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ANÁLISE DA EFETIVIDADE DE ÁREAS MARINHAS PROTEGIDAS: MODELANDO A EFETIVIDADE E INDICADORES DE SUCESSO PARA ÁREAS MARINHAS PROTEGIDAS BRASILEIRAS

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Dissertação apresentada ao Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos, Instituto de Ciências Biológicas e da Saúde. Universidade Federal de Alagoas, como requisito para obtenção do título de Mestre em CIÊNCIAS BIOLÓGICAS, área de concentração em Conservação da Biodiversidade Tropical.

Orientador: Prof. Dr. Vandick da Silva Batista

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RESUMO

Constantes esforços estão sendo feitos em todo o mundo para aumentar a efetividade no manejo de Áreas Marinhas Protegidas (AMPs), promovendo assim a conservação e o uso sustentável dos recursos naturais. Avaliar a efetividade no manejo de AMPs é necessário para guiar o sucesso do manejo. O uso de indicadores traz respostas rápidas e econômicas sendo consideradas ferramentas poderosas para conseguir respostas objetivas e precisas. Através de modelagem por média, a efetividade de AMPs brasileiras foi analisada a partir de diferentes fontes de dados especialmente pelo RAPPAM realizado pela WWF-Brazil. Os resultados indicam que os principais indicadores de efetividade em AMPs brasileiras são monitoramento e pesquisa, Investimento, Recursos humanos, Conflitos entre usuários e gestão e Participação social. Gestores pesquisadores de AMPs devem focar seus esforços em manter esses indicadores controlados de acordo com o contexto local de suas respectivas AMPs.

Palavras-chave: Áreas Marinhas Protegidas – Brasil. Áreas Marinhas Protegidas – Conservação. Proteção ambiental – Efetividade de manejo.

ABSTRACT

Continuous efforts are being recorded worldwide to increase effective management of Marine Protected Areas for conservation and sustainable use of natural resources. Effectiveness evaluation is needed to guide managers to successful management. Potential indicators are powerful tolls for monitoring and evaluation giving quick and costless answers. Through model averaging, we assessed the effectiveness of Brazilian MPAs and found the main indicators of effectiveness obtained from multiple data sets, especially RAPPAM from WWF-Brazil. We found that Monitoring/Research, Investment, Human Resources, Social Participation and Conflicts of users and management are the main indicators of effectiveness in Brazilian MPAs. MPAs Managers and scientists should focus their effort in control these indicators and adapt them to the specific background of their MPAs.

Key-words: Marine Protected Areas – Brazil. Marine Protected Areas – Conservation. Management Effectiveness – Environmental Protection.

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1 APRESENTAÇÃO

Avaliações de benefícios gerados pela conservação de recursos naturais de uso comum devem ser efetuadas para monitorar medidas implementadas e adaptar o manejo quando necessário (HOCKINGS et al., 2000; LEVERINGTON et al., 2008). Indicadores de efetividade de manejo são ferramentas úteis para a pesquisa gestão de Áreas Marinhas Protegidas (AMPs), já que tais indicadores oferecem informações precisas e de forma rápida ao estado de conservação dos recursos naturais (ABLAN; MCMANUS; VISWANATHAN, 2004). Emponderando gestores e pesquisadores com informações claras sobre o que influencia a efetividade do manejo, estaremos contribuindo para melhorar o planejamento das ações nas AMPs, permitindo o alcance dos objetivos da AMPs em conservar a biodiversidade marinha (JAMESON; TUPPER; RIDLEY, 2002).

Uma vez constatado o sucesso de uma AMP, é de se esperar que os benefícios gerados pela conservação dos recursos pesqueiros alcancem áreas externas à Zona de exclusão de pesca (HILBORN et al., 2004). Este fenômeno é conhecido como efeito de transbordamento (*Spillover effect*), conhecido por incrementar a biodiversidade e os estoques de recursos pesqueiros em áreas adjacentes à área protegida (RUSS et al., 2004). Esta forma de benefício em uma AMP só é perceptível a longo prazo, com respostas dependentes do estado inicial da área, insumos e participação social (ABESAMIS; RUSS, 2005; GARCÍA-RUBIES; HEREU; ZABALA, 2013; STOBART et al., 2009). A relação da participação social com a exportação de benefícios pesqueiros em uma AMP se deve ao fato ao desconhecimento dos benefícios adquiridos com a conservação dos recursos naturais. Isto gera conflitos entre a comunidade e a gestão, comprometendo a efetividade do sistema em beneficiar a biodiversidade de forma qualitativa e quantitativa e consequentemente disponibilizando estes benefícios para a sociedade.

Esta dissertação está dividida em três capítulos. O primeiro capítulo, composto pela presente seção, é uma breve apresentação do conteúdo principal da dissertação. O segundo capítulo é uma revisão de literatura onde o objetivo foi reunir a bibliografia de maior relevância acerca dos temas efetividade de manejo em AMPs, indicadores de

efetividade de manejo em AMPs, *Spillover* e conflitos em AMPs. O terceiro capítulo é o artigo principal da dissertação cujo objetivo é identificar os indicadores de efetividade de manejo em AMPs através da modelagem da efetividade de manejo.

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2 REVISÃO DA LITERATURA

2.1 Áreas Marinhas Protegidas

Ecossistemas naturais terrestres e marinhos estão sofrendo com expansão urbana, sobre-exploração dos recursos naturais e outras ameaças ambientais de ordem antrópica. Tudo isso afeta a estabilidade do quadro socioeconômico de muitas nações, colocando em risco a segurança alimentar, saúde ambiental (NAUGHTON-TREVES; HOLLAND; BRANDON, 2005; RUDDLE; HICKEY, 2008). Em um esforço para manter um ambiente seguro e garantir a perpetuação do uso dos recursos naturais pelas gerações futuras, surgem iniciativas conservacionistas por todo o mundo. Neste contexto, organizações como a Organização das Nações Unidas para Alimentação e Agricultura (FAO), Organizações não governamentais como o Fundo Mundial para Vida Silvestre (WWF) e a União Internacional par Conservação da Natureza (IUCN), são proeminentes no cenário de políticas ambientais e conservação da biodiversidade (CHAPE et al., 2005; FRANCIS; NILSSON; WARUINGE, 2002). Em relação ao uso e conservação de recursos pesqueiros, surgem as diversas Organizações Regionais para Manejo da Pesca (RFMOs). Estas organizações são formadas por países que possuem interesse em fortalecer suas políticas de manejo dos recursos pesqueiros (RFMOS, 2015) e também são relevantes na tentativa de explorar de forma sustentável os recursos pesqueiros.

No Brasil, recursos pesqueiros estão seriamente em perigo. Isto se deve não apenas à sobrepesca, mas também à falta de informação e regulamentação adequada para o manejo desses recursos. Estatísticas pesqueiras não são feitas desde 2011, tornando impossível controlar e até mesmo caracterizar de forma adequada a pesca no território brasileiro. Além disso, no ano de 2015 o Ministério da Pesca e Aquicultura foi extinto, passando assuntos desta natureza para o Ministério da Agricultura, Pecuária e Produção Alimentar. Este cenário de mudanças jurisdicionais e falta de políticas efetivas coloca em risco a sustentabilidade do uso dos recursos pesqueiros no país. Além disso, a recente portaria 445 do Ministério do Meio Ambiente lançada em 2014 está sendo ameaçada pela influência política das grandes indústrias pesqueiras

fortalecidas pelo apelo social dos pescadores de larga escala, pondo em risco a conservação de espécies recentemente inseridas na lista de espécies ameaçadas por esta portaria (DARIO et al., 2015; PINHEIRO et al., 2015).

Com o crescimento da população humana, aumenta também a demanda por alimento em todo o mundo. Junto ao pensamento lucrativo, isto pode gerar sobre-exploração dos recursos de uso comum por parte da sociedade, dando origem ao fenômeno social conhecido por tragédia dos comuns (HARDIN, 1968). Devido ao uso desregrado dos recursos de uso comum, intervenção governamental é fundamental para controlar o usufruto destes recursos, seja por políticas penais, assegurando os direitos de uso, intervindo em decisões comuns ou subsidiando a implementação da gestão-comunitária (DIETZ et al. 2003; OSTROM; COX 2010; MANSBRIDGE 2014).

Com base nessa ideia de proteção dos recursos de uso comum, são propostas soluções para o gerenciamento e proteção destes recursos, entre elas a criação de áreas protegidas, as quais quando se encontram em meio marinho são denominadas Áreas Marinhas Protegidas (AMPs). Dentre as várias medidas conservacionistas desenvolvidas pela ciência e cuja teoria foi comprovada na prática, as AMPs são consideradas a melhor medida de manejo de recursos naturais e da biodiversidade (AGARDY, 1994; BÉNÉ; MACFADYEN; ALLISON, 2005). O manejo de recursos naturais em AMPs frequentemente possui uma abordagem ecossistêmica, não focam em espécies ou recursos isoladamente e considera a proteção de toda a cadeia de interação ecossistêmica (Carr & Ramondi 1999; Naughton-Treves et al. 2005).

A criação e administração adequada de AMPs é assunto de interesse mundial. A Convenção em Diversidade Biológica (CDB) é um acordo assinado por 196 países, dos quais 157 o ratificaram. A república brasileira foi signatária do acordo em 1992 e o ratificou em 1994 (UNO; UNEP, 2015). Este acordo tem como principais objetivos a conservação da diversidade biológica, o uso sustentável dos componentes da biodiversidade e seus patrimônio genético e por fim, a seguridade na partilha, acesso e transferência dos recursos genéticos e suas tecnologias (CONVENTION ON BIOLOGICAL DIVERSITY, 2004a).

Para o alcance das metas de proteção da biodiversidade e dos biomas no mundo, foi acordado na CBD que cada nação deveria criar áreas protegidas de não-uso (*No-Take Areas*) em 10% das principais ecorregiões até 2010, criar e adequar os seus sistemas nacionais de áreas protegidas no bioma marinho até 2012 (CONVENTION ON BIOLOGICAL DIVERSITY, 2004b). Novas metas foram estabelecidas para 2020 em caráter de urgência a fim de atender as metas não atendidas até 2012 além de estabelecer as metas a serem alcançadas até 2050 (BRASIL et al. 2010).

2.2 Áreas Marinha protegidas no Brasil

No Brasil, existem 1839 Unidades de Conservação (UCs), das quais, pouco mais de 120 estão no bioma marinho (CNUC/MMA, 2014). Mesmo com um número consideravelmente razoável de AMPs, o quadro brasileiro de proteção neste bioma ainda está atrasado em relação as suas metas (SCHIAVETTI et al. 2013). Além disso, apenas designar uma área oceânica ou costeira como um a AMP não é suficiente para que os benefícios advindos da proteção sejam alcançados. É preciso estabelecer objetivos, planejar ações e suprir as necessidades básicas de execução do manejo para alcançar os resultados esperados (GUIDETTI et al. 2008). O termo “Parque de papel”, do inglês *Paper park* tem sido usado para se referir à áreas protegidas que são criadas legalmente, mas que são muito mal manejadas, o que causa o fracasso na proteção de seus recursos, espécies e processos (JAMESON et al. 2002).

As primeiras AMPs criadas no Brasil foram os Parques Estaduais de Ilhabela e Ilha Anchieta no estado de São Paulo em 1977, seguidas pela Reserva Biológica Atol das Rocas instituída em 1979 no estado do Rio Grande do Norte sob jurisdição federal (CNUC/MMA, 2014). A partir dos anos 80 surgiram inúmeras AMPs sob as esferas administrativas federais, estaduais e municipais. Hoje existem 59 AMPs federais geridas pelo o Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). Muitas outras estão sob jurisdição estadual e municipal e são geridas pelas secretarias estaduais e municipais do meio ambiente de seus respectivos estados e municípios entre outras instituições ambientais (CNUC/MMA, 2014). Esta fragmentação da administração das AMPs no Brasil está entre os principais problemas enfrentados pelos gestores em implementar e regulamentar as AMPs dificultando o alcance dos objetivos

de criação destas (GERHARDINGER et al., 2011). Além disso, esta fragmentação institucional das AMPs torna algumas dessas AMPs difíceis de serem contabilizadas para análise.

A fragmentação institucional também contribui para a falta de efetividade das AMPs no Brasil. Primeiramente, as unidades de conservação eram geridas pelo Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis (IBAMA). Em 2007 houve uma divisão institucional dividindo o IBAMA em mais uma instituição, o ICMBio, cujo objetivo é gerir as UCs federais. Repartições públicas recém criadas enfrentam problemas administrativos como falta de verba e recursos humanos e procedimentos burocráticos mal implementados, tornado o alcance de seus objetivos mais difíceis (CHIARAVALLOTI et al., 2015).

2.2.1 Sistema Nacional de Unidades de Conservação - SNUC

O Sistema Nacional de Unidades de Conservação (SNUC), foi criado com objetivo de dividir as áreas protegidas em diferentes categorias de uso, estabelecendo as permissividades e legislações inerentes a cada categoria proposta por esse sistema sob jurisdição de qualquer esfera administrativa (MINISTÉRIO DO MEIO AMBIENTE, 2000).

O SNUC divide áreas protegidas em duas categorias: áreas de proteção integral e áreas de uso sustentável, as quais permitem a utilização sustentada de seus recursos, havendo a divisão da área em setores com diferentes finalidades de uso. Essas duas categorias por sua vez, se dividem em mais doze subcategorias de proteção. No grupo de proteção integral temos Parques Nacionais, que preservam integralmente a biodiversidade em seu interior permitindo apenas a visitação e pesquisa. Monumentos Naturais, que protegem belezas cênicas naturais e seus componentes promovendo a visitação. Estações Ecológicas, onde apenas são permitidas apenas pesquisas em seu interior. Reservas Biológicas, onde pesquisa e visitação educacional são estritamente regulamentadas. Refúgio de Vida Silvestre onde são protegidas comunidades silvestres e seu habitat.

No grupo de áreas de uso sustentável temos Áreas de Proteção Ambiental, onde é permitida a existência de áreas privadas e empreendimentos em conjunto com a

utilização dos recursos naturais de forma sustentável. Áreas de Relevante Interesse Ecológico, que são porções de um ecossistema de características únicas havendo proteção dos recursos interiores permitindo a utilização dos recursos naturais de forma sustentável. Reservas de Fauna, onde são protegidas populações animais focais e seu habitat. Reservas Extrativistas, que é a única categoria que surge a partir de demanda social de uma população tradicional. Reserva de Desenvolvimento Sustentável, que permite a convivência de populações com a utilização dos recursos de forma sustentável. Existem mais duas categorias de unidade de conservação no SNUC: Floresta Nacional e Reserva Particular do Patrimônio Natural, mas essas categorias não são encontradas no bioma marinho costeiro (MINISTÉRIO DO MEIO AMBIENTE, 2000).

As áreas de proteção integral são assim definidas por proteger a biodiversidade e os recursos naturais dentro de toda sua área, não havendo permissão de uso direto dos recursos em seu interior. Já as áreas de proteção de uso sustentável, possuem sua área dividida em porções que permitem a utilização das áreas de diferentes formas, havendo zonas de uso sustentável dos recursos e zonas de não uso dentro da reserva. Há um debate acerca da legitimidade das áreas de proteção de uso sustentável devido sua permissividade de uso (LOCKE; DEARDEN, 2005; MARTINO, 2005). Por outro lado, há também controvérsias, quanto à implementação de áreas de proteção integral, por conta dos impactos socioculturais destas, em decorrência da desapropriação e dos direitos de uso destas áreas, por comunidades tradicionais previamente existentes (FISKE, 1992; MASCIA; CLAUS, 2009; WEST; IGOE; BROCKINGTON, 2006). Todavia, para que houvesse manejo independente e efetivo por parte da sociedade nos recursos de uso comum, seriam necessárias mudanças morais e éticas na conduta social (LAM; PAULY, 2010; PITCHER; LAM, 2010).

2.3 Avaliação de efetividade do manejo de Áreas Marinhas Protegidas

A efetividade do manejo de uma área protegida é definida por Hockings et al., 2000 pela interação entre três elementos: 1. Desenho e zoneamento, que, se refere às caraterísticas biofísicas da área protegida; 2. adequação das medias de manjo e dos processos, que se refere ao modo de atuação da gestão visando obter êxito nas ações

do manejo; 3. Alcance dos objetivos da Área Protegida, que está relacionado à medida que as áreas protegidas estão alcançando seus objetivos declarados, sejam de elementos biológicos ou sociais.

Leverington et al. 2010 definem a efetividade do manejo em Áreas Protegidas como a interação entre seis elementos pertinentes à AP e ao manejo dessas áreas. Estes elementos são: 1. Inserção, que diz respeito às características inerentes à área, vulnerabilidades à que ela esteja exposta e ao amparo legal das políticas públicas; 2. Planejamento que diz respeito à criação, demarcação e zoneamento adequados, e principalmente ao estabelecimento de objetivos e criação de planos de manejo; 3. Investimentos, que estão relacionados à captação de recursos para a devida execução do manejo, recursos humanos em número e capacitação adequados, infraestrutura, equipamentos e instalações apropriadas; 4. Processos, que são os meios pelos quais a o manejo toma as ações necessárias para o alcance dos objetivos da AP; 5. Resultados, definido pelo alcance dos objetivos propostos; 6. Efeitos produzidos na AP e nos entornos em função das ações do manejo.

De forma geral, é necessário planejamento e execução do manejo para alcançar os objetivos da criação de uma AMP, caracterizando assim a sua efetividade de manejo (JAMESON; TUPPER; RIDLEY, 2002). Das 59 AMPs federais existentes no Brasil, apenas 36 possuem plano de manejo (CNUC/MMA, 2014) o qual é fundamental para a sua implementação e consequentemente o alcance de seus objetivos, por estabelecer as diretrizes das ações a serem tomadas no manejo da área.

Análises da efetividade de manejo de uma AMP são raras já que tais análises devem incorporar dados, sociais, econômicos, ambientais e governamentais, os quais muitas vezes não estão disponíveis ou não existem. Em função dessa lacuna, muitas metodologias para Avaliação de Efetividade de Manejo (AEM) de AMPs possuem diferentes enfoques e graus de complexidade de aplicação. Podemos então modelar a efetividade de manejo a depender da necessidade e contexto da avaliação (HOCKINGS et al., 2000; LEVERINGTON et al., 2008).

Visando avaliar a efetividade das UCs no Brasil, o IBAMA e a WWF-Brasil iniciaram em 2005 um processo de avaliação da efetividade de manejo das UCs federais do Brasil e que foi repetido em 2010 mostrando uma pequena evolução na

efetividade do manejo nas UCs no bioma marinho (WWF-BRASIL; ICMBIO, 2007, 2012). A avaliação aplicada foi baseada no *Rappid Assessment and Priorization of Protected Areas* (*RAPPAM*), cuja metodologia consiste na aplicação de questionários aos gestores de Áreas protegidas, onde as questões são respondidas de forma qualitativa e tem como objetivo identificar as potencialidades e fraquezas no manejo, além de medir a efetividade (ERVIN, 2003).

2.3.1 Indicadores de efetividade de manejo em AMPs

Neste contexto, propõe-se o uso ‘indicadores de manejo’. Estes indicadores oferecem uma avaliação rápida, econômica e precisa, de como recursos marinhos são manejados em AMPs. Assim, estes indicadores tem o potencial de trazer respostas simples a fenômenos mais complexos de serem avaliados. Como AMPs estão inseridas em um contexto muito amplo de interações entre fatores que podem influenciar a sua efetividade, é recomendado o uso de indicadores chave para obter a informação desejada (ABLAN; MCMANUS; VISWANATHAN, 2004). Estes indicadores precisam ser as variáveis que melhor representem a variação da efetividade de manejo. Alguns estudos medem ou associam o sucesso de AMPs a partir de alguns indicadores, como mostrados a seguir:

A execução do manejo e as boas práticas administrativas são essenciais para o alcance dos objetivos propostos no planejamento de uma AMP, levando à efetividade destas (GUIDETTI et al., 2008); Em virtude dos conflitos sociais existentes no momento da criação de Unidades de conservação pela regulamentação no uso dos recursos, a efetividade da gestão de uma AMP depende do grau de afinidade que os gestores terão de lidar com os conflitos entre usuários e gestão (ROSSITER; LEVINE, 2014; WATSON et al., 2015); o grau de participação social nos processos de uma AMP, desde sua criação, planejamento e execução, são fundamentais para aquisição de bons resultados no manejo dessas áreas, uma vez que a população passa a colaborar com as medidas adotadas pela gestão (GERHARDINGER; GODOY; JONES, 2009; GUTIÉRREZ; HILBORN; DEFEO, 2011); Tamanho e idade das AMPs também estão relacionados á efetividade de uma AMP, uma vez que o tamanho e desenho apropriado são fatores limitantes para o alcance de objetivos específicos. Por outro lado, os resultados das

ações do manejo só são perceptíveis com o passar do tempo, caso estas medidas sejam tomadas devidamente (CLAUDET et al., 2008; WILHELM et al., 2014); Desenvolvimento econômico de uma região afeta a efetividade do manejo em uma AMP de modo que mais tecnologias são disponibilizadas para a aexecução do manejo, o nível educacional da população é consecutivamente melhor e os recursos são mais facilmente adquiridos (BENNETT; DEARDEN, 2014); O amparo legal, afeta positivamente a efetividade de uma AMP quando as políticas ambientais relacionadas aos componentes da AMP são bem aplicadas nas circunstâncias adequadas (BENNETT; DEARDEN 2014); A presença de grandes populações humanas próximas à uma AMP tende a gerar efeitos negativos na conservação dos recursos, uma vez que mais impactos antrópicos são gerados como poluição, sobre-explotação e expansão urbana (ABLAN; MCMANUS; VISWANATHAN, 2004); O nível de importância biológica e socioeconômica em uma AMP também são apontados como fatores limitantes de seu sucesso, pois recursos de maior importância tendem a ser melhor conservados caso a devida conscientização de sua importância seja feita frente a comunidade (ROSSITER; LEVINE, 2014); Existência de monitoramento e pesquisa na AMPs também são associadas ao seu sucesso, uma vez que as ações e resultados estejam sendo monitorados, possibilitando sua melhora (FRASCHETTI et al., 2002); Planejamento da gestão (HIMES, 2007); Recursos financeiros são responsáveis essenciais para a execução das ações do manejo, desdo o planejamento a sua implementação (JAMESON; TUPPER; RIDLEY, 2002); Recursos humanos são apontados como uma das principais fontes do sucesso de AMPs (HECK; DEARDEN; MCDONALD, 2012). Profissionais capacitados e em número suficiente possibilitam realizar as ações do manejo eficientemente.

Embora muitos estudos apontem quais os indicadores de efetividade de manejo melhor refletem a afetividade de manejo de uma AMP, a escolha de indicadores é determinada pelo contexto em que estas AMPs estão inseridas podendo responder de formas diferentes a um determinado indicador.

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3 ARTIGO - MODELING EFFECTIVENESS OF BRAZILIAN MARINE PROTECTED AREAS

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Abstract

The large increase in the 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 that 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. In this study, we use an innovative multi-model inference approach to identify the most important managerial, social and biogeophysical variables that are associated with the management effectiveness of Brazilian MPAs. Management effectiveness is measured using indicators from WWFs RAPPAM assessment of 2005 and 2010. The variables most associated with management effectiveness were: 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. We discuss the potential causal relationships between these variables and provide suggestions for how management effectiveness may be increased.

Key-words: Marine Protected Areas; RAPPAM; Model averaging; Indicators of effectiveness; Effectiveness evaluation.

Introduction

The creation of Protected Areas (PAs) for conserving nature was a defining feature of the 20th century [1]. The remarkable success of the PA concept is reflected in the expansion of the area of terrestrial land with some form of protection, which rose from <2% in 1900 to 12.5 % as of 2014 [2]. One of the main drivers of the rapid expansion of PAs was the obligation of 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 revised, with current targets of at least 17 per cent of terrestrial land and 10 per cent of coastal and marine areas under protection by 2020 [4]. Moreover, Target 11 of the Aichi Biodiversity Targets states that the protected area networks should be “equitably managed, ecologically representative and well connected systems”.

The global conservation community has clearly been remarkably successful at gazetting land for the protection of nature. Perhaps inevitably given the rapid rate of growth, 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 and pollution threaten nature both inside and outside of reserves [8, 9]. Moreover, in order to justify their role in competition with other land uses 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 [10].

Multiple management objectives and complex governance are characteristics of most Marine Protected Areas (MPAs) [11], which frequently have an auxiliary role in protecting valuable fishery resources [12]. Like their terrestrial counterparts, many MPAs in the developing world are perceived as being ineffectively managed [13], leading both the public and decision makers to question their value [14, 15]. Thus, 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 that is sufficiently flexible that it can encompass the diverse objectives, plans, and strategies of modern MPA networks [16, 17]. Ideally, an assessment system should also bring rapid and low

cost answers, while being sufficiently detailed to identify the main sources of variability in MPAs effectiveness [18]. The best known and most widely used example of such a system for MPAs is probably WWF`s Rapid Assessment and Prioritization of Protected Areas Management or RAPPAM [17]. RAPPAM is delivered through a questionnaire applied to MPA managers which contains 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 [17].

Precise assessment of management effectiveness (as through RAPPAM) provides scientists with opportunities to better understand what factors are most responsible for variation in management effectiveness within an MPA network. These factors are likely to be diverse and interacting, and include variation in : i) enforcement and investment [19]; ii) conflicts of users and management [20]; iii) social participation [21], and; iv) physical characteristics such as size and age [22]. In this article, we take advantage of two recent (2005/2010) RAPPAM evaluations of Brazilian MPAs to statistically model the relationship between MPA effectiveness and the managerial, social and physical characteristics of Brazilian MPAs. Brazil is an ideal case study to investigate MPA management effectiveness because the MPA network is currently very limited, covering only 0.35% of the Brazilian EEZ [23, 24], and there have been very few attempts to understand the drivers of management effectiveness.

Materials and Methods

MPA network

We assessed 54 Brazilian marine protected areas (MPAs) (Figure 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, we considered another 21 full protection MPAs, consisting of 8 National Parks (NPs), 5 Biological Reserves (BRs), 8 Ecological Stations (ESs), and Wildlife Refuge (WRs). The total set of MPAs covers 54 of the 59 federal Brazilian MPAs in the coastal and marine biome.

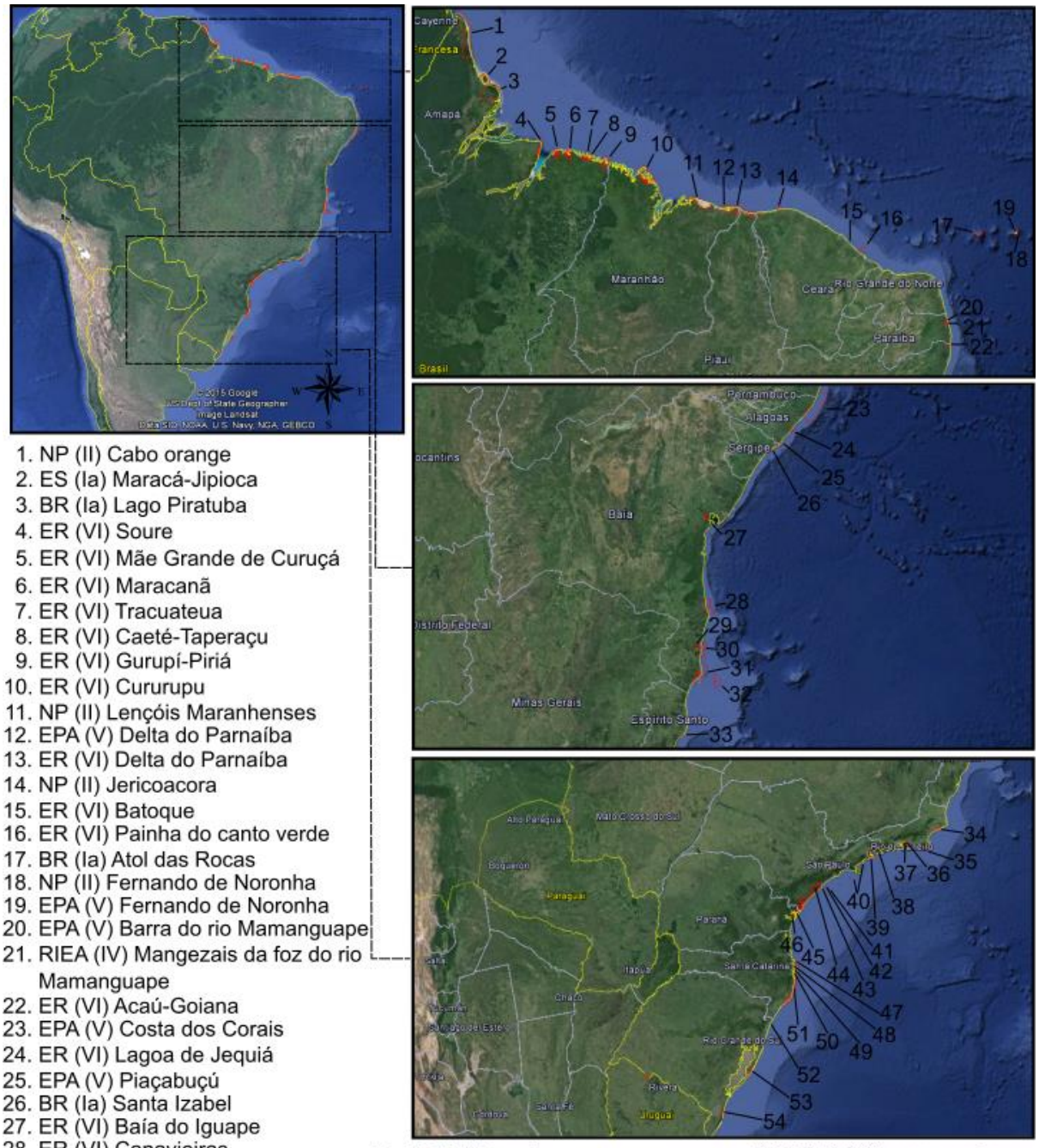

Figure 1: Map of Brazilian MPAs under federal jurisdiction. The name of each MPA is followed by the acronyms of the category According to SNUC and to IUCN in parenthesis. (adapted from Google.Earth).

Explanatory Variables

We identified 15 potential explanatory variables that could explain variations in management effectiveness: 1) *Financial investment*; 2) *Human resources*; 3) *Legal support*; 4) *Social participation*; 5) *Monitoring/Research*; 6) *Biological importance*; 7) *Socioeconomic importance*; 8) *Conflicts of users and management*; 9) *MPA age*; 10) *Management plan age*; 11) *MPA size*; 12) *Distance to coast*; 13) *Human population*; 14) *Economic development level*, and; 15) *IUCN category* (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 first eight explanatory variables were calculated using data from WWF's RAPPAM analysis of Brazilian MPAs, collected in 2005 and 2010 and available from WWF's PA Observatory [25]. 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' [17]. For the purposes of statistical analysis, each of these responses were converted into numbers from zero to three. Zero corresponded to the worst scenario (complete failure to achieve indicator). One corresponded to a bad scenario (partial failure to achieve indicator). Two corresponded to a good scenario (partial success to achieve indicator). Three is the optimal scenario (complete success to achieve indicator). Then, we summed the values of question compounding each varable to obtain the variable value. There was no upper limit to the number of indicators to form each variable (See table 1 on supplementary material for more detail).

Data on *MPA age*, *age of management plan*, *MPA size* and *distance* (from the centre 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/), we measured the distance from the border of the MPA nearest distance from MPA border to coast and the maximum distance from MPA border to coast. The average between these two values was defined as the *Distance to coast*.

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

Table 1: Predictor variables, their source and expected relationship with effectiveness.

Variable	Source	Expected Relationship	Conceptual basis for expected correlation and support literature
Investment (INV)	RAPPAM: Questions 12a to 12f.	Positive	More investment allows applying actions and planning more effectively [2].
Human resources (HUMRES)	RAPPAM: Questions 9a to 9e.	Positive	Staff in adequate number and capacity are responsible for executing actions and meeting objectives [3].
Legal support (LEGSUP)	RAPPAM: Questions 7a to 7e.	Positive	The legal instruments and law support in a MPA gives the management more capacity to apply the MPA politics [4].
MPA age (MPAGE)	ICMBio	Positive	As long as a MPA is properly managed, the experience grows affecting positively the effectiveness.
Management plan age (PLAGE)	ICMBio	Positive	Planning is necessary to trace objectives and strategies to reach the expected goals [5].
MPA size (MPASIZE)	ICMBio	Negative	Larger MPA are more difficult to protect and monitor reducing their 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 [7,8].
Monitoring/ Research (MONRES)	RAPPAM: Questions 15a to 15g.	Positive	Monitoring and research gives information that facilitates the planning and decisions making of management [9].
Distance from center of protection to coast (DIST)	ICMBio and Google maps.	Positive	Resources located at higher distances from human populations are more difficult to be exploited [10].
Biological	RAPPAM:	Positive	Higher levels of importance lead to more

Variable	Source	Expected Relationship	Conceptual basis for expected correlation and support literature
importance (BIOIMP)	Questions 3a to 3j.		concern, improving the enforcement and the effectiveness [5,7].
Socio economic importance (SOCIMP)	RAPPAM: Questions 4a to 4j.	Positive	Higher levels of importance lead to more concern, improving the enforcement and the effectiveness [5,7].
Human population (POPUL)	IBGE census: Municipal population	Negative	More people increases the demand for resources, leading to more exploitation of nearby resources [11].
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 [4].
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 [7].
IUCN Categories (IUCNCAT)	ICMBio	*	As the different categories have different access rules, it should influence the management effectiveness.
RAPPAM evaluation (EVALUA)	RAPPAM realization	*	The information made available for management at the first evaluation, would influence the values of management effectiveness

* No expected correlation.

Response variable

Overall management effectiveness of each MPA was quantified using data from the ‘outputs’ section from the RAPPAM surveys (2005 and 2010). This section contains 13 statements assessing the effectiveness of the PA over the previous 2 years in relation to the specific threats and pressures, PA 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 was obtained by summing the scores of all relevant questions.

Statistical analysis

Initially, we used Wilcoxon's Rank Sum test to assess how the views of MPA managers regarding different managerial dimensions changed between the two RAPPAM assessments. However, the primary objective of our study was to assess which PA 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 PA 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. We therefore adopted a multi-model inference approach [26, 27] to model the relationship between perceived management effectiveness and PA characteristics. The main advantages of this approach are that it provides insights about parameters on all models under consideration, calculating the contribution of each model and explanatory variable in relation to how well they are supported by the data [28].

We calculated all possible variable combinations (without interactions) using the MuMIn package for R Software. We then 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), we used a model averaging approach to obtain averaged parameter estimates and the relative importance of each explanatory variable. For this process, we considered only models with ΔAICc ≤ 4 [27]. All analyses were implemented using R Software v3.1.3 [29].

To calculate the evolution in values of management effectiveness and it's indicators we subtract their values in the evaluation of 2010 from the evaluation of 2005. So, the evolution is the variation of these variables among the evaluations, with negative values representing decrease in variables across evaluations and positive values representing improvement of these variables.

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, we were able to identify a set of variables that show high importance in terms of explaining PA 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) and greater public participation (SOCPART). These three variables were selected in all of the models (N = 81) in our analysis (variable relative importance = 1.00). Other variables were also important and were frequently selected in models. These include *distance to the coast* (relative importance = 0.75) and PA investment (relative importance = 0.63), both showing a positive relationship with management effectiveness. Higher levels of conflicts between PA users and managers (relative importance 0.96) were negatively associated with management effectiveness.

It is interesting to note that the year of the evaluation (EVALUA, relative importance = 0.91) was frequently included in 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 < 0.35).

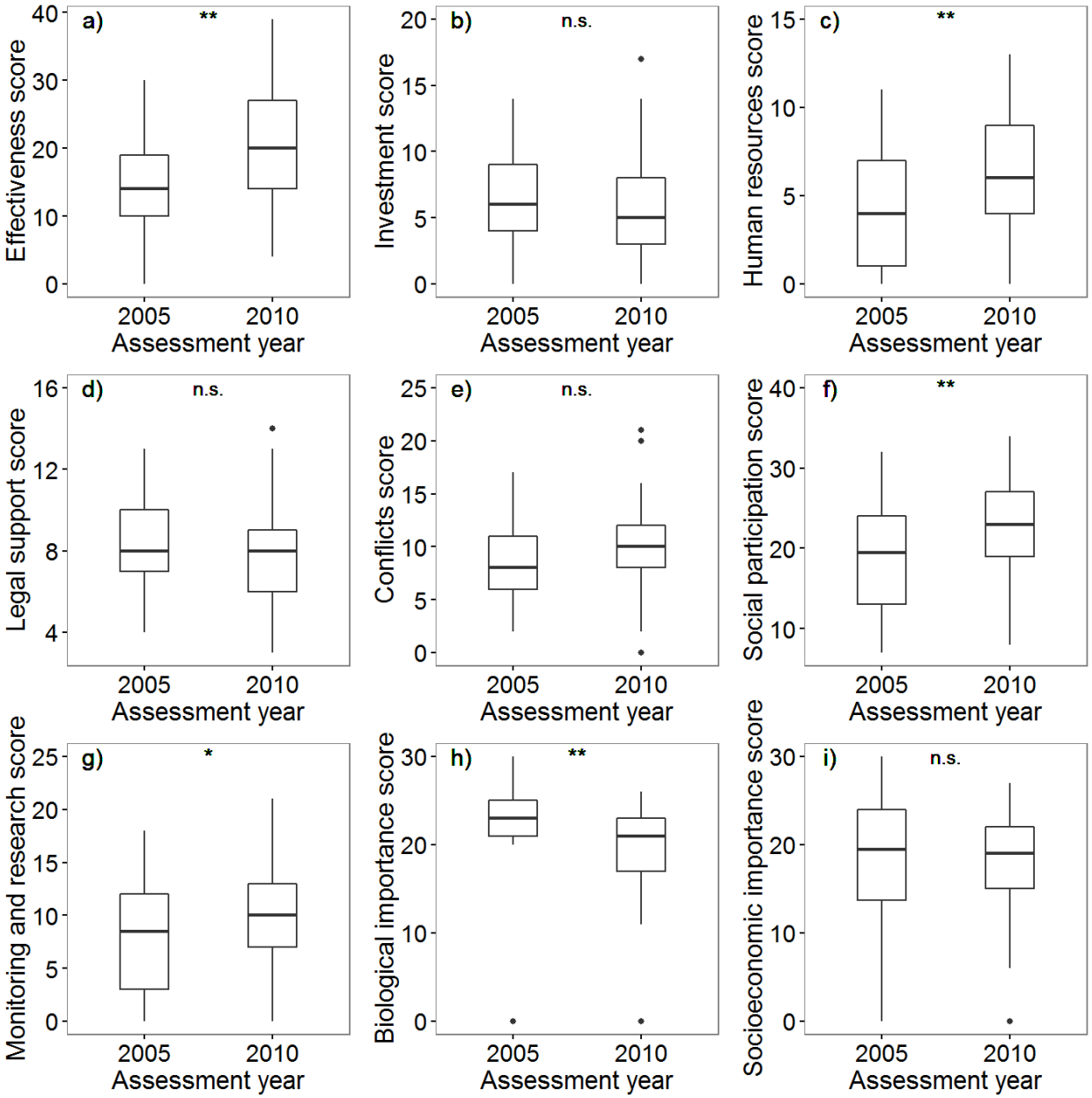

Figure 2: Distribution of summed RAPPAM scores reported in 2005 and 2010 for the questions relating to: a) Management effectiveness, b) Investment, c) Human resources, d) Legal support, e) Conflicts between users and MPA management, f) Social participation, g) Monitoring and research, h) Biological importance and i) Socioeconomic importance.

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	0.919	2.349	-	-
HUMRES	0.711	0.195	1.00	81
MONRES	0.705	0.113	1.00	81
SOCPART	0.367	0.107	1.00	81
CONFL	-0.418	0.156	0.96	76
EVALUA (2010)	2.024	1.198	0.91	72
DIST	0.010	0.008	0.75	57
INV	0.153	0.162	0.63	48
POPUL	>0.001	>0.001	0.32	26
MPAGE	0.021	0.048	0.27	24
MPASIZE	>0.001	>0.001	0.19	17
PLAGE	0.019	0.069	0.15	14
LEGSUP	0.015	0.083	0.10	10
BIOIMP	-0.003	0.021	0.09	9
GNP	-0.002	0.013	0.08	8
SOCIMP	>-0.001	0.017	0.06	7
IUCN II	-0.119	0.666	0.04	5
IUCN III	-0.233	1.395	0.04	5
IUCN IV	-0.319	1.637	0.04	5
IUCN V	-0.127	0.691	0.04	5
IUCN VI	-0.209	1.051	0.04	5

Legend: INV: Investiment, 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).

In the evolution of management effectiveness and indicators of effectiveness across the evaluations, Environmental Protected Areas showed the worst results in evolution, with most negative values in management effectiveness, human resources, investment and social participation. All National Parks showed positive evolution of management effectiveness, with few indicators showing negative evolution (Table 3).

Tabela 3: Evolution of management effectiveness and indicators in each MPA.

MARINE PROTECTED AREA (IUCN category)	EF	MR	HR	IN	CO	SP
EPA Costa dos Corais (V)	-44,01	11,9	-40	-44,45	28,57	9,34
EPA Barra do Rio Mamanguape (V)	-19,23	-42,86	13,34	-16,67	-4,76	-33,08
EPA Cananéia-Iguapé-Peruíbe (V)	-19,23	11,11	-40	-22,22	-14,28	-13,13
EPA Delta do Parnaiba (V)	-10,68	20,64	-33,33	27,78	19,05	7,33
EPA Fernando de Noronha (V)	-5,56	-61,11	-6,67	-27,77	0	-16,67
EPA Piaçabuçu (V)	-5,34	-2,38	-6,67	-22,22	4,76	-28,03

MARINE PROTECTED AREA (IUCN category)	EF	MR	HR	IN	CO	SP
EPA Cairuçu (V)	15,38	-16,67	-6,67	0	-9,52	-39,65
EPA Guapi-Mirim (V)	18,8	2,38	60	44,44	-9,53	1,26
EPA Baleia Franca (V)	27,14	-19,04	13,33	-44,45	-9,52	4,29
EPA Anhatomirim (V)	52,78	28,57	13,33	11,11	-38,09	33,08
RIEA Ilha Ameixal (IV)	35,9	37,3	13,34	11,11	14,29	-0,25
RIEA Ilhas Queimada Grande e Queimada Pequena (IV)	*	*	*	*	*	*
RIEA Manguezais da Foz do Rio Mamanguape (IV)	*	*	*	*	*	*
ES Guaraqueçaba (Ia)	-11,96	-13,49	-20	-33,33	19,05	-32,33
ES Tupinambás (Ia)	4,06	-14,29	0	-22,22	-28,57	-15,15
ES Tamoios (Ia)	6,41	45,23	-6,66	-16,66	-33,33	35,86
ES Carijós (Ia)	17,74	-1,59	-26,67	-16,67	4,76	-7,32
ES Tupiniquins (Ia)	24,36	-28,57	33,33	-22,23	-4,76	-2,28
ES Maracá Jipioca (Ia)	38,03	22,22	20	5,55	4,77	1,01
ES Taim (Ia)	39,53	21,43	33,33	5,55	0	-9,09
ES Guanabara (Ia)	*	*	*	*	*	*
NP Restinga de Jurubatiba (II)	5,12	-33,33	-6,67	61,11	28,57	19,69
NP Jericoacoara (II)	11,75	6,35	26,67	16,67	33,33	10,86
NP Lagoa do Peixe (II)	16,45	30,15	-13,33	-33,34	0	-8,84
NP Fernando de Noronha (II)	21,79	-2,38	20	33,33	-14,29	-6,82
NP Abrolhos (II)	25,21	0	-20	33,33	38,09	-12,12
NP Lençois Maranhenses (II)	38,89	53,17	60	44,45	0	35,86
NP Superagui (II)	45,94	50,8	60	-11,11	42,85	27,77
NP cabo orange (II)	54,27	33,34	20	-33,34	-33,33	-2,28
BR Comboios (Ia)	-10,68	-29,36	13,33	0	4,76	-5,56
BR Atol das Rocas (Ia)	4,27	-14,29	26,66	-38,89	23,81	-18,44
BR Santa Isabel (Ia)	4,92	-19,05	-13,34	33,34	-14,28	-6,06
BR Lago Piratuba (Ia)	20,72	13,49	33,33	-38,89	-4,76	16,42
BR Arvoredo (Ia)	36,11	27,78	-13,33	5,56	-4,77	11,11
ER Cururupu (VI)	-13,03	-15,87	-13,33	-27,78	-4,76	4,3
ER Corumbau (VI)	-9,19	-13,49	0	-11,11	-14,28	1,77
ER Batoque (VI)	2,57	-12,7	33,33	11,11	0	-7,83
ER Delta do Parnaiba	4,28	1,58	6,67	0	-14,29	8,33
ER Pirajubaé (VI)	10,04	-34,12	40	44,44	9,53	-4,8
ER Baia de Iguape (VI)	10,47	30,95	0	-27,78	-23,81	-8,84
ER Lagoa do Jequiá (VI)	10,47	7,94	60	11,11	71,43	22,48
ER Caeté-Taperaçu (VI)	17,95	52,38	0	-33,33	4,77	5,05
ER Soure (VI)	18,37	38,1	40	-11,11	28,57	9,34
ER Mae Grande de Curuça (VI)	24,15	28,57	13,33	22,23	4,77	18,44
ER Maracanã (VI)	24,15	71,43	40	22,22	0	21,47
ER Arai-Peroba (VI)	25,64	38,1	26,66	-16,66	23,8	7,83
ER Gurupi-Piriá (VI)	28,21	14,29	20	5,56	0	16,17
ER Arraial do Cabo (VI)	36,32	-14,29	60	27,78	28,57	50
ER Tracuateua (VI)	48,72	33,33	13,33	-5,55	19,04	38,39
ER Acaú-Goiana (VI)	*	*	*	*	*	*
ER Canavieiras (VI)	*	*	*	*	*	*
ER Cassurubá (VI)	*	*	*	*	*	*
ER Canto Verde (VI)	*	*	*	*	*	*

MARINE PROTECTED AREA (IUCN category)	EF	MR	HR	IN	CO	SP
WR Ilha dos Lobos (III)	-18,37	33,33	33,33	-16,66	23,81	18,44

Legend: EPA: Environmental Protection Areas, RIEA: Areas of Relevant Ecological Interest, ER: Extractive Reserves, NP: National Parks, BR: Biological Reserves, ES: Ecological Stations and WR: Wildlife Refuge, IN: Investiment, HR: Human resources, CO: Conflicts of users and management, SP: Social participation, MR: Monitoring/Research, '*': impossible to measure evolution

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 is expected, 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, and it is therefore vitally important to maximize gains in effectiveness with whatever funds are available [30]. In light of this, it is interesting to note that MPA manager's perceptions of management effectiveness generally improved between 2005 and 2010, despite slightly more negative opinions the current status of MPA investment.

The measures of "human resources" and "investment" in the Brazilian context relate to the availability of federal resources ring-fenced for MPA management. Human resources have previously been identified as one of the most important components of MPA management [31]. Once again this is entirely expected 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 human resource status reported in the latest RAPPAM assessment even in iconic Brazilian MPAs, such as *NP Abrolhos* and *EPA Costa dos Corais* (See Table 3 SOM), staffing may be at sub-optimal levels [30] thereby potentially compromising management effectiveness. Analysing the questionnaires, the lower values in human resources relates to the number of human resources and the higher values relates to the capacity and habilities of the existing human resources.

The process of creating a MPA is normally instigated by the need to conserve natural resources that are suffering from over-exploitation. Inevitably, restricting the use of resources in a MPA leads to social conflicts that need to be well managed to avoid

compromising the ability to meet the MPA's objectives. This was clearly demonstrated in our models by the strong negative association between the level of conflict and management effectiveness of the MPA. The question on RAPPAM shows related to demand for resources and illegal activities seemed to decrease the management effectiveness. By extension, one potential way to increase management effectiveness is to decrease conflict through mechanisms such as co-management or increased participation [19, 32]. Indeed, social participation was very strongly associated with management effectiveness (Table 2).

Social participation has been characterized in terms of the actors involved in the MPA management process and degree to which the goals of the community are met by the MPA objectives [33]. 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 [34]. This policy resonated with MPA managers and seems to have set the foundations for more successful actions and positive views towards social participation as reported in the latest RAPPAM assessment. 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*) with high levels of community participation also having high levels of management effectiveness [30] (See Table 3 SOM). The questionnaires shows lower values for the question related to environmental education and higher values for questions related to communication and decision-making.

As "social participation" decreases, the level of "conflicts" tends to grow, reducing the effectiveness of management actions [35-37]. 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 [36]. Our results clearly support the positive impact of social participation and negative effect to user conflicts on management effectiveness.

The positive association between “monitoring/research” and management effectiveness may represent a positive feedback loop of cause and effect. 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 [38, 39]. 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 [40]. Such a relationship can be seen in successful and well managed MPAs such as *NP Fernando de Noronha*, *NP Abrolhos, BR Atol das Rocas* and *EPA Costa dos Corais* (See Table 3 SOM) 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, incentivising illegal behaviours, and consequently threatening management effectiveness if not well controlled [41]. Likewise, “distance to coast” affects the capacity of human populations to exploit a MPA, since it is less economically viable and less practical to exploit distant resources [42]. However, increasing isolation also makes it more difficult to implement effective monitoring and surveillance of the illegal activities.

Legal support refers to legislation and legal instruments that allows the accomplishing of law by the managerial body in a MPA. The decreasing in legal support to MPAs is a global trend with policy ignoring, lack of enforcement and funding the most concerning causes [2]. Beyond these causes, the decreasing in legal support (Figure 2) is also related to the institutional split of IBAMA in ICMBio in 2007. This administrative change in a public agency changes the practices and proceedings, needing adaptation by managers to act legally in their MPA [30]. This event possibly should bring them less support and drive their perception of legal support to a lower level.

The negative correlation of the variable Biological importance to management effectiveness is contrarious to our model expectations, as higher levels of biological importance is supposed to attract more conservationist practices [3 5]. However, we should remember that biological or ecological components are not only important to ecosystems functioning, being also of socioeconomic importance. High socioeconomic

demands from important resources or environmental services in a MPA without the proper enforcement, should lead to drastic biological losses bringing ineffectiveness to management [43].

The evolution of management effectiveness showed changings in the values for each MPA across the evaluations, with negatively rated values for Environmental Protected Area and positively rated values for National Parks. Although our modelling do not showed a high influence of management category in management effectiveness, it indicates that management has improved differently between categories. The decrease in management effectiveness observed for EPAs possibly can be related to the flexibility in rules for use and occupation in this category [23]. Overall, these results support our initial hypotheses regarding the direction of the relationship between management effectiveness and our set of explanatory variables, and specifically highlight the importance of variables that represent interactions between different publics and the MPA.

The RAPPAM methodology is an effective analysis to assess the management effectiveness of PAs and identify their strengths and weaknesses. However, this method do not allow a deeper analysis in the management of PAs, and some peculiar and specific aspects should miss in the results. Moreover, the analysis takes in consideration only the view of the manager that has a unique view of the MPA processes, but we believe that management effectiveness evaluation would be more accurate if the community view was used to assess the management effectiveness of PAs.

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, our 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 [44-46]. Moreover, it should be possible to build a good relationship with local communities and solve management conflicts, even when resources are scarce [47, 48].

Increasing management effectiveness also requires clear planning and effective administration: features that are often lacking in Brazilian MPAs. For example, Of the 54 MPAs analysed here, only 11 had management plan at the time of the 2005 evaluation, with only six more achieving this important milestone by 2010. In this context, the failure of the system to achieve its main goal of conserving biodiversity [5, 49, 50] is clearly understandable. Without a management plan, a MPA manager often has no clear road-map to guide decisions limiting the capacity for effective and prompt actions [20].

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ANNEXES – Supporting Information

Here we show with detailed description about how our data was acquired.
Table 1shows how each variable used in our analysis was built. The Variables are linked to the questions of RAPPAM the we elected as relevant to build these indicators.

Table 1 SOM: Questions of RAPPAM used to build each variable related to effectiveness.

Variable	Module of Rappam	Questions
Biologial importance	Biologial importance	03a – There are many threatened species inside the PA. 03b – There are many species overexploited or with reduced population inside the PA? 03c – The PA has a high level of biodiversity. 03d – The PA has many endemic species. 03e – The PA has an essential function to the landscape. 03f – The PA contributes to the representativity of the PAs System. 03g - There are minimum viable populations of key-species in the PA. 03h – The PA keep the historic diversity standards. 03i – The PA protect the ecossystems that has been reduced. 03j - The PA conserve a significative diversity and natural processes.
Socioeconomic importance	Socioeconomic importance	04a – The PA is a source of emplyment to local communities 04b – The local communities subsist from natural resources in the PA. 04c – The PA offer oportunities of local development through the sustainable use of resources. 04d – The PA has religious or spiritual importance. 04e – The PA has stethical, historic or culural values. 04f – The PA keeps animal and vegetal species with social, economic or cultural value. 04g - The PA keeps animal species with social, economic or cultural value. 04h – The PA has a high recreational value. 04i – The PA contributes to the environmental services and benefits. 04j – The PA has a high educational or scientific value.
Conflicts of users and management	Vulnerability	05b – The local communities subsist from natural resources in the PA. 05c – The PA offer oportunities of local development

Variable	Module of Rappam	Questions
		through the sustainable use of resources. 05d – The cultural practices, creeds and traditional uses are in conflict with the PA objectives. 05e – The Market value of natural resources in the PA is high. 05f – The PA is acessible to ilegal acitivities. 05g – There is a great demand for natural resources from the PA. 05h – The management of the PA is pressed to develop actions in disacording with the objectives of the PA.
Legal support	Legal support	07a – The PA and it's resources are lagally sustained. 07b – The ownership situation is regular. 07c – The demarcation and sinalization of the PA are adequate. 07d – The human and financial resources are adequate to develop tha protection actions. 07e – There is legal support ta manage conflicts.
Human resources	Human resources	09a – There are enough human resources to manage the PA properly. 09b – The staff are capable to develop the management actions. 09c – There are oportunities of capacitation and team development adequated to the needs of the PA. 09d – There are periodic evaluations of staff development and progress. 09e – The work conditions are adequate to keep a proper team to meet the objectives of the PA.
Social participation	Comunication and information	10a – The communication structure is adequate between the PA and other administrative bodies. 10d – There is adequate systems for data storage, processing and analyse. 10e – There is effective communication between the PA and the local communities. 10f - There is effective communication between the local communities.
	Decision Making	14a – The PA is internally well organized. 14b – The decision making in the management is clear 14c – The PA colaborates with partners , comunities and other organizations. 14d – The local communities are angaged in the management of the PA taking part in the decision making.

Variable	Module of Rappam	Questions
		14e – The communication between the staff and administration of the PA is effective. 14f – Ther is a consil, implemented and affective. 14g – There is effective interaction between the PA and related entities. 14h – There is implementation of educational actions consistente and continuously to the meeting of objectives in the PA (only in 2010)
Investment	Financial Resources	12a – The financial resources of the last 5 years is adequate to the meeting of objectives of the PA. 12b – There is a prevision of financial resources to the next 5 years. 12c – The administration practices of finances of the PA are adequate to na effective management. 12d – The allocation of resources is in according with the priorities of the PA. 12e – The financial prevision at long date to the PA is stable. 12f – The PA is capable of atract external resources.
Monitoring and research	Research, Evaluation and monitoring	15a – The impact of the legal activities is monitored and registered precicely. 15b – The impact of the ilegal activities is monitored and registered precicely. 15c – The ecological researchs are in accordign with the needs of the PA. 15d - The socio economic researchs are in accordign with the needs of the PA. 15e – The PA team and community have regular access to information generated from the researchs in the PA. 15f – The critical needs of research and monitoring in the PA are identified and priorized. 15g – The PA team have access to recente scientifc knowledge (only in 2010)
Results	Results	16a – The PA planned the management in the last two years. 16b – The PA recovered areas and developed actions to mitigate the impacts in the last two years. 16c – The PA managed adequatelly the wildlife, habitat or natural resources inthe last two years. 16d – The PA developed outeach actions to the society in the last two years. 16e – The PA controled the visiting adequate to the need in the last two years.

Variable	Module of Rappam	Questions
		16f – The PA improved and mantained the infrastructure in the last two years. 16g – The PA prevented and detected threats and applied the law in the last two years. 16h – The PA supervised and evaluated the staff development in the last two years. 16i – The PA developed actions of capacitation and developement of human resources in the last two years. 16j – The PA supported the organization, capacitation and development of local communities in the last two years. 16k – there were research development in according with the PA objectives in the last two years. 16l – The management outcomes were monitored in the last two years. 16m – The PA developed Environmental educational actions in the last two years (only in 2010).

Table 2 shows the MPAs and their respective municipalities. To calculate the population and the economic development in each MPA we summed the values of population and GNP (Gross National Product) of each city in a given MPA.

Table 2 SOM: MPAs and their respective cities and respective states in brackets.

MARINE PROTECTED AREA (by type*)	Year of creation	Municipalities (STATE**)
EPA costa das algas	2010	Aracruz (ES), Fundão (ES), Serra (ES)
EPA costa dos corais	1997	Tamandaré (PE), Barra de Santo Antônio (AL), Japaratinga (AL), Maceió (AL), Maragogi (AL), Passo de Camaragibe (AL), Porto Calvo (AL), Porto de Pedras (AL), São Luís do Quitunde (AL), São Miguel dos Milagres (AL), Paripueira (AL), Rio Formoso (PE), São José da Coroa Grande (PE), Barreiros (PE)
EPA Baleia franca	2000	Florianópolis (SC), Garopaba (SC), Içara (SC), Imbituba (SC), Jaguaruna (SC), Laguna (SC), Palhoça (SC), Paulo Lopes (SC),Tubarão (SC)
EPA barra de mamaguape	1993	Baía da Traição (PB), Lucena (PB), Marcação (PB), Rio Tinto (PB)
EPA Anhatomirin	1992	Governador Celso Ramos (SC)
EPA Cairuçu	1983	Parati (RJ)

MARINE PROTECTED AREA (by type*)	Year of creation	Municipalities (STATE**)
EPA Cananeia Iguape Peruíbe	1984	Ilha Comprida (SP), Peruíbe (SP), Miracatu (SP), Itariri (SP), Iguape (SP), Cananéia (SP),
EPA Fernando de Noronha	1986	Fernando de Noronha (PE)
EPA Guapimirim	1984	Guapimirim (RJ), Itaboraí (RJ), Magé (RJ), São Gonçalo (RJ)
EPA Guaraqueçaba	1982	Antonina (PR), Campina Grande do Sul (PR), Guaraqueçaba (PR), Paranaguá (PR)
EPA Piaçabuçú	1983	Feliz Deserto (AL), Piaçabuçu (AL)
EPA Delta do Parnaíba	1996	Ilha Grande (PI), Paulino Neves (MA), Tutóia (MA), Água Doce do Maranhão (MA), Araioses (MA), Chaval (CE), Barroquinha (CE), Luís Correia (PI), Parnaíba (PI), Cajueiro da Praia (PI)
RIEA Ilha do ameixal	1985	Peruíbe (SP)
RIEA Ilha de queimada grande e ueimada pequena	1985	Peruíbe (SP)
RIEA Manguezais da foz do rio mamanguape	1985	Marcação (PB), Rio Tinto (PB)
ES guanabara	2006	Guapimirim (RJ), Itaboraí (RJ), São Gonçalo (RJ)
ES Carijós	1987	Florianópolis (SC)
ES guaraqueçaba	1982	Guaraqueçaba (PR)
ES Maracá Jipioca	1981	Amapá (AP)
ES Tamoios	1990	Angra dos Reis (RJ), Parati (RJ)
ES Tupinambas	1987	São Sebastião (SP), Ubatuba (SP)
ES Tupiniquins	1986	Cananéia (SP), Itanhaém (SP), Peruíbe (SP)
ES Taim	1986	Rio Grande (RS), Santa Vitória do Palmar (RS)
NM Ilhas Cagarras	2010	Niterói (RJ)
NP Lagoa do Peixe	1986	Mostardas (RS), São José do Norte (RS), Tavares (RS)
NP Restinga de Jurubatiba	1998	Quissamã (RJ), Macaé (RJ), Carapebus (RJ)
NP Jericoacoara	2002	Jijoca de Jericoacoara (CE), Cruz (CE)
NP Cabo Orange	1980	Calçoene (AP), Oiapoque (AP)
NP Superagui	1989	Guaraqueçaba (PR)
NP Lençóis Maranhenses	1981	Primeira Cruz (MA), Barreirinhas (MA)
NP Fernando de	1988	Fernando de Noronha (PE)

MARINE PROTECTED AREA (by type*)	Year of creation	Municipalities (STATE**)
Noronha		
NP Abrolhos	1983	Alcobaça (BA), Caravelas (BA)
BR Atol das Rocas	1979	Natal (RN)
BR Comboios	1984	Aracruz (ES), Linhares (ES)
BR Lago Piratuba	1980	Pracuúba (AP), Tartarugalzinho (AP), Amapá (AP)
BR Santa Isabel	1988	Pacatuba (SE), Pirambu (SE)
BR Arvoredo	1990	Bombinhas (SC), Florianópolis (SC), Governador Celso Ramos (SC)
ER Mãe grande de Curuçá	2002	Curuçá (PA)
ER Araí peroba	2005	Augusto Corrêa (PA), Pitimbu (PB), Goiana (PE)
ER Acaú Goiana	2007	Caaporã (PB)
ER Arraial do Cabo	1997	Arraial do Cabo (RJ)
ER Baia do Iguape	2000	Arraial do Cabo (RJ)
ER Batoque	2003	Aquiraz (CE), Caravelas (BA), Nova Viçosa (BA)
ER Cassurubá	2009	Alcobaça (BA) Prado (BA)
ER Corumbau	2000	Porto Seguro (BA), Canavieiras (BA), Una (BA)
ER Canavieiras	2006	Belmonte (BA), Água Doce (MA)
ER Cururupus	2004	Cururupu (MA), Santa Isabel (PI), Araióses (MA)
ER Delta do Parnaíba	2000	Ilha Grande (PI)
ER Gurupi Piriá	2005	Viseu (PA)
ER lagoa de Jequiá	2001	Jequiá da Praia (AL)
ER maracanã	2002	Maracanã (PA)
ER Caeté Taperaçú	2002	Bragança (PA)
ER Tracuateua	2005	Tracuateua (PA)
ER Pirajubaé	1992	Florianópolis (SC)
ER Prainha do Canto Verde	2009	Beberibe (CE)
ER Soure	2001	Soure (PA)
WR Santa Cruz	2010	Aracruz (ES), Fundão (ES), Serra (ES)
WR Ilha dos Lobos	1983	Porto Alegre (RS)

*Marine Protected Areas acronyms: EPA: Environmental Protection Areas, RIEA: Areas of Relevant Ecological Interest, ER: Extractive Reserves, NP: National Parks, BR: Biological Reserves, ES: Ecological Stations and WR: Wildlife Refuge

** State acronyms: AL: Alagoas, AP: Amapá, BA: Bahia, CE: Ceará, ES: Espírito Santo, MA: Maranhão, PA: Pará, PB: Paraíba, PE: Pernambuco, PI: Piauí, RJ: Rio de janeiro,

RN: Rio Grande do Norte, RS: Rio Grande do Sul, SE: Sergipe, SC: Santa Catarina and SP: São Paulo.

The suplementary table 3 shows the main indicators of management effectiveness for each MPA according to our modelling of eefectiveness. These results were used to generate the fitness values for the Brazilian MPAs

Table 3 SOM: Relative contribution of each Indicator of effectiveness in Brazilian MPAs. Values are given in percentage.

MARINE PROTECTED AREA (IUCN category)	2005						2010					
	Effec.	MONRES	HUMRES	INV	CONFL	SOCPART	Effec.	MONRES	HUMRES	INV	CONFL	SOCPART
ESEC da Guanabara (Ia)	*	*	*	*	*	*	74.36	52.38	86.67	94.44	42.86	86.11
ESEC de Carijós (Ia)	69.44	77.78	60.00	61.11	28.57	87.88	87.18	76.19	33.33	44.44	33.33	80.56
ESEC de Guaraqueçaba (Ia)	22.22	27.78	20.00	33.33	19.05	54.55	10.26	14.29	0.00	0.00	38.10	22.22
ESEC de Maracá Jipioca (Ia)	5.56	11.11	0.00	16.67	9.52	21.21	43.59	33.33	20.00	22.22	14.29	22.22
ESEC de Tamoios (Ia)	50.00	16.67	53.33	33.33	33.33	36.36	56.41	61.90	46.67	16.67	0.00	72.22
ESEC do Taim (Ia)	52.78	50.00	40.00	27.78	28.57	75.76	92.31	71.43	73.33	33.33	28.57	66.67
ESEC dos Tupiniquins (Ia)	50.00	66.67	26.67	55.56	47.62	60.61	74.36	38.10	60.00	33.33	42.86	58.33
ESEC Tupinambás (Ia)	47.22	66.67	46.67	50.00	42.86	81.82	51.28	52.38	46.67	27.78	14.29	66.67
REBIO Atol das Rocas (Ia)	77.78	100.00	6.67	61.11	33.33	54.55	82.05	85.71	33.33	22.22	57.14	36.11
REBIO de Comboios (Ia)	72.22	72.22	26.67	22.22	28.57	66.67	61.54	42.86	40.00	22.22	33.33	61.11
REBIO de Santa Isabel (Ia)	69.44	66.67	46.67	22.22	33.33	72.73	74.36	47.62	33.33	55.56	19.05	66.67
REBIO do Lago Piratuba (Ia)	30.56	38.89	6.67	77.78	42.86	36.36	51.28	52.38	40.00	38.89	38.10	52.78
REBIO do Arvoredo (Ia)	63.89	72.22	53.33	22.22	14.29	66.67	100.00	100.00	40.00	27.78	9.52	77.78
PARNA da Lagoa do Peixe (II)	52.78	55.56	73.33	55.56	28.57	72.73	69.23	85.71	60.00	22.22	28.57	63.89
PARNA de Jericoacoara (II)	47.22	22.22	33.33	22.22	28.57	69.70	58.97	28.57	60.00	38.89	61.90	80.56
PARNA do cabo orange (II)	27.78	33.33	13.33	77.78	57.14	60.61	82.05	66.67	33.33	44.44	23.81	58.33
PARNA do Superagui (II)	36.11	44.44	20.00	38.89	19.05	66.67	82.05	95.24	80.00	27.78	61.90	94.44
PARNA dos	27.78	27.78	6.67	33.33	57.14	36.36	66.67	80.95	66.67	77.78	57.14	72.22

Lençois Maranhenses (II)												
PARNA de Fernando de Noronha (II)	50.00	50.00	20.00	61.11	66.67	81.82	71.79	47.62	40.00	94.44	52.38	75.00
PARNA dos Abrolhos (II)	38.89	66.67	53.33	11.11	23.81	78.79	64.10	66.67	33.33	44.44	61.90	66.67
PARNA Restinga de Jurubatiba (II)	66.67	100.00	66.67	5.56	33.33	63.64	71.79	66.67	60.00	66.67	61.90	83.33
REVIS Ilha dos Lobos (III)	72.22	66.67	46.67	72.22	33.33	45.45	53.85	100.00	80.00	55.56	57.14	63.89
ARIE Ilha Ameixal (IV)	0.00	5.56	53.33	5.56	80.95	36.36	35.90	42.86	66.67	16.67	95.24	36.11
ARIE Ilhas Queimada Grande e Queimada Pequena (IV)	*	*	*	*	*	*	28.21	47.62	40.00	33.33	61.90	47.22
ARIE Manguezais da Foz do Rio Mamanguape (IV)	47.22	94.44	0.00	0.00	42.86	36.36	*	*	*	*	*	*
APA Anhatomirim (V)	13.89	33.33	26.67	33.33	52.38	36.36	66.67	61.90	40.00	44.44	14.29	69.44
APA Barra do Rio Mamanguape (V)	83.33	100.00	33.33	55.56	52.38	96.97	64.10	57.14	46.67	38.89	47.62	63.89
APA Costa dos Corais (V)	72.22	16.67	66.67	55.56	14.29	54.55	28.21	28.57	26.67	11.11	42.86	63.89
APA da Baleia Franca (V)	47.22	33.33	60.00	55.56	52.38	81.82	74.36	14.29	73.33	11.11	42.86	86.11
APA de Cairuçu (V)	0.00	16.67	26.67	0.00	52.38	75.76	15.38	0.00	20.00	0.00	42.86	36.11
APA de Cananéia-Iguapé-Peruíbe (V)	83.33	55.56	60.00	44.44	57.14	90.91	64.10	66.67	20.00	22.22	42.86	77.78
APA de Fernando de Noronha (V)	38.89	61.11	20.00	33.33	47.62	66.67	33.33	0.00	13.33	5.56	47.62	50.00
APA de Guapi-Mirim (V)	55.56	50.00	26.67	50.00	66.67	84.85	74.36	52.38	86.67	94.44	57.14	86.11
APA de Piaçabuçu (V)	36.11	50.00	6.67	27.78	19.05	69.70	30.77	47.62	0.00	5.56	23.81	41.67
APA Delta do	38.89	22.22	60.00	11.11	33.33	45.45	28.21	42.86	26.67	38.89	52.38	52.78

Parnaiba (V)												
RESEX Acaú-Goiana (VI)	*	*	*	*	*	*	33.33	47.62	40.00	33.33	57.14	52.78
RESEX Corumbau (VI)	52.78	61.11	33.33	33.33	61.90	45.45	43.59	47.62	33.33	22.22	47.62	47.22
RESEX de Canavieiras (VI)	*	*	*	*	*	*	58.97	57.14	53.33	44.44	38.10	69.44
RESEX de Cassurubá (VI)	*	*	*	*	*	*	20.51	28.57	20.00	27.78	66.67	63.89
RESEX de Cururupu (VI)	36.11	44.44	20.00	27.78	71.43	48.48	23.08	28.57	6.67	0.00	66.67	52.78
RESEX do Batoque (VI)	33.33	55.56	20.00	11.11	42.86	60.61	35.90	42.86	53.33	22.22	42.86	52.78
RESEX Mae Grande de Curuça (VI)	19.44	0.00	6.67	33.33	33.33	45.45	43.59	28.57	20.00	55.56	38.10	63.89
RESEX Maracanã (VI)	19.44	0.00	6.67	50.00	38.10	42.42	43.59	71.43	46.67	72.22	38.10	63.89
RESEX Arai-Peroba (VI)	0.00	0.00	6.67	22.22	38.10	39.39	25.64	38.10	33.33	5.56	61.90	47.22
RESEX Arraial do Cabo (VI)	27.78	66.67	20.00	11.11	47.62	33.33	64.10	52.38	80.00	38.89	76.19	83.33
RESEX Caeté-Taperaçu (VI)	0.00	0.00	6.67	33.33	33.33	39.39	17.95	52.38	6.67	0.00	38.10	44.44
RESEX da Baia de Iguape (VI)	30.56	16.67	13.33	38.89	71.43	72.73	41.03	47.62	13.33	11.11	47.62	63.89
RESEX da Lagoa do Jequiá (VI)	30.56	11.11	0.00	0.00	28.57	30.30	41.03	19.05	60.00	11.11	100.00	52.78
RESEX de Gurupi-Piriá (VI)	0.00	0.00	6.67	22.22	38.10	39.39	28.21	14.29	26.67	27.78	38.10	55.56
RESEX de Soure (VI)	27.78	0.00	6.67	27.78	33.33	54.55	46.15	38.10	46.67	16.67	61.90	63.89
RESEX do Delta do Parnaiba	44.44	55.56	40.00	33.33	66.67	66.67	48.72	57.14	46.67	33.33	52.38	75.00
RESEX Pirajubaé (VI)	36.11	72.22	33.33	0.00	61.90	57.58	46.15	38.10	73.33	44.44	71.43	52.78
RESEX Tracuateua (VI)	0.00	0.00	6.67	22.22	38.10	39.39	48.72	33.33	20.00	16.67	57.14	77.78
RESEX do Canto	*	*	*	*	*	*	58.97	14.29	60.00	16.67	57.14	83.33

Verde (VI)

Acronyms: APA: Environmental Protection Areas; ARIE: Areas of Relevant Ecological Interest; RESEX: Extractive Reserves; PARNA: National Parks; REBIO: Biological Reserves; ESEC: Ecological Stations; REVIS: Wildlife Refuge. MONRES: Monitoring/Research; HUMRES: Human Resources; CONFL: Conflicts of users and management; SOCPART: Social participation; Symbols: 'Ia, II, III, IV, V and VI': IUCN categories of MPAs; '*': not evaluated.

4 CONCLUSÃO GERAL

Aumentar a efetividade das Éreas Marinha Protegidas (AMPs) Brasileiras requer um comprometimento em administrar lidando com fatores contextuais (ex.: distância da AMP para grandes centros populacionais, etc). Não obstante, Esta análise apoia a ideia de que se ações são constantemente avaliadas, se a infraestrutura é melhorada e existe previsão regular de verba, a efetividade do manejo pode ser melhorada. Além disso, é possível construir uma boa relação com comunidades locais e resolver conflitos administrativos, mesmo com recursos escassos.

Aumentar a efetividade de manejo também requer um planejamento claro e uma administração efetiva, o que comumente é tido como uma carência em AMPs brasileiras. Por exemplo, das 54 AMPs avaliadas neste trabalho, apenas 11 possuiam plano de manejo no momento da avaliação de 2005, com um acréscimo de seis planos de manejo na avaliação seguinte. Nesse contexto, a falha do sistema em alcançar o objetivo de conservação dos biomas e da biodiversidade é claramente compreensível. Sem um plano de manejo, um gestor não possui um direcionamento preciso para guiar suas decisões, limitando sua capacidade de ação.

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