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Temporal assessment of the management effectiveness of reef environments: The role of marine protected areas in Brazil

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ABSTRACT

Marine protected areas (MPAs) are being successful in the management of fishing resources and conservation of biodiversity in many parts of the world. The assessment of the management effectiveness provides examples to improve the management of these areas. Thus, this study assessed the management effectiveness of 11 MPAs with reef environments in the coast of Brazil, in the period of 10 years (2005, 2010, and 2015), through the method of Rapid Assessment and Priorization of Protected Area Management (RAPPAM). The questionnaire was also used to address the pressure (activities that affect the MPA in the last 5 years) and threats (activities that can potentially affect the MPA in the next 5 years. From the 11 MPAs assessed, the highest values of pressures and threats were obtained for two areas in the year of 2005 and four areas in 2015 (above 35%). The mean management effectiveness between 2005 and 2015 increased from 55.6% (±8.2) in 2005 to 60% (±11.5) in 2015. However, even with this increase, the mean effectiveness of some MPAs is still below the limit considered ideal for satisfactory management (<40%), and the number of MPAs with good management (>60%) has not changed over time.

1. Introduction

Coral reefs are among the most diverse and productive ecosystems on Earth, and they function as indicators of health and resources for marine environments (Mumby, 2006; Mumby and Steneck, 2008; Xu and Zhao, 2014). Moreover, they provide other services to the population, such as coastal protection against wave action and storm surges, pharmacotherapy, and areas for recreation and tourism (Moberg and Folke, 1999; Diedrich, 2007). However, these environments are suffering increasing degradation around the world, and, according to Wilkinson (2008), human activities are responsible for the destruction of 19% of the coral reefs worldwide, and for putting other 35% under action of some kind of threat of loss in 10–40 years.

The problems related to the presence of human population near reef environments are due to the overexploitation of fishing stocks (Sadovy, 2005; Mumby et al., 2006; Newton et al., 2007; Jackson, 2008), the traffic of vessels, with the consequent stranding and shedding of substances at the sea (Chabanet et al., 2005; Game et al., 2008; Ramirez and Lozano, 2014), the presence of invader exotic species, which leads to a loss of biodiversity because of competition for habitat and food (De Paula and Creed, 2004; Morris et al., 2010; Sammarco et al., 2010), and tourism, which causes degradation in the reefs (Leão and Kikuchi, 2005; Mumby and Steneck, 2008; Hilmi et al., 2012).

Furthermore, the entering of sediments and organic matter into marine environments, because of the misuse use of the soil, deforestation, and burnings, raise the concentration of nutrients in the water, especially nitrogen and phosphorous, and it is one of the main sources of degradation of reefs in the world (Fabricius, 2005; Wooldridge, 2009; Wagner et al., 2010; Loiola et al., 2013). Besides, the deforestation and burning of fossil fuels also act by altering the chemistry of the water, due to the increase of CO_2 in the atmosphere, which elevates the water acidity, reduces the amount of calcium available in the environment for the reef constructors, calcareous algae and others, which directly influences the development of the carbonate structures of these individuals and the construction of reefs (Sabine et al., 2004; Cao et al., 2007; Silverman et al., 2009; Sarmento et al., 2015).

The creation of marine protected areas (MPAs) is important to limit the degradation of reef environments (Aronson and Precht,

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2006; Mumby, 2006), support the recovery and stabilization of the functional reef groups (Doyen et al., 2007), and provide areas with no-take recourses (Wantiez et al., 1997; Shanks et al., 2003). However, protected areas (PA) worldwide are facing a series of problems, such as visitor impacts, inadequate management planning, unsustainable resource use, inadequate research, and low law enforcement (Leverington et al., 2010). Moreover, there are problems related to the non-creation and non-implementation of management plans (Worboy et al., 2006; Robles et al., 2007; Lu et al., 2012), the land issues of the protected areas, the scarcity of basic infrastructure and of employees active in the elaboration of policies and conservation strategies (Medeiros and Young, 2011).

In view of these problems, studies that assess the management effectiveness of marine protected areas are essential to provide useful information to managers and decision-makers who manage protected areas (Medeiros, 2006; Day et al., 2012; Schiavetti et al., 2012). The evaluation of management effectiveness is essential for the PAs since it improves the planning strategies by means of priority criteria (Margules and Pressey, 2000). Izurieta-Valery (1997) defines the management effectiveness as "a set of characteristics, actions, attitudes, capacities, and specific competencies that allow a protected areas to satisfactorily perform the function and meet the objectives for which it was created." To guide this effectiveness evaluation process, the World Commission On Protected Areas (WCPA), in 1995, created a table that could serve as reference for the creation of assessment methodologies (Hockings et al., 2000).

Among the methods of assessment of effectiveness, one of the most accepted is the Rapid Assessment and Priorization of Protected Area Management (RAPPAM) (Ervin, 2003a), as it allows a global analysis of the management effectiveness, identifying the strengths and weaknesses of it and analyzing the pressures and threats (Leverington et al., 2010). The questionnaire is one of the few that covers all six elements of the WCPA: context, planning, inputs, process, outputs, and outcomes (Hockings et al., 2000). This methodology has already been applied in South Africa (Goodman, 2003), Spain (Corral, 2010), Taiwan (Lu et al., 2012), China, Russia, and Bhutan (Ervin, 2003b), totaling more than 53 countries and 1.600 protected areas in the world (Leverington et al., 2010). In the present study, we investigated the effects of the pressures and threats, and assessed the management effectiveness of 11 protected marine areas in Brazil for a period of 10 years.

2. Materials and methods

2.1. Study area

The National Action Plan for the Conservation of Coral Reefs (PAN Corals) defined the priority areas for conservation in the coast of Brazil (Castro et al., 2016) and selected to the research all federal marine protected areas that participated in the questionnaire of Rapid Assessment and Priorization of Protected Area Management (RAPPAM) applied by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) and by the World Wide Found from Brazil (WWF-Brasil) in the years 2005 and 2010, totalizing 11 MPAs (Fig. 1), divided into four categories of the International Union for Conservation of Nature (IUCN) (Table 1).

2.2. Sample design

The RAPPAM questionnaire created by Jamison Ervin (2003a) and applied in this work has 96 questions for the year of 2005, 101 for 2010, and 115 for 2015, divided into 5 topics and 14 modules, plus a profile of MPA and the list of pressures and threats. In 2005, 2010, the RAPPAM questionnaire was applied by the ICMBio and WWF-Brasil in marine and land protected areas of Brazil, with the data available at the website of WWF-Brasil (2015) and the questionnaire available in Ogana et al. (2012). We used this website to obtain the data of the 11 marine protected areas analyzed. The information related to the questions, the answers, and who provided them are available at http://observatorio.wwf.org.br/unidades. The application of the questionnaire in the years of 2005 and 2010 took place through workshops, with the participation of managers and environmental analysts of the federal protected areas of Brazil. Between the application in 2005 and 2010, the ICMBio and WWF-Brasil modified the wording of some questions of the questionnaire without altering the focus of the questions (Ogana et al., 2012).

The questionnaire in the year of 2015 was applied for the same 11 MPAs. However, it presented some modifications in writing, with the questions being changed for marine reality, as this is a questionnaire elaborated to be applied to marine protected areas with reef environments (Supplementary Material Table 1). This modification consisted of including 14 new questions, distributed in 7 modules, and altering the list of pressures and threats affecting the MPAs, now with 14 impacting activities, based on the proposed modifications, chiefly by Corral (2010), who was the only researcher to date to modify the RAPPAM questionnaire for application only in protected marine areas. This questionnaire was answered only by the manager of the protected area, through the Google survey tool, between April and August 2015, and an initial contact with the managers was made to explain the methodology of the questionnaire. When the manager did not answer all the questions, they were forwarded, via e-mail, making it possible to solve any doubt that existed in filling out the questionnaire. If the manager informed that he had no knowledge and/or information to answer a given question, it would be removed from the score analysis of the questions.

2.3. Data analysis

Table 2 shows a list with the pressures (activities that caused impacts in the last 5 years prior to application of the questionnaire) and threats (activities that may cause impacts in the next 5 years after application of the questionnaire) for the MPAs in the years of 2005, 2010, and 2015. The pressures and threats are analyzed according to the scope, impact, and permanence of the occurrence, with scores ranging from 1 to 4, according to the intensity of each activity. The score obtained in these 3 categories was multiplied successively to inform the degree of each pressure and threat in the respective MPA, and can reach a maximum value of 64 points for each activity.

To check the criticality of pressures and threats in the questionnaires applied in 2005, 2010, and 2015, the sum of the total scores of pressures and threats in each MPA for each year was carried out. This value was divided by the maximum possible score for each questionnaire (1024 in 2005 and 2010, and 896 in 2015), to obtain in percentage the criticality of the pressures and threats of each MPA.

To assess the significance of the differences between the 4 activities present in all survey questionnaires (construction of infrastructure, tourism and recreation, waste disposal, and exotic species) we used a permutation multivariate analysis of variance (PERMANOVA, Anderson, 2001), with the Euclidean distance, to verify the differences of the joint activities per year, and the Kruskal-Wallis to test whether the variables showed significant differences between the years. In addition, we also made an analysis between the degree of threat in 2015 and the biological importance of each MPA, to verify which areas need greater attention from management.