipal population	Negative	More people increases the demand for resources, leading to more exploitation of nearby resources [41].
15-Biological importance (BIOIMP)	RAPPAM: Questions 3a to 3j.	Positive	Higher levels of importance lead to more concern, improving the enforcement and the effectiveness [30,33].

[a] No expected correlation.

[31]. However, it is often the case that two or more models can be considered similarly plausible when the differences between their AIC scores (ΔAIC) are relatively small; some authors suggest that models with a ΔAIC varying between 4 and 7 can also represent plausible hypothesis [31]. In such cases, the selection of a single "best" model is often difficult and a model averaging approach can be employed as a way to robustly calculate the contribution of each model and explanatory variable in relation to how well they are supported by the data [32].

All possible variable combinations (without interactions) were calculated using the MuMIn package for R Software. Then, was identified the best performing models according to Akaike's Information Criterion corrected for sample size (AICc) and Akaike's weights (ωAICc). However, because no single best model could be identified (ωAICc < 0.9 for all models), a model averaging approach was used to obtain averaged parameter estimates and the relative importance of each explanatory variable. A conservative approach was adopted for the model averaging process: models were considered as plausible only with ΔAICc ≤ 4 [31]. All analyses were implemented using R Software v3.1.3 [33].

3. Results

A significant change in RAPPAM scores was observed for five dimensions of MPA management assessed in this work (Fig. 2). Our results indicate that there was a significant increase in the reported scores for overall MPA management effectiveness ($W = 794$, p-value $= 0.001$), human resources ($W = 836$, p-value $= 0.003$), social participation ($W = 872$, p-value $= 0.006$) and monitoring and research ($W = 948$, p-value $= 0.027$) between the 2005 and 2010 RAPPAM assessments. There was also a significant reduction in the reported biological importance score ($W = 1665$, p-value $= 0.007$).

As anticipated, no single model provided a very strong fit to the data (all models had ωAICc < 0.02, Table S3). Despite this fact, a set of variables could be identified showing high importance in terms of explaining MPA management effectiveness (Table 2). High scores for management effectiveness were associated with more positive perceptions of PA *human resources* (HUMRES), higher monitoring and research (MONRES), greater *social participation* (SOCPART) and Period of *RAPPAM Evaluation* (EVALUA). These four variables were selected in all models ($N = 81$, variable relative importance $= 1.00$). Other variables were also important and were frequently selected in models. These include MPA *investment* (relative importance $= 0.76$) and *distance to the coast* (relative importance $= 0.68$), both showing a positive relationship with management effectiveness. Higher levels of *conflicts* between MPA users and managers (relative importance 0.99) were negatively associated with management effectiveness.

It is interesting to note that the year of the *evaluation* (EVALUA, relative importance $= 1.00$) was included in all the best set of models, corroborating our previous results that management effectiveness was more positively assessed in 2010 compared to 2005. The remaining variables were occasionally included in the best set of models, but their relative importance was generally low (relative importance < 0.36).

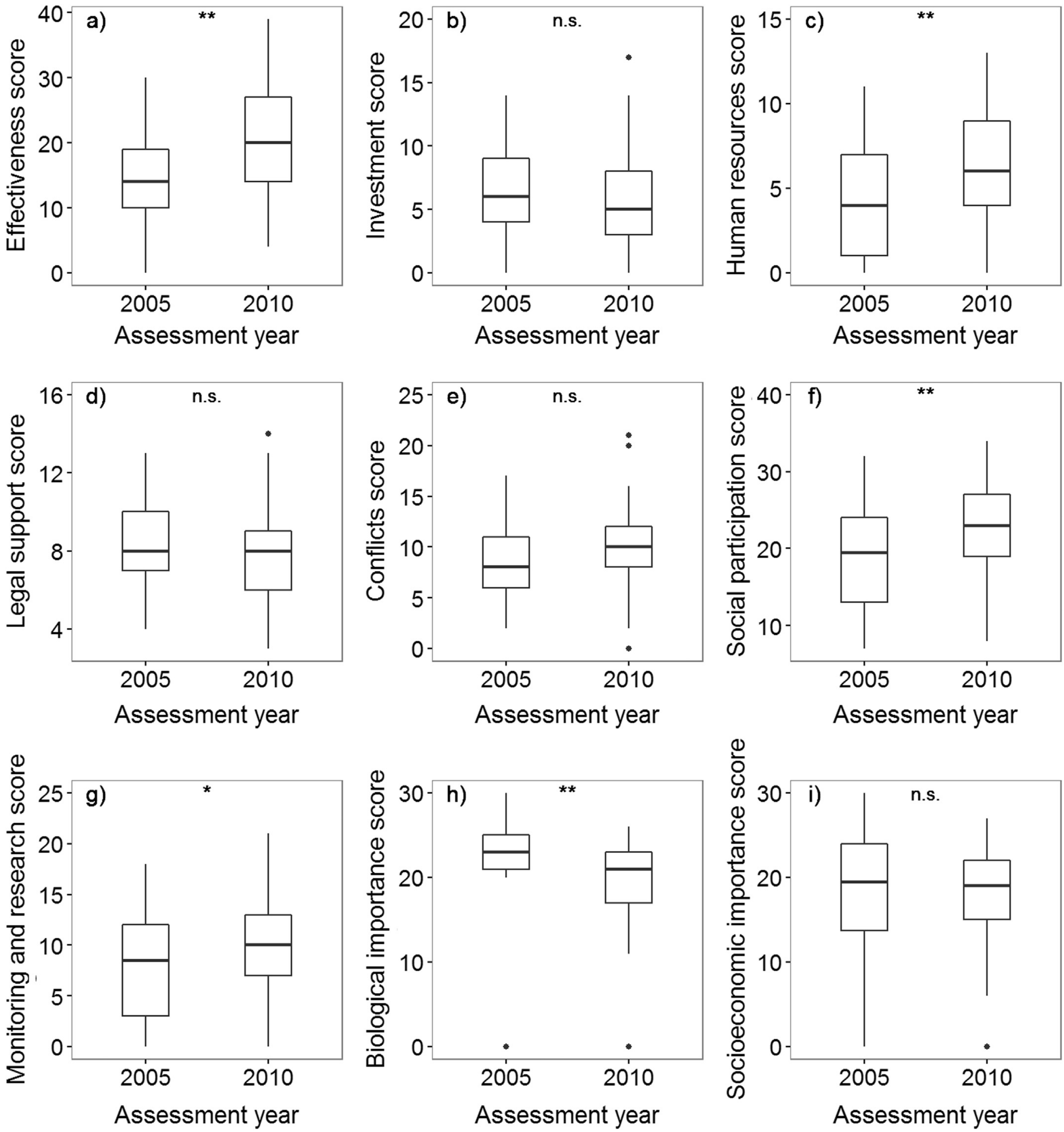

Fig. 2. Distribution of summed RAPPAM scores reported in 2005 and 2010 for the questions relating to: a) management effectiveness, b) investment, c) human resources, d) legal support, e) conflicts between users and MPA management, f) social participation, g) monitoring and research, h) biological importance and i) socioeconomic importance.

4. Discussion

The variables most associated with management effectiveness of Brazilian MPAs are *monitoring/research*, *human resources*, *investment*, *social participation* and *conflicts of users and management*. The positive association between *investment* and management effectiveness was anticipated, as effective conservation clearly needs adequate investments [13]. However, this needs to be put into the context that financing of MPAs will always be limited. It is therefore vitally important to maximize gains in effectiveness with whatever funds are available [34].

Human resources and *investment* relate to the availability of federal government resources that have been ring-fenced for MPA management. Human resources have previously been identified as one of the most important components of MPA management [35]. Once again this is anticipated given that the effectiveness of management actions depends, to a large extent, on having a sufficient number of appropriately qualified staff. It should be noted that despite the significant improvement in the state of human resources reported in the 2010 RAPPAM assessment, staffing levels may be at sub-optimal

Table 2
Summary statistics of the model averaging procedure assessing the relationship between Brazilian MPA outcomes and the set of explanatory variables.

Variable	Estimate	Adjusted standard error	Variable relative importance	Number of containing models
Intercept	−81.680	33.740	–	–
HUMRES	0.279	0.077	1.00	71
MONRES	0.375	0.057	1.00	71
SOCPART	0.312	0.097	1.00	71
EVALUA 2010	0.041	0.017	1.00	71
CONFL	−0.247	0.073	0.99	70
INV	0.125	0.067	0.76	52
DIST	0.001	0.001	0.68	46
POPUL	> 0.001	> 0.001	0.36	26
PLAGE	0.011	0.010	0.21	17
MPASIZE	> 0.001	> 0.001	0.20	16
MPAGE	0.005	0.005	0.19	16
BIOIMP	−0.043	0.046	0.18	15
LEGSUP	0.054	0.089	0.11	10
GNP	−0.002	0.003	0.09	9
SOCIMP	−0.008	0.055	0.07	7
IUCNCAT II	−0.248	0.126	0.01	1
IUCNCAT III	−0.412	0.297	0.01	1
IUCNCAT IV	−0.607	0.217	0.01	1
IUCNCAT V	−0.204	0.123	0.01	1
IUCNCAT VI	−0.392	0.110	0.01	1

Legend: INV: Investment, HUMRES: Human resources, LEGSUP: Legal support, CONFL: Conflicts of users and management, SOCPART: Social participation, MONRES: Monitoring/Research, BIOIMP: biological importance, SOCIMP: Social importance, MPAGE: Marine protected area age, PLAGE: Management plan age, MPASIZE: Marine protected area size, DIST: Distance of the center of protection to the coast, POPUL: Human population size, GNP: Economic development index, EVALUA: RAPPAM evaluation; IUCNCAT: Categories of MPAs according to IUCN (Ia, II, III, IV, V and VI).

even in iconic Brazilian MPAs such as *NP Abrolhos* and *EPA Costa dos Corais* [34].

The process of creating a MPA is often instigated by the perceived need to conserve natural resources that are suffering from over-exploitation. Inevitably, restricting the use of resources in such MPAs can lead to social conflicts. These conflicts need to be well managed to avoid compromising the ability of the MPA to meet its objectives. This was clearly demonstrated in the models by the strong negative association between the level of conflict and management effectiveness. By extension, one potential way to increase management effectiveness would be to decrease conflict through mechanisms such as co-management or increased social participation [23,36].

Social participation relates to the degree to which the goals of the community align with the MPA's objectives [37]. Unfortunately, the RAPPAM methodology does not allow a deeper analysis of social participation, but rather provides an overview of the relationship of indicators in each MPA. The Brazilian government has long recognized the importance of social participation and, since 2000, has prioritized the insertion of community representatives in PA decision-making bodies [38]. This policy is being progressively implemented by MPA managers, incrementally building the foundations for more successful governance. Indeed, actions to stimulate social participation have been demonstrably successful in several extractive reserves (e.g. *ER Maracanã*, *ER Tracuateua*, *ER Corumbau* and the *EPA Baleia Franca*) [34].

As *social participation* decreases, the level of *conflict* tends to grow, reducing the effectiveness of management actions [10,39,40]. Conflicts are typically measured in terms of community compliance with environmental laws, user disagreements with management measures, the gap between the management expectations of managers and users, and the frequency of infractions inside the MPA [10]. The results of this study clearly support the positive impact of social participation and the negative effects of user conflicts on management effectiveness. It should be noted that the RAPPAM data may be subject to over-estimation or underestimation by some of the interviewed managers. For example, *ES Tamoios*, located in Paraty Bay, had low reported conflicts between managers and users (33.3% in 2005 and 0% in 2010) and high values of social participation in 2010 (72.2%) (Table 3 supporting information). However, Lopes et al. [16,17] reported high levels of conflicts in the same area between the MPA and fishers in 2010-12.

The positive association between *monitoring/research* and management effectiveness may represent positive feedback. In one hand, more monitoring and research increases the availability of information that can be used for planning and action which, in turn, improves management effectiveness [41,42]. In turn, MPAs with high management effectiveness become desirable targets for future studies, attracting researchers who wish to study and monitor areas with low levels of human impact [43]. Such a relationship can be seen in successful and well managed MPAs such as *NP Fernando de Noronha*, *NP Abrolhos* and *BR Atol das Rocas*, which are magnets for both national and international researchers.

The explanatory variables *population* and *distance to coast* also had a high relative importance. The presence of human populations near a MPA tends to increase the demand for natural resources, facilitating illegal exploitation and threatening management effectiveness [44]. Likewise, *distance to coast* affects the capacity of human populations to exploit an MPA, since it is less economically viable and less practical to exploit distant resources. For example, an optimal foraging model was demonstrated among Amazon River fishers, with fishing trips more concentrated near villages to reduce costs and increase profits [45]. Recent work also demonstrated an increase in abundance of fishing resources with distance from human population centers [46] However, increasing isolation also makes it more difficult to implement effective monitoring and surveillance of the illegal activities.

Legal support refers to legislation and enforcement tools used by the MPA managerial body. Decreasing legal support for MPAs is a global trend, with a lack of enforcement and funding the most concerning causes [2]. In Brazil, the decrease in legal support is also related to the institutional division of Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) in 2007. This administrative restructuring changed the practices and proceedings of new institutes, requiring adaptation by MPA managers [30] and potentially weakening their perceptions of legal support.

The negative correlation of *Biological importance* to management effectiveness is contrary to expectations, as higher levels of biological importance are supposed to attract better conservation practices [39]. However, it should be remembered that biological or ecological components are not only important to ecosystem functioning, but are also of socioeconomic importance. Thus, high socioeconomic demands for important natural resources or environmental services in a MPA could lead to ecological degradation [47].

Investment, *Human resources*, *Monitoring and research* and *Legal support* are governance variables. Governments and managers can influence many of the components that compose these indicators. For example, *Investment* depends to a large extent on government financing or external funding generated by MPA manager's actions. *Human resources* is dependent on government funding or NGO support. *Legal support* is also almost entirely bound to the government's capacity to deliver appropriate policies to increase capacity, enforce actions and acquire more compliance from local communities. *Monitoring and research* is highly dependent on the management body and partnership with Universities and other research bodies.

Social participation and *Conflicts of users and management*" are socioeconomic variables and are strongly influenced by social attitudes, values, knowledge, and markets, among other factors [20]. However, *Social participation* and *Conflicts* also are influenced by the MPA management body, since management actions can increase or decrease the levels of *Conflicts* and *Social participation*. From the biophysical indicators, *Distance to coast* cannot be influenced by management after the MPA planning stage.

Increasing management effectiveness also requires clear planning and effective administration: features that are often lacking in Brazilian MPAs [11]. For example, of the 54 MPAs analysed here, only 11 had management plans at the time of the 2005 evaluation, with only 6 more achieving this important milestone by 2010. In this context, the failure of the system to achieve its main goal of conserving biodiversity [5,48,49] is clearly understandable. Without a management plan, an MPA manager often has no clear road-map to guide decisions thereby limiting the capacity for effective and prompt actions [24].

The objective of the RAPPAM methodology is to assess the management effectiveness of PAs and identify their strengths and weaknesses. However, this method does not allow a deeper analysis, and only takes in consideration the views of the MPA managers. Another option would be to analyze research data comparing biodiversity and resource yields inside and outside MPAs (e.g spillover). Such data is only available for a few Brazilian MPAs [16,17,50,51]. An alternative approach would be to interview not only MPA managers, but other stakeholders related to the MPA, such as fishers, enterprises, tourists, researchers and local people, etc. Again, this has only been done in a small number of Brazilian MPAs [16,17,52].

5. Conclusions

Increasing the management effectiveness of Brazilian MPAs will be exceedingly challenging, with managers frequently compromised by contextual factors (e.g. distance of the MPA to large human populations, etc.). Nevertheless, this analysis supports the work of previous studies that suggest that if actions are regularly evaluated, infrastructure is improved and stable funding sources acquired, management effectiveness can be increased [53–55]. Moreover, it should be possible to build a good relationship with local communities and solve management conflicts, even when resources are scarce [56,57].

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2016.09.018.. These data include Google maps of the most important areas described in this article.

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