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

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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

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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