UNIVERSIDADE FEDERAL DO PARANÁ

DANIELE ALVES VILA NOVA

FERRAMENTAS ESPACIAIS E DE PLANEJAMENTO SISTEMÁTICO NA AVALIAÇÃO DE ÁREAS MARINHAS PROTEGIDAS EM AMBIENTES RECIFAIS DA COSTA BRASILEIRA

CURITIBA

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Tese apresentada como requisito parcial à obtenção do grau de Doutor em Ecologia e Conservação, no Curso de Pós-Graduação em Ecologia e Conservação, Setor de Ciências Biológicas, da Universidade Federal do Paraná.

Orientador: Prof. Dr. Sergio Ricardo Floeter
Co-orientador: Prof. Dr. Carlos Eduardo Leite Ferreira

CURITIBA

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Ministério da Educação
UNIVERSIDADE FEDERAL DO PARANÁ
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ECOLOGIA E CONSERVAÇÃO

PARECER

Os abaixo-assinados, membros da banca examinadora da defesa da tese, a que se submeteu **Daniele Alves Vila Nova** para fins de adquirir o título de Doutora em Ecologia e Conservação, são de parecer favorável à **APROVAÇÃO** do trabalho de conclusão da candidata.

Secretaria do Programa de Pós-Graduação em Ecologia e Conservação.

Curitiba, 27 de março de 2014.

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“Make a radical change in your lifestyle and begin to boldly do things which you may previously never have thought of doing, or been too hesitant to attempt. So many people live within unhappy circumstances and yet will not take the initiative to change their situation because they are conditioned to a life of security, conformity, and conservation, all of which may appear to give one peace of mind, but in reality nothing is more damaging to the adventurous spirit within a man than a secure future. The very basic core of a man's living spirit is his passion for adventure. The joy of life comes from our encounters with new experiences, and hence there is no greater joy than to have an endlessly changing horizon, for each day to have a new and different sun. If you want to get more out of life, you must lose your inclination for monotonous security and adopt a helter-skelter style of life that will at first appear to you to be crazy. But once you become accustomed to such a life you will see its full meaning and its incredible beauty.”

— Jon Krakauer

“There are no safe paths in this part of the world. Remember you are over the Edge of the Wild now, and in for all sorts of fun wherever you go.”

— J.R.R. Tolkien

RESUMO GERAL

Esse trabalho apresenta o primeiro conjunto de análises espaciais abrangendo ambientes recifais rasos em toda a costa Brasileira, conflitos de uso, áreas marinhas protegidas (AMPs) existentes, comparando-os com as áreas prioritárias para conservação estabelecidas pelo governo, dentro do contexto de manejo com base em ecossistema. Análises de *hotspots* de diversidade com peixes recifais como *proxy* para ambientes recifais também foram realizados *a priori*, como indicador de incompatibilidades entre o atual sistema de AMPs e áreas de alta riqueza de espécies, número de espécies ameaçadas e endemismo na costa brasileira. É evidente que o atual sistema de AMPs precisa ser ampliado em nível nacional, e o exercício de expansão das AMPs em áreas com recifes costeiros aqui apresentados pode ser usado como referência em outros sistemas marinhos, para integrar as AMPs num contexto com base em ecossistemas. Os recifes são provavelmente o ecossistema marinho mais estudado no Brasil, e mesmo estando inseridos em AMPs de vários níveis de proteção e uso, eles ainda estão sob várias ameaças. Atualmente, cerca de 2% de toda a Zona Econômica Exclusiva do Brasil está inserida em AMPs, sendo que o Brasil é signatário da meta de 10% estabelecida pela Convenção da Diversidade Biológica para 2020. Semelhante à outros países emergentes, como China, Índia, Indonésia, México e África do Sul, além do baixo número de AMPs, estas ainda enfrentam problemas substanciais de efetividade. Este estudo, ao comparar as áreas de *hotspots* de peixes recifais e AMPs revelou que a costa do nordeste e o estado do Espírito Santo são as regiões mais críticas para medidas de conservação de peixes recifais. O exercício de priorização espacial com organismos recifais (peixes, corais, algas) e as AMPs existentes mostrou a importância do aumento da rede de AMPs, principalmente no nordeste. Estas áreas são equivalentes às áreas prioritárias para a conservação indicadas para criação ou ampliação de AMPs estabelecidas pelo governo em 2007, e para controle da pesca. Dessa forma, reiteiramos a urgência de que tais medidas sejam realizadas. É fundamental que sejam estabelecidas iniciativas para integrar o sistema de AMPs dentro das práticas de gestão ecossitêmica, para que usos conflitantes sejam administrados de forma complementar e não antagônica. Como as ferramentas de gestão espaciais incluem múltiplas áreas e objetivos, inserir a expansão do sistema de AMPs no contexto do planejamento espacial irá contribuir para minimizar influências externas que poderiam reduzir a efetividade das AMPs. Tal expansão deve incluir áreas fechadas pra pesca, seja por meio de AMPs de proteção integral ou no zoneamento das AMPs de uso múltiplo.

Palavras chave: priorização espacial, manejo com base em ecossistemas, planejamento espacial marinho, Zonation, *hotspots*, Meta de Aichi 11, peixes recifais, corais.

ABSTRACT

This work presents the first set of spatial analysis covering all reef environments throughout the Brazilian coastline to a depth of 50m, use conflicts, current marine protected areas (MPAs), and comparing the results with priority areas for conservation designed by the government, within the context of ecosystem-based management. Analyses of reef fish hotspots as a proxy for reef environments were performed *a priori*, to highlight mismatches between the current system of MPAs and areas of high species richness, threatened and endemic species on the Brazilian coastline. It is clear that the current system of MPAs needs to be expanded nationally, and the spatial prioritization exercise presented in this study encompassing use conflicts, MPAs and coastal reefs may be used as a reference for other marine systems, to insert MPAs within the ecosystem-based management approach. Reefs are probably the most studied marine ecosystem in Brazil, and even being inserted within MPAs of multiple levels of protection and use, they are still under various threats. Currently, about 2% of the Exclusive Economic Zone of Brazil is inserted in MPAs, whereas Brazil is a signatory of the 10% target set by the Convention of Biological Diversity for 2020. Similar to other emerging countries such as China, India, Indonesia, Mexico and South Africa, together with the low number of MPAs, most of MPAs in these countries still face substantial problems of effectiveness. The study observing the mismatches between hotspots of reef fish and MPAs showed that the northeastern coast and the state of Espírito Santo are the most critical regions for conservation of reef fish. The spatial prioritization exercise with reef organisms (fish, corals, algae) and existing MPAs showed the importance of expanding the MPA network, especially in the Northeast. These output areas correspond to the priority areas for conservation set for creation or expansion of MPAs, and for fisheries management by the government. Thus, we reinforce the urgency of such measures to be undertaken. It is essential that initiatives to integrate MPAs within the ecosystem-based management practices are established, so that conflicting uses are managed in a complementary manner. While using tools for spatial planning, it is possible to include multiple objectives, and inserting the expansion of MPAs system in the context of spatial planning will help to minimize external influences that could reduce the effectiveness of MPAs. Such expansion should include areas closed to fishing, whether through no-take MPAs or within no-take zones in multiple-use MPAs.

Keywords: spatial prioritization, ecosystem-based management, marine spatial planning, Zonation, hotspots, Aichi target 11, reef fish, corals.

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1 INTRODUÇÃO GERAL

Sobrepesca, poluição e destruição de habitats, juntamente com recentes alterações climáticas globais vêm sendo apontadas como umas das principais causas para a perda da diversidade em ambientes marinhos e declínio gradual na produtividade desses sistemas (TOROPOVA *et al.,* 2010). As Áreas Marinhas Protegidas (AMPs) são uma das ferramentas mais utilizadas para a conservação de ecossistemas e manejo dos recursos marinhos, entretanto, atualmente abrangem apenas 3% dos oceanos em todo o globo (ROBERTS *et al.,* 2001; TOROPOVA *et al*., 2010; IUCN/UNEP-WCMC, 2013). Dependendo dos objetivos específicos que envolvem a sua criação, as AMPs podem ser classificadas em diferentes categorias de acordo com critérios estabelecidos pela União Internacional para a Conservação da Natureza (DAY *et al.,* 2012). No Brasil, o processo de criação de AMPs é regido pelo Sistema Nacional de Unidades de Conservação (‘SNUC’, BRASIL, 2000), ainda que o termo 'áreas marinhas protegidas' não seja definido dentro do SNUC. Diferentes usos e categorias das AMPs podem ser observados na Tabela 1.

As AMPs também são utilizadas como medida de avaliação dos esforços realizados por países para o manejo dos oceanos de forma independente. Dentro da Convenção da Diversidade Biológica (CDB), por exemplo, existem metas de conservação que são ratificadas por países signatários, servindo como base para planejamento dentro das escalas governamentais mais elevadas (CBD, 2011). Dentre elas, as metas de Aichi, que estabelecem alvos para 2020, têm servido de guia em agendas governamentais em mais de 100 países, sendo a meta nº. 11 uma das mais relevantes para ambientes costeiros e marinhos:

> “*Até 2020*, pelo menos 17 por cento de áreas terrestres e de águas continentais e *10 por cento de áreas marinhas e costeiras, especialmente áreas de especial importância para biodiversidade e serviços ecossistêmicos, terão sido conservados por meio de sistemas de áreas protegidas geridas de maneira efetiva e equitativa, ecologicamente representativas e satisfatoriamente interligadas e por outras medidas espaciais de conservação, e integradas em paisagens terrestres e marinhas mais amplas*” (CBD, 2011, com *ênfase*).

Tabela 1. Tipos de categorias e uso de Áreas Marinhas Protegidas, de acordo com as definições da UICN e do SNUC. As categorias I-III da UICN equivalem às Unidades de Proteção Integral do SNUC, enquanto que as categorias IV-VI equivalem às Unidades de Uso Sustentável (Adaptado de MMA, 2010; DAY *et al.,* 2012).

Categoria UICN	Objetivos	Categoria equivalente SNUC (aproximada)
Ia	- proteger a diversidade biológica e conservar aspectos físicos - áreas de referências para pesquisas científicas e monitoramento	Reserva Biológica, Estação Ecológica
Ib	- manter a integridade ecológica e condição natural	(não há correlação específica)
II	- proteger processos ecológicos de larga escala - propiciar educação e recreação	Parque
III	- conservar aspectos naturais específicos, de grande valor para visitantes	Monumento Natural, Refúgio da Vida Silvestre
IV	- proteger espécies ou habitats específicos	(não há AMP correspondente nessa categoria específica)
V	- manter paisagens - conservar valores da interação entre pessoas e natureza	Área de Proteção Ambiental, Área de Relevante Interesse Ecológico
VI	- proteger ecossistemas naturais e uso sustentável de recursos naturais em sinergia - associar valores culturais e sistemas de manejo tradicionais	Reserva Extrativista, Reserva de Desenvolvimento Sustentável

Recentemente, o processo de planejamento e criação de AMPs vêm sendo mais integrado às necessidades de manejo e desafios de uso da paisagem como um todo (DOUVERE, 2008; HALPERN *et al.,* 2010). A conectividade entre ambientes marinhos é evidente pela troca constante de energia, feita por intermédio de organismos que migram, bem como pelo fluxo de águas (CROWDER & NORSE, 2008). Essa conectividade ainda permite a troca de matéria orgânica, dispersão de propágulos, além de permitir o desenvolvimento de espécies que necessitam de diferentes áreas para completar seu ciclo de vida (Figura 1). Uma vez que diferentes sistemas estão conectados por fatores físicos, químicos e biológicos, impactos locais em um dado ambiente podem ser refletidos em outros adjacentes. (CROWDER & NORSE, 2008). Dentro deste contexto, o conceito de manejo com base em ecossistema (sigla EBM, do inglês *ecosystem-based management*) engloba essas características de conectividade e inter-dependência, estabelecendo práticas de manejo de forma integrada, de modo a sempre considerar os humanos como componente vital em todo o processo (MCLEOD *et al.,* 2005).

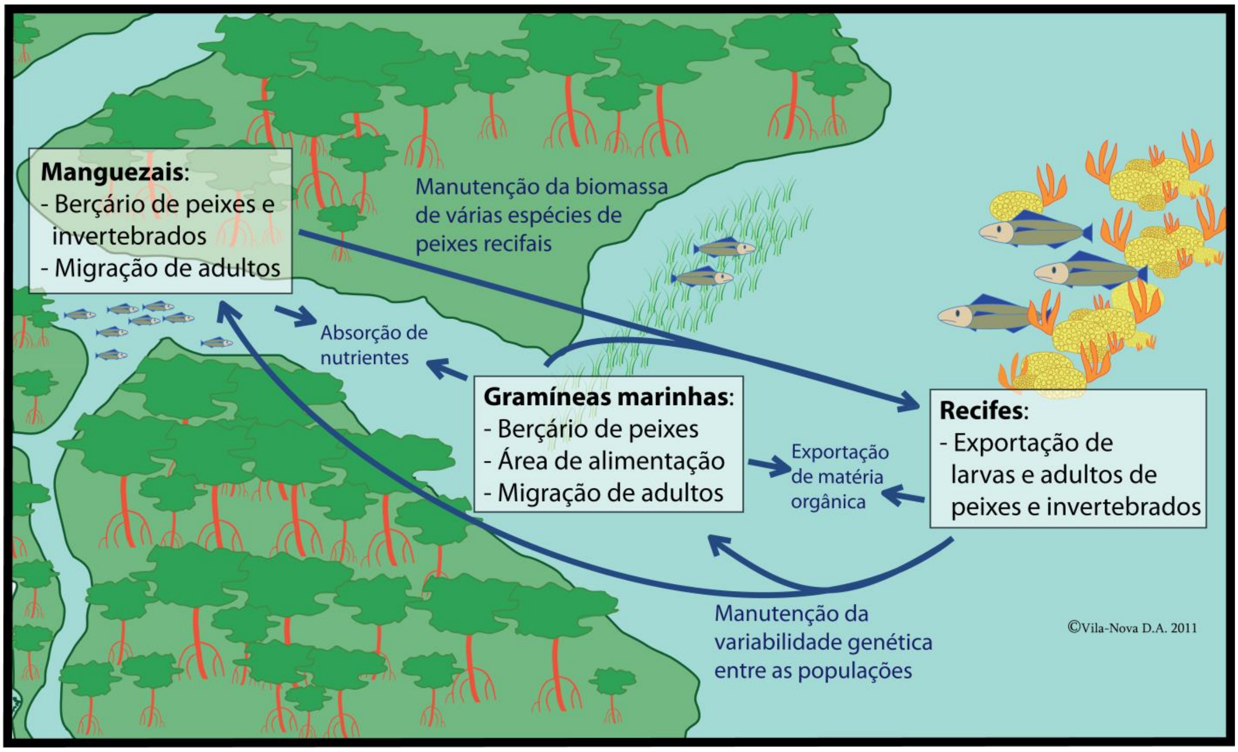

Figura 1. Esquema exemplificando a conectividade entre ambientes marinhos.

Dentro das práticas de EBM, as ferramentas de planejamento espacial e sistemático consideram habitats e ecossistemas como ‘lugares’ ou ‘espaços’, integrando, além dos componentes biofísicos, atributos sociais, culturais, econômicos e até políticos (CROWDER & NORSE, 2008). Este processo de planejamento espacial e sistemático pode e deve ser repetido várias vezes durante a sua execução à medida que novos desafios/atores são incorporados dentro do conjunto de procedimentos de manejo (Figura 2). Esta estratégia contribui para o planejamento contínuo, prevendo futuras necessidades e condições, e garantindo que as decisões tomadas sejam planejadas (GILLIAND & LAFFOLEY, 2008).

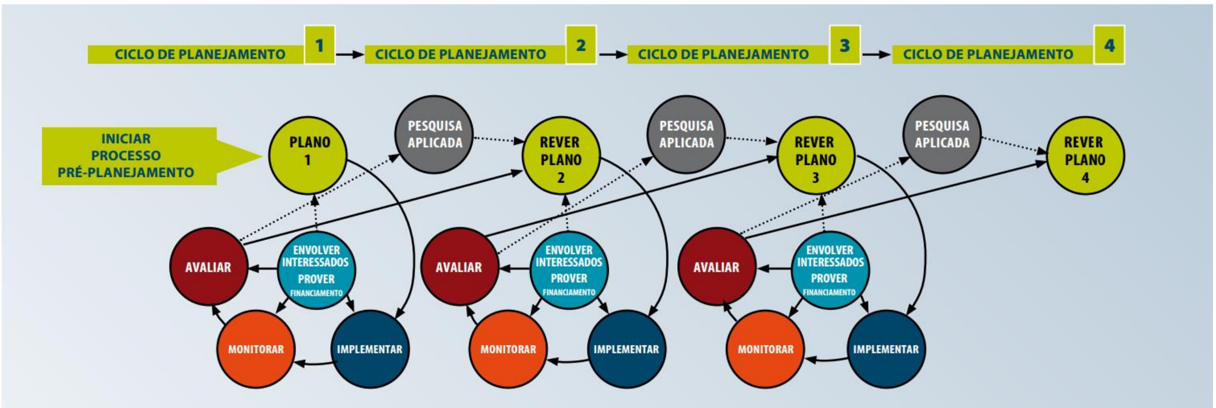

Figura 2. Estratégia do Planejamento Espacial Marinho, dentro dos conceitos de EBM (extraído de http://unesdoc.unesco.org/images/0021/002144/214417por.pdf Acesso em 6 Jan 14).

Apesar do foco mais holístico do EBM representar uma distinção do delineamento mais convencional das AMPs, existem semelhanças entre as abordagens de EBM e AMPs, além de grande potencial de sobreposição de metas dependendo da natureza do sistema a ser manejado (HALPERN *et al.,* 2010). O número de AMPs criadas dentro de um contexto de EBM ainda é baixo, principalmente quando se considera as AMPs de forma individualizada, e não inseridas em uma rede de AMPs (UNEP-WCMC, 2008, HALPERN *et al*., 2010). Porém, com o crescimento do uso de ferramentas espaciais no manejo e desenho de áreas marinhas (DOUVERE, 2008, AGARDY *et al.,* 2011), inserir as AMPs no escopo do EBM se torna uma estratégia interessante para ser considerada. Essa mudança de visão compartimentalizada dos instrumentos de gestão para algo mais integrado é bastante pertinente principalmente aos países emergentes, uma vez que o crescimento econômico acelerado característico destes países frequentemente resulta em ações conflitantes com medidas mais sustentáveis.

Os recentes avanços econômicos em países como África do Sul, Brasil, China, Índia, Indonésia e México têm chamado a atenção de países desenvolvidos a ponto de chamar este fenômeno de 'A ascensão do Sul' (UNDP, 2013). Porém, atividades ligadas ao desenvolvimento acelerado vêm causando mudanças drásticas na paisagem natural: na China, por exemplo, atividades ligadas à expansão costeira já causaram um declínio de 80% na cobertura de corais nos últimos 30 anos (HUGHES *et al.,* 2013). No México, atividades ligadas ao turismo e ao desenvolvimento no litoral vêm causando uma degradação contínua nos recifes (TORRES & MOMSEN, 2005; ACOSTA-GONZÁLEZ *et al.,* 2013). Além disso, a alocação de recursos para a recuperação da biodiversidade é frequentemente uma estratégia com baixo apelo político, simplesmente porque requer investimentos a longo prazo que podem não mostrar resultados durante um termo político. Para que não haja negligência em tomadas de decisões que incluam medidas de recuperação e manejo, uma gestão integrada deve ser mantida.

No Brasil, a perda da diversidade marinha (*e.g.*, VILA-NOVA *et al.,* 2011; BENDER *et al.,* 2013) segue tendências semelhantes aos padrões globais de declínio (*e.g.*, BURKE *et al.,* 2011, HALPERN *et al.,* 2008). Estratégias de conservação do ambiente marinho podem ser observadas em diversas escalas, níveis de governança e de efetividade (MMA, 2010, GERHARDINGER *et al.,* 2011). Na esfera nacional, as AMPs vêm sendo estabelecidas desde meados dos anos 70, com a criação da Reserva Biológica do Atol das Rocas (DECRETO Nº 83.549, 5/06/1979). Outras iniciativas incluem a definição de Áreas Prioritárias para a Conservação da Biodiversidade (MMA, 2007) e o estabelecimento de Planos de Ação Nacional (INSTRUÇÃO NORMATIVA Nº 25/2012). Atualmente, cerca de 2% de toda a Zona Econômica Exclusiva do Brasil está inserida em AMPs (MMA, 2013), sendo que o Brasil é signatário da meta de 10% estabelecida pela CDB para 2020 (CBD, 2011).

A distribuição das AMPs no Brasil é bastante desigual, tanto em categoria de proteção quanto em proporção de ambientes protegidos (MMA, 2010, MAGRIS *et al.,* 2013, SCHIAVETTI *et al.,* 2013). Os recifes no Brasil estão entre os ambientes com maior proporção dentro de AMPs, particularmente os recifes mais rasos, próximos à costa (PRATES, 2006; MMA, 2010). No Brasil, os ambientes recifais podem ser observados na costa, desde o Maranhão até Santa Catarina, além das ilhas oceânicas: Atol das Rocas, Arquipélago de Fernando de Noronha, Arquipélago de São Pedro e São Paulo, Ilhas da Trindade e Martim Vaz. Existem dois tipos de recifes, os quais podem co-ocorrer em uma mesma região: os recifes biogênicos (algas calcáreas, corais, rodolitos) e os recifes rochosos (granito, arenito) (CASTRO & PIRES, 2001, AMADO-FILHO *et al.,* 2012). A diversidade associada a estes ambientes recifais é de grande importância para populações humanas, em especial aquelas que dependem dos recifes para alimento, renda (pesca, turismo) e proteção. Apesar de inseridos em AMPs, uma boa parte dos recifes brasileiros se encontra sob médio ou alto risco devido a impactos provenientes de atividades humanas e efeitos decorrentes das alterações climáticas, além de problemas estruturais de gestão (GERHARDINGER *et al.,* 2011, BURKE *et al.,* 2011).

Uma das características da meta nº. 11 de Aichi infere que, muito além do percentual de proteção a ser alcançado, esta meta também se refere à efetividade das AMPs já estabelecidas, e aquelas que serão estabelecidas futuramente, sendo representativas e interligadas à outras medidas espaciais de conservação (CBD, 2011). Considerando o atual status de 'saúde' dos recifes brasileiros (*e.g.* BURKE *et al.,* 2011), aliados ao baixo número de AMPs no Brasil, faz-se necessário avaliar a representatividade das AMPs existentes bem como estabelecer uma rede de AMPs para alcançar essas diretrizes essenciais à efetividade. Além disso, é fundamental que se estabeleçam iniciativas para integrar o sistema de AMPs dentro das práticas de gestão do EBM, para que usos conflitantes sejam administrados de forma complementar e não antagônica.

Esta tese tratou de apresentar um panorama sobre o *status* de conservação de ambientes recifais costeiros no Brasil. Primeiramente, para contextualizar o país num cenário global, foi feito um trabalho de revisão comparativo entre países emergentes que possuem ambientes recifais costeiros e que se encontram em situação econômica similar ao Brasil. Para este trabalho de revisão, surgiu a oportunidade de estabelecer uma cooperação entre pesquisadores da África do Sul, China, Índia, Indonésia e México, o que permitiu uma apresentação da situação de cada um destes países sob um olhar local. Posteriormente, foi realizada uma análise mais pontual sobre a situação atual do sistema de AMPs no Brasil quanto à proteção de ambientes recifais costeiros. Para tanto, foi realizada análise de *hotspots* com peixes recifais, que é um grupo biológico com alta representatividade dos ambientes recifais, devido ao variado número de funções realizadas no sistema. Finalmente, foi realizado um estudo de priorização espacial na mesma região de estudo do trabalho com *hostpots*, para simular uma expansão das AMPs considerando os conceitos de EBM. Além de peixes recifais, corais e algas foram incluídas nas análises, bem como informações sobre pesca (artesanal e industrial), áreas com portos e com exploração de óleo e gás. Os resultados são os primeiros em escala nacional a tratar da expansão das AMPs com essa abordagem ecossistêmica, tendo o potencial de servir como referência para estudos em outros ambientes marinhos.

1.1 OBJETIVOS GERAIS

- Revisar e avaliar o status atual das Áreas Marinhas Protegidas e apresentar estudos de caso sobre a conservação de ambientes recifais na África do Sul, Brasil, China, Índia, Indonésia e México;
- Analisar incompatibilidades entre o atual sistema de Áreas Marinhas Protegidas no Brasil e hotspots de diversidade, através de um estudo de caso com peixes recifais;
- Discutir práticas de planejamento sistemático para a conservação marinha no Brasil;
- Apresentar um estudo de caso sobre planejamento sistemático em ambientes recifais costeiros do Brasil.

2 ARTIGO I

An outlook on marine conservation in emerging countries: What have we been protecting?

Daniele A. Vila-Nova, Sangeeta Mangubhai, Kartik Shanker, Kerry Sink, Min Liu, Jesús Ernesto Arias-González, Carlos Eduardo L. Ferreira, Sergio R. Floeter

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An outlook on marine conservation in emerging countries: What have we been protecting?

Running title: Marine conservation in emerging countries

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ABSTRACT

Most marine ecosystems are under high risk of continuing biodiversity loss, caused mainly by overfishing, marine/watershed-based pollution, and poorly planned coastal development. Allocating resources to the recovery of biodiversity is usually an unappealing strategy for policy makers, simply because it requires long-term investments that are unlikely to show results during a political term. We analyzed the current status of Marine Protected Areas (MPAs) and present case studies of reef conservation in Brazil, China, India, Indonesia, Mexico and South Africa. MPAs are generally too few in these countries, providing only 1-2% biodiversity protection (*cf*. the CBD's target for 2020 is 10%) and with few exceptions, are poorly managed. Locally managed areas are increasingly promoted as a good strategy for reef conservation and may be able to better persist through changing political leadership. However, government and communities must work together in order to achieve conservation targets and to foster more sustainable policies.

IN A NUTSHELL:

- Brazil, China, India, Indonesia, Mexico and South Africa have a proportionally low Marine Protected Area (MPAs) coverage for the relative size of their Exclusive Economic Zones and a high proportion of reefs that are heavily impacted.
- Planning for results that will outlast political terms is required in order to meet long-term conservation targets.
- Locally managed areas and multiple country commitments aiming at the establishment of representative networks of MPAs, have been pointed as effective strategies for reef conservation.
- Both MPAs and locally managed areas must be inserted within a broader spatial planning context.

KEYWORDS: MPAs, reefs, Aichi target 11, locally managed areas, governance

Cumulative impacts on the ocean have caused severe biodiversity losses around the world, and Marine Protected Areas (MPAs) have been widely promoted as a solution to reverse these effects and assist in the recovery of stocks of exploited species (Roberts *et al.* 2001; Toropova *et al*. 2010; Kerwath *et al.* 2013). In no-take MPAs (where fishing is prohibited), biomass recovery has been shown to be faster when compared to other types of MPAs (sustainable, multiple-use - which usually possess only a small portion of no-take zones), although user conflicts can be a major challenge for implementation (Toropova *et al*. 2010; Aburto-Oropeza *et al.* 2011; Graham *et al.* 2011). On the other hand, multiple-use MPAs may have more chance of success in areas with overlapping uses (Cinner *et al*. 2012) and may better address issues related to social and environmental justice. Global initiatives, such as the Convention on Biological Diversity (CBD), have established goals that include MPAs as a tool for managing marine biological resources and the associated ecosystem services. The CBD’s Aichi Biodiversity Target-11 aims that "by 2020, at least (...) 10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through *effectively and equitably managed, ecologically representative and well-connected systems of protected areas* and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes" (CBD 2011*, emphasis added*; Panel 1).

While such targets may guide global accountability for the sustainable maintenance of environmental resources, distinct regional and local characteristics (*i.e.,* cultural, socio-economic and political contexts) ultimately influence each country's achievements. Balancing marine conservation and economic growth has been one of the biggest challenges for many governments, notably in emerging countries: in China activities related to development have resulted in at least 80% coral decline over the past 30 years (Hughes *et al.* 2013); in Mexico mass tourism and coastal development have caused continuous degradation of coral reefs (Torres and Momsen 2005; Acosta-González *et al.* 2013). Since coastal communities in the tropics have a strong reliance on marine fisheries, and an increasing number of reports show climate change and ocean acidification as emerging threats to marine ecosystems (*e.g.*, Toropova *et al.* 2010), it is imperative to build a framework for conservation where goals for both resource exploitation and maintenance of ecosystem services are included. In this sense, integrated management must become more than just a marketable term in the political realm.

In this review, we analyze the current marine conservation commitments in six emerging countries: Brazil, China, India, Indonesia, Mexico and South Africa, and present case studies regarding reef conservation in these countries. We chose the BRICS countries with tropical and/or subtropical reefs (Brazil, China, India, South Africa), as well as Mexico and Indonesia for having representative reef areas in the Caribbean and the Coral Triangle, respectively (Figure 1). These countries are dealing with the difficult task of promoting rapid economic growth while protecting some of the most diverse marine ecosystems on the planet. Here, we discuss the different strategies that are being applied and the political commitments being made in these countries to meet conservation targets in the context of the rapid development. For this review, researchers from the countries evaluated were asked to provide a short text with information from their respective country regarding:

- What has been done by the Government in order to meet the CBD's 10% target for MPAs?

- Is there any other governmental approach focused in reef conservation? Any positive/negative outcomes?

- Are there any other non-governmental initiatives (NGO-based, community-based) working towards reef conservation? Any positive/negative outcomes?

Each feedback was assembled to provide a panel containing valuable reports from local experiences (Panel 2).

THE RISE OF THE SOUTH?

Recent economic/development advances in countries such as Brazil, China, India, Indonesia, Mexico and South Africa have drawn the attention of developed countries, so much so that this phenomenon has been called 'The Rise of the South' (UNDP 2013). Decreasing poverty, as reflected in a significant improvement in Human Development Index and Gross Domestic Product values (Figure 2), is one example of the substantial changes being observed in emerging countries. Nevertheless, such development, especially when it occurs at a fast pace and focuses on rapid profits rather than long-term results, may cause severe and sometimes irreversible changes in the environment, especially when such activities usually demand the use of natural areas (*e.g.*, the creation and enlargement of ports, roads, industrial parks).

In a study using biodiversity value and job-related indicators to inform marine resources management performance in 53 countries, only South Africa scored among the top 10, whereas Brazil and India were placed among the last 10 (Table 1; Alder *et al.* 2010). The six countries this paper focuses on have densely populated coastal cities in many areas and communities that are highly dependent on reef systems for income, food and coastal protection (Burke *et al.* 2011; von Glasow *et al*. 2013). Most of the reefs in these countries are under risk or severely threatened (Figure 3; Burke *et al.* 2011). The existing coverage of MPAs or MPA networks, does not cover sufficient and representative reef habitats, and inadequate financial and human resources are provided to manage them efficiently (Figure 3, Table 1; Mora *et al.* 2006). With few exceptions, MPAs in emerging countries also face the challenge of poor enforcement and poor compliance or support from local communities (UNEP-WCMC 2008; Toropova *et al.* 2010).

In terms of area currently under protection, Indonesia is making large commitments, although unlike the other countries evaluated, the total target is less than 10% (Indonesia's target for 2020: 200,000 km² or 20 million ha, roughly 3.3% of its EEZ; Table 1). Area-wise, China, Brazil and Mexico have more ambitious percentage targets for their EEZ's, but they are still far from achieving this (Figure 3, Table 1). Nonetheless, there are some evidences of how both governmental and non-governmental initiatives have helped contribute to marine conservation targets (Panel 2). The involvement of local communities in planning, monitoring and/or implementation of MPAs can be a key component for protected area effectiveness, and good examples have been documented in countries like Brazil, India, Indonesia, Mexico and South Africa (UNEP-WCMC 2008; Toropova *et al*. 2010). This is pertinent because the maintenance of biodiversity – especially for exploited species – in reefs and other fragile systems, should be addressed within a broad social context, considering all implications and compromises inherent within social systems (Ban *et al.* 2013; Panel 2). When this does not happen, MPAs end up being created opportunistically rather than systematically, which ultimately leads to inadequate protection of representative habitats (Solano-Fernández *et al.* 2012).

A regional effort worth highlighting is the Coral Triangle Initiative, a six-country commitment (which includes Indonesia) to protect the most biodiverse coral reefs in the world, which includes the establishment of representative networks of MPAs as a key aspect of its strategy. Systematic science-based planning has been promoted in all countries evaluated in this review, but each country is at a different stage of planning and/or implementation (Panel 2).

HOW FEASIBLE IS 10%? IS IT ENOUGH?

Globally, the total coverage of MPAs is nearing the 3% mark, and researchers are optimistic that if this continues to increase at a rate of 1% each year, the 10% target can still be met by 2020 (IUCN/UNEP-WCMC 2013). However, during this time period, there will likely be one or two changes in governance at the highest levels (*i.e*., presidents, ministries, governors and mayors) in the countries included in this paper, which implies uncertainty around previous government's agendas and whether they would persist through changes in political term. Sustained biodiversity recovery is often not a priority for governments, simply because it requires continuing investments that may not show results during a political term. Investments are therefore interrupted due to changes in political regimes which may have very different management and policy priorities. In some cases already limited budgets are cut down or reallocated for other urgent or higher profile demands, like health and education. In other cases, access to closed MPAs is included in political campaigns to win votes. Additionally, corruption can reduce the funds available for conservation activities. More specifically, an increase in investments towards the establishment of MPA networks is needed if emerging countries are to achieve all milestones for the Aichi target-11 (Panel 1).

The reality is that, in order to meet the 10% target, all countries evaluated in this review would have to at least quintuple their current levels of protection within the next seven years (Table 1). However, unless a persistent timetable for marine conservation is strictly sustained or adhered to during political transitions, it is most likely that conservation targets will not be met by 2020. Indonesia appears currently to be an exception: Large new MPAs/networks have contributed to a Presidential target of 20 million ha of coastal and marine waters protected by 2020 (Panel 2). However, this figure still falls short of the commitment Indonesia has made under the CBD and it is not known what percentage of Indonesia's existing MPAs are effectively managed (Mangubhai *et al.* 2011; Panel 2). In China, the government has committed the increase of the total areas of MPAs from currently 1.1% to 3% of the

National Sea Area by 2015, with a further increase to 5% by 2020, in which the MPAs in coastal waters will reach at least 11% (Panel 2). In 2008, South Africa set a target to protect 20% of its marine territory but progress is slow. For the other emerging countries, this level of commitment is not evident. On the other hand, best practices for marine conservation in countries where targets were already achieved can help guiding some next steps. A recent review of coastal and marine environments in Australia, using a scientific-based process, led to the establishment of a representative network of MPAs in 2012 (NRSMPA 2012); this increase of MPAs in Australia was also the major responsible for the MPA expansion under a global perspective (IUCN/UNEP-WCMC 2013). In Cuba, approximately 25% of its marine territory is currently protected, and such result was achieved after a gap analysis led by the government (CNAP 2009).

Moreover, with the rise of emerging countries' financial capital, there is also an increment in investments towards research and higher education. Robust, local research groups have been initiated and with the facility of funding for international partnerships and scientific exchanges, well-established methods and approaches are now easily disseminated among countries. Tools created for supporting systematic conservation planning (Margules and Pressey 2000) and ecosystem-based management (*e.g.*, Ball and Possingham 2000; Moilanen *et al.* 2012), first developed to meet needs in developed countries, are now being adapted in different parts of the world (MMA 2010; UNEP-WCMC 2008; Sink 2011). Such science-based tools are extremely useful when there is sufficient data and/or local expertise are available, which fortunately is the case with the countries evaluated in this review. Here we find a great opportunity to bring together findings from academia with the development of policies leading to implementation of conservation targets, even if there is still a long way to go.

One important aspect of reaching conservation targets is the effectiveness of current and future MPAs: the Aichi target-11 aims for 10% MPA coverage; but as such, this number has little meaning if protection is inadequate and rules and regulations are not enforced within MPAs (Panel 1; CBD 2011). The integration of ecological principles (adequacy, connectivity, representativeness, resilience), cultural (including traditional and local knowledge) and political factors (boundaries, action plans) within a broader planning should also help MPAs to achieve better effectiveness (UNEP-WCMC 2008; Spalding *et al.* 2013). If these are not treated as integral and complementary priorities, the growing demand for development and the management of valuable diversity can easily become opposing ‘forces’ in political decisions.

Locally managed areas and co-management approaches among stakeholders (*e.g.*, fishermen, local villages and non-government initiatives) have also been successful strategies for marine conservation in several countries (Panel 2; Spalding *et al.* 2013). In fact, the engagement and empowerment of local communities can be critical to guaranteeing effectiveness of protected areas in developing regions, because this approach also addresses social issues, needs and aspirations. Both MPAs established by top-down governmental decrees and local managed areas are important tools for marine conservation that reef and other coastal ecosystems can benefit from. Top down approaches can be important for securing areas from high impact development such as large ports, mining, oil and gas extraction, and can formalize community led efforts, obtain government support and help secure resources for implementation, especially the enforcement of laws and regulations.

Nonetheless, despite the fact that overall protection rate of reefs is much higher when compared to other marine habitats (*i.e.*, seamounts, upwellings, unconsolidated sediment habitats, kelp forests), the quality of such protection is still questionable in many regions (Figure 3; Toropova *et al*. 2010; Woods *et al.* 2010; Mangubhai *et al.* 2011). A relatively small number of no-takes areas (*i.e.*, no-take MPAs or no-take zones in multiple-use MPAs) (Figure 3; Table 1) are extremely important to maintain or aid in the recovery of fish populations (Toropova *et al*. 2010; Aburto-Oropeza *et al.* 2011; Graham *et al.* 2011), and foster resilience in reefs (Cote and Reynolds 2005; Woods *et al.* 2010), and should therefore become more common within management frameworks. In the light of environmental global changes and the increasing demand for natural resources, joint efforts with the local communities seem to be scaling up the process of managing reefs, despite the top-down declaration for the 2020 target (Fox *et al.* 2012; Spalding *et al.*2013). Even though well-established local managed areas can endure changing policies (which may create uncertainties for long-term results), government and communities must work together in order to achieve conservation targets and promote more sustainable policies.

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FIGURE CAPTIONS

Figure 1. Reefs are important in many countries around the globe in providing substantial ecosystem services, particularly in emerging countries. Examples of reef systems in the countries assessed in this review: a. Fernando de Noronha, Brazil (photo by JP Krajewski); b. Guangdong Province, China (photo by M Liu); c. Lakshadweep atoll, India (photo by R Arthur); d. Bali, Indonesia (photo by JP Krajewski); e. Puerto Morelos, Mexico (photo by L Alvarez); f. Sodwana Bay, South Africa (photo by K Sink).

Figure 2. Human development can be an indicator for an increase in use conflicts, particularly in the coastal/marine interface. The improvement of overall life quality in these countries is remarkable. However, new demands are created with the rise of financial capital, both individually (such as need for larger houses/apartments complex, better transportation and leisure) and communally (such as city infrastructure improvements). Big cities near the coast are rarely able to preserve water quality and healthy shallow marine ecosystems (*e.g.*, coral reefs). GDP = gross domestic product; HDI = Human Development Index. Sources: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2119rank.html (Viewed 26 Mar 2013); CIESIN 2012; UNDP 2013.

Figure 3. The small amount of Marine Protected Areas in emerging countries can be of little help for reefs under severe variable threats. Stressors such as overfishing/destructive fishing, marine-based pollution/damage, coastal development and watershed-based pollution may cumulatively cause impacts in fragile marine systems like reefs. Brazil, China, India and South Africa have 75% or more of its reefs under very high or high risk, with China having 91.8% of its reefs within such categories. Reefs in Indonesia scored 57.4% under very high or high risk, whereas Mexico scored nearly 50%. The extremely low number of no-take MPAs is also alarming (also refer to Table 1). The Exclusive Economic Zone (EEZ) pie chart sizes are proportional to its total area. Source: Integrated Local Threats adapted from Burke *et al*. 2011 (also refer to Table 1 for more source content).

TABLE LEGENDS

Table 1. Current marine conservation status in emerging countries with significant reef environments. All countries possess a very low number of Marine Protected Areas (MPAs), and even a smaller value for no-take MPAs. Marine living resource management performance for each country can be also a good indicator for existing policies and sustainable use effectiveness and, with the exception of South Africa (ranked among the top 10), all countries analyzed in this study ranked very low scores (in a scale of 0-10).

Figure 1

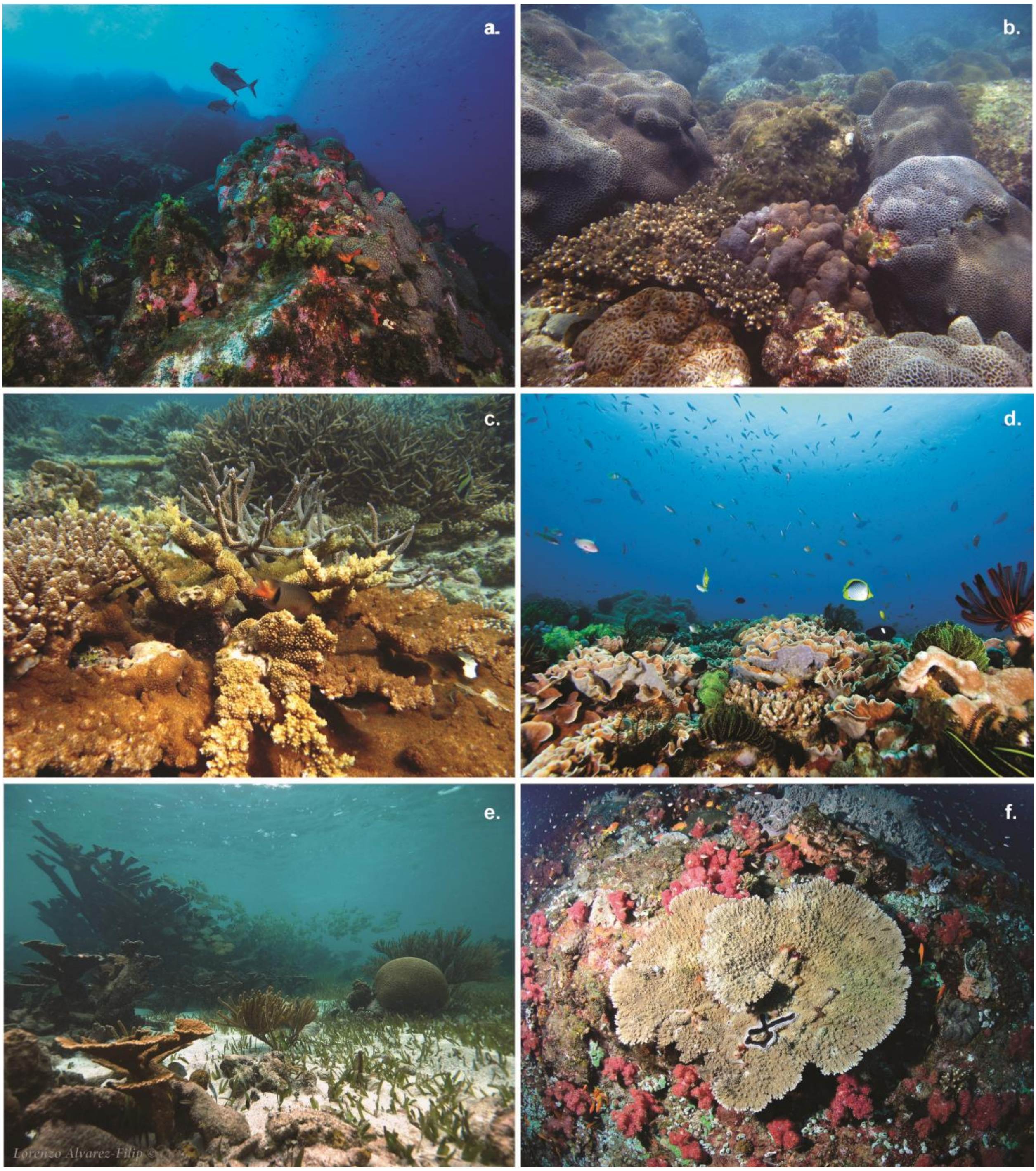

Figure 2.

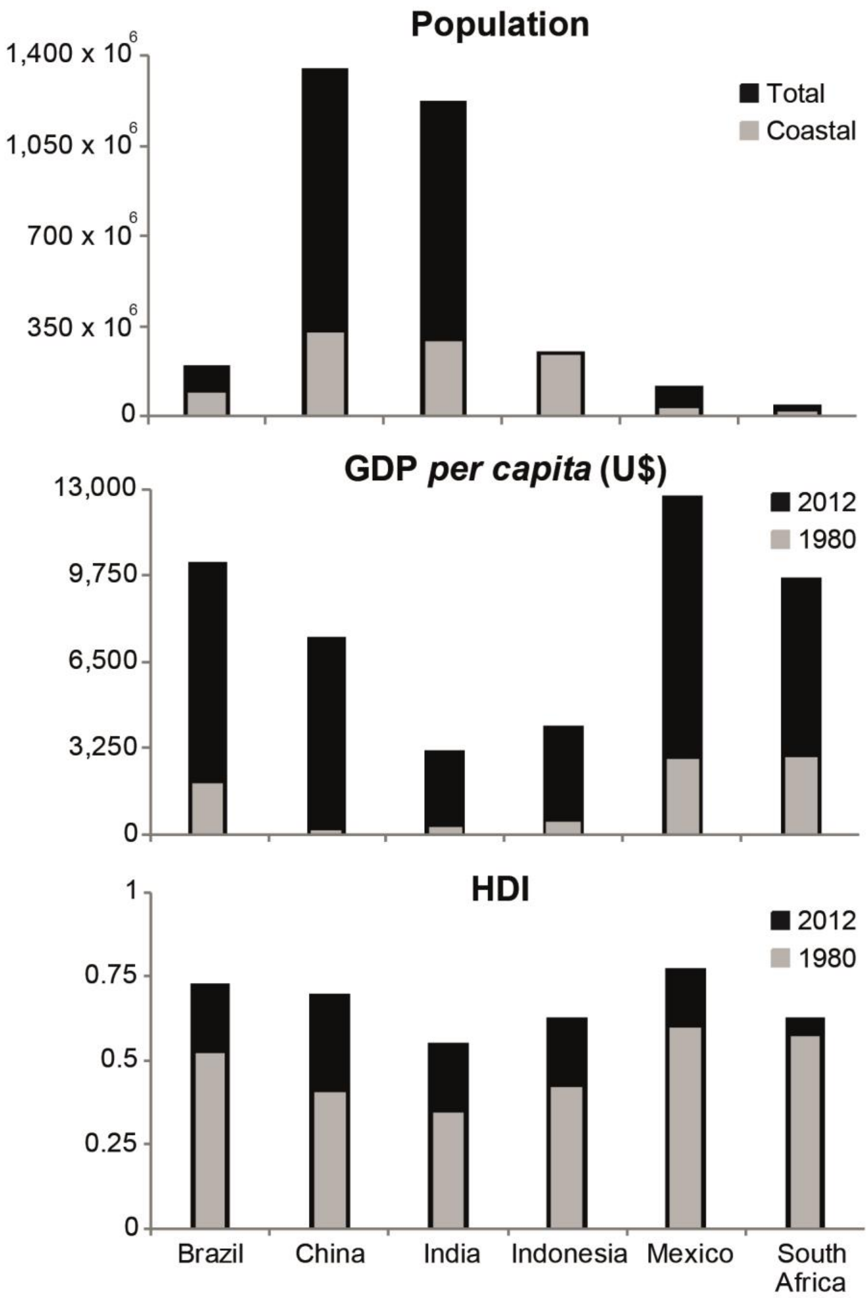
Population
1,400 x 10^6
1,050 x 10^6
700 x 10^6
350 x 10^6
0
Total
Coastal
GDP per capita (U$)
13,000
9,750
6,500
3,250
0
2012
1980
HDI
1
0.75
0.5
0.25
0
2012
1980
Brazil
China
India
Indonesia
Mexico
South Africa

Figure 3.

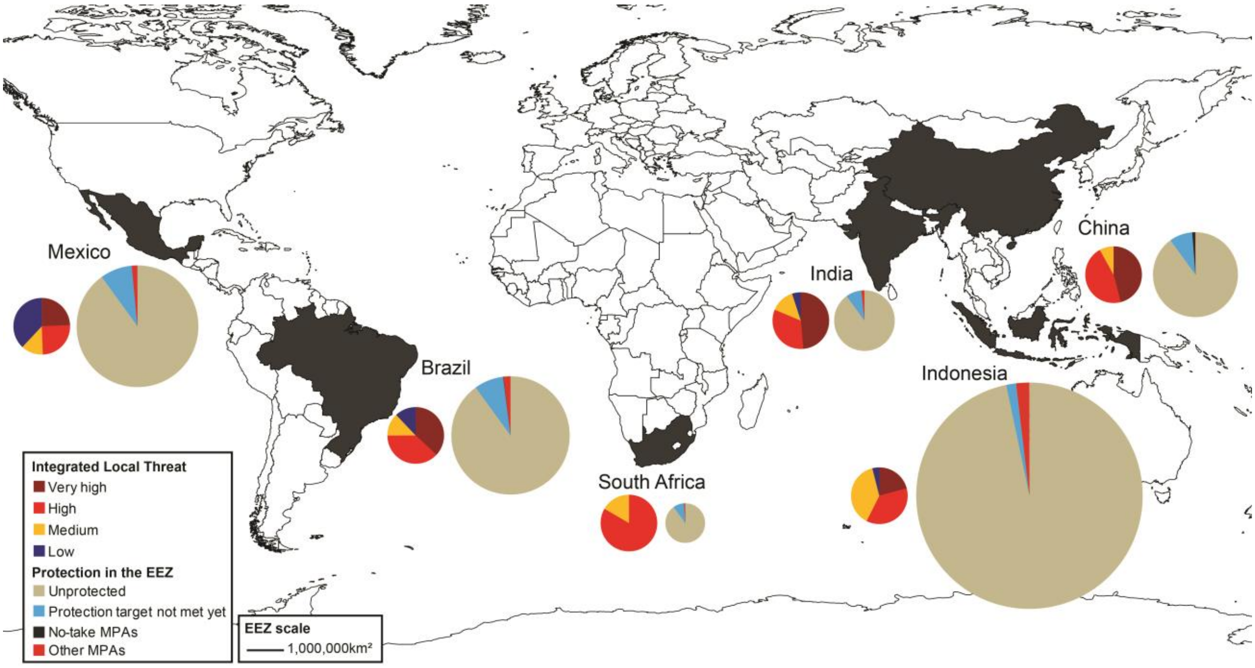
Mexico
Brazil
South Africa
India
China
Indonesia
Integrated Local Threat
Very high
High
Medium
Low
Protection in the EEZ
Unprotected
Protection target not met yet
No-take MPAs
Other MPAs
EEZ scale
1,000,000km²

Table 1.

Country	EEZ area (km^2)[a]	Conservation target for 2020[b]	Current Protection (no-take MPAs)[c]	Marine Resources Management Score[d]
Brazil	3,179,693	10%	2% (0.1%)	2.8
China	2,285,872	10%	1.2% (1.1%)	3.7
India	1,630,356	10%	1.6% (n/a)	2.7
Indonesia	6,079,377	~3.3%	1.9% (n/a)	3.5
Mexico	3,269,386	10%	1.5% (0.01%)	3.8
South Africa	1,066,655	10%	<1% (0.01)	4.8

[a]EEZ = Exclusive Economic Zone; Source http://www.seaaroundus.org/eez/ Viewed 6 Apr 2013.

[b]All countries but Indonesia: Source http://www.cbd.int/sp/targets Viewed 20 Oct 2013; Indonesia (country's target: 200,000km^2): UNEP-WCMC 2008.

[c]n/a = value not available at a national level. Brazil: MMA 2013; China, Mexico and South Africa: UNEP-WCMC 2008; Mexico no-take MPAs: Guarderas *et al.* 2008; India and Indonesia: available at http://www.wdpa.org/resources/statistics/2011MDG_National_Stats.xls Viewed 26 Mar 2013.

[d]Source: Alder *et al*. 2010.

Panel 1. The CBD's milestones established for Aichi Targets can be seen as guidelines for governments in their planning to achieve such commitment in due time.

Milestones for Target-11 included in the Programme of Work on Protected Areas are:

- By 2012, in the marine area, a global network of comprehensive, representative and effectively-managed national and regional protected area systems is established;
- By 2012, all protected areas are effectively and equitably managed, using participatory and science-based site planning processes that incorporate clear biodiversity objectives, targets, management strategies and monitoring and evaluation protocols;
- By 2015, all protected areas and protected area systems are integrated into the wider land- and seascape, and relevant sectors, by applying the Ecosystem Approach and taking into account ecological connectivity, likely climate change impacts and, where appropriate, the concept of ecological networks

(CBD 2011)

Panel 2. What are the plans for marine and reef conservation? Reports on challenges, initiatives and outcomes

- Brazil: In 2007, Brazil set priority areas to guide decision making and policies (MMA 2010). Currently, approximately 2% of the EEZ has some status of protection, with only 0.14% being no-take Marine Protected Areas (MPAs) (MMA 2010, 2013; Table 1). MPAs in Brazil face challenges of poor inter-institutional coordination of coastal and ocean governance, poor management within individual MPAs, bureaucratic administrative system and financial shortages (Gerhardinger *et al.* 2011). User conflicts in Brazil's EEZ have recently escalated, mainly because of Oil & Gas areas and expansion of fishing grounds. No-fishing zones within multiple-use MPAs are used at a very small scale, and studies show increase in biomass for exploited species when compared to the other areas of the MPA (MMA 2010). In 2013, the Ministry of the Environment created a 5-year National Action Plan for Reef Conservation (NAPRC) in Brazil. The NAPRC can bring good prospects in a sense that it will be science-driven and will encompass reef types through an ecosystem-based management (EBM) framework. The tools and expertise are available for this approach; however, structural deficiencies within marine governance in Brazil can still harm even the most optimistic expectations (Gerhardinger *et al.* 2011).

- China: In 2012, the State Council of China released the National Marine Functional Zonation of 2011-2020, which stated that the total area of MPAs should reach at least 5% of the National Sea Area by 2020 (NMFZ 2012). In order to achieve the goal, the 12th Development Planning (2011-2015) of the National Marine Affairs declared that the total area of MPAs should reach to 3% of the National Sea Area by 2015. For reef conservation, areas are focused on Daya Bay and Xuwen (Guangdong Province), Weizhou Island (Guangxi Zhuang Nationality Autonomous Region), coastal waters of Hainan Island and Xisha Islands (Hainan Province), through artificial breeding of hard corals and ecological remediation. Put aside of the argument whether the 10% of coastal and marine areas can be conserved by 2020, a couple of problems should be highlighted. First, several Marine Nature Reserves at national level have officially reduced their protected areas (Guan and An 2013). The protected areas conflict with marine exploration is the main reason. Second, several Marine Nature Reserves are under re-evaluation, and under the pressure of area reduction through local government (M. Liu, personal observation).

- India: Corals are protected in India under the Indian Wildlife (protection) Act (1972); Hard corals (all Scleractinians), black coral, organ pipe coral, fire coral and sea fans (Gorgonians) are listed in Schedule 1 of the Act and receive the highest degree of protection. In adition, many of the coral reef areas lie within national parks. The Gulf of Mannar Marine National Park on the southeast coast of the Indian subcontinent, and the Gulf of Kachchh National Park on the northwest coast, constitute the main coral reef areas on the mainland coast of India. Both areas are currently relatively degraded. The best remaining coral reefs in India are in the Lakshadweep, Andaman and Nicobar Islands. There are over 100 MPAs in the Andaman and Nicobar Islands, protecting nearly 40% of coastal habitats in the islands, but only two are exclusively marine (Andrews and Sankaran 2002). The Lakshadweep Islands, which have some of the best reefs in India, do not have any MPAs, but they are a small group of islands that have not yet been subject to heavy reef fishing (or commercial exploitation), and hence reefs have recovered better than expected from bleaching events (Arthur *et al*. 2005, 2006). In the Lakshadweep, fishing methods so far have been largely sustainable with regard to reefs as they have focused on pole and line tuna fishing. Researchers are currently trying to establish community monitoring projects that can help sustain fishery practices that help the resilience of reefs.

- Indonesia: In 2007 the President of Indonesia committed to the Coral Triangle Initiative (CTI), an initiative amongst the six countries with the most diverse coral reefs on this planet (CTI 2009). At the same time the President committed to protecting 20 million ha by 2020. Responding to this commitment, sixteen international and national experts gathered to analyze biodiversity and distribution data to (i) produce a scientifically valid ranking of marine ecoregions in Indonesia to help the government and its partners prioritize marine biodiversity conservation investment, and (ii) contribute to the establishment of an ecologically representative national system of MPAs (Huffard *et al.* 2009). While efforts to expand MPAs in Indonesia is urgently needed to halt the decline of coral reef ecosystems, there is concern about inadequate human and financial resources to effectively manage existing and newly declared MPAs, with growing examples of non-compliance within existing MPAs (Clifton and Unsworth 2010; Mangubhai *et al.* 2011; Campbell *et al.* 2012). The CTI, while still in its infancy, is galvanizing greater resources and efforts to address these gaps including the production of guidelines for protected areas, new legislation to enable the designation of MPA networks, national level efforts to build MPA capacity building training centers, testing of alternative co-management governance models, and looking more closely at long term sustainable financing options.

- Mexico: In recent years there has been a boom in the establishment of MPAs in Mexico. Also, a recent gap analysis for marine biodiversity conservation, executed by over 80 experts from the academia, non-profits and the public sector, found 105 priority sites (CONABIO-CONANP-TNC-PRONATURA 2007). Responsible fisheries initiatives have also become more common in many areas in Mexico. For instance, the Alianza Kanan Kay is an inter-sectorial collaborative initiative with the common objective of contributing to the replenishment of traditional fisheries through the creation of an effective fish refuge (*i.e.*, no-take) network. It aims to cover 20% of the territorial sea of the state of Quintana Roo, Mexico, by 2015 (Healthy Reefs Initiative, 2012, Alianza Kanankay 2013). These refuges are located within the Biosphere Reserves of Sian Ka'an and Banco Chinchorro and join the current network of fish refuges, consisting of eight sites established in November 2012 at the request of the Fishing Cooperative of Cozumel (as a result of years of working alongside fishermen). Together, these add more than 144km^2 of the state of Quintana Roo's territorial waters under the protection of fish refuge zones, which are a complement to the conservation efforts in the region.

- South Africa: Although South Africa has 23 Marine Protected areas, there are still gaps in representation (Attwood *et al.* 1997; Sink *et al.* 2012). Despite these gaps, MPAs are supporting biodiversity protection and resource recovery (Kerwath *et al.* 2013). Protection levels generally decline further south and west with offshore and deep reefs and the temperate west coast reef ecosystems being poorly represented in the protected area network (Sink *et al.* 2012). Many MPAs are zoned and there is evidence that no-take

MPAs offer greater benefits than areas zoned for use (Kerwath *et al.* 2013, Currie *et al.* 2012). South Africa has undertaken numerous marine systematic biodiversity plans and has developed a National Protected Area Expansion Strategy that includes ambitious targets for MPAs. There are efforts underway to expand and re-zone existing MPAs, establish new MPAs in unprotected coastal regions and in the offshore environment. South Africa piloted a co-management approach in reef monitoring in the subtropical area which had numerous benefits for reef management. This approach led to improved understanding of reef sensitivity, impacts on reefs and raised the capacity of dive operators leading scuba diving activities. Other initiatives include citizen science projects for reef mapping and atlasing of corals, echinoderms and fish.

3 ARTIGO II

Reef fish hotspots as surrogates for marine conservation in the Brazilian coast

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Reef fish hotspots as surrogates for marine conservation in the Brazilian coast

Running head: Reef fish hotspots in Brazil

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HIGHLIGHTS

- A snapshot for reef conservation in Brazil is reported
- There is a great mismatch between reef fish hotspots and current Marine Protected Areas
- The northeast coast and the state of Espírito Santo are the most critical areas for mitigating actions

ABSTRACT

Brazil currently protects 2% of its Economic Exclusive Zone in the sea and is in the process of outlining a national action plan to guide decision making towards reef conservation. Here we use reef fish hotspots as a case study to inform mismatches in the current Marine Protected Areas (MPAs) network in Brazil. Both quantity and protection level of MPAs is uneven: there is a very small number and area of no-take MPAs, whereas approximately 70% of MPAs are for sustainable use. We report a clear mismatch between MPAs and reef fish hotspots in Brazil: the northeast coast and the state of Espírito Santo are the most critical areas for conservation actions. Because MPAs can no longer be considered as a 'quick fix' tool, but rather, a very complex social-political operation, we urge that the MPA network in these most critical areas should be expanded (including more no-take zones) within a broader spatial planning to lessen user conflicts.

KEYWORDS

Conservation planning, MPAs, no-take, indicators, EBM, threatened, endemic, functional groups.

INTRODUCTION

Marine Protected Areas (MPAs) are one of the most advertised tools for ecosystem conservation and management of marine resources, however, MPAs currently cover only 3% of the oceans across the globe (Roberts et al. 2001; Toropova et al. 2010; IUCN / UNEP-WCMC 2013). Human impacts such as overfishing, pollution and habitat destruction, along with recent global climate change have been identified as a major causes for biodiversity losses in marine environments and gradual decline in the productivity of these systems (Toropova et al. 2010). Recently, the process of planning and creating MPAs have been more integrated to other management needs and the challenges of considering the seascape as a whole (Douvere 2008; Halpern et al. 2010.).

Hotspots are traditionally defined as areas with high richness, endemism, and number of species under threats (Reid 1998), being a valuable strategy to pinpoint priority areas for conservation and patterns of biodiversity (Reid 1998; Roberts et al. 2001). In this sense, hotspots have been widely used as part of the planning process for MPAs (e.g., Roberts et al. 2002; Worm et al. 2003; Luciflora et al. 2011). Nevertheless, hotspot analyses are even best informative when combined to other approaches, such as ecosystems representativeness (Reid 1998). When such information is unavailable, the use of surrogates may be an interesting component to help meet conservation targets in areas where more refined biological data is absent (Roberts et al. 2002). In this sense, reef fish have been tested as an important surrogate for other taxa in marine conservation planning, especially at low protection targets (*i.e.*, 10-20% of the area, Ward et al. 1999; Beger et al., 2003). Reef fish are responsible for energy flow on reefs and play an important role in influencing function, structure (Bellwood et al. 2004; Dulvy et al. 2004), as well as contributing to social, economic and cultural components of the region (Gladstone 2007).

In Brazil, studies on marine diversity loss (*e.g.*, Vila-Nova et al. 2011; Bender et al. 2013) show results with the similar patterns of global decline (*e.g.*, Burke et al. 2011; Halpern et al. 2008). Marine conservation strategies across the country can be observed in different scales, levels of governance and effectiveness (MMA, 2010 Gerhardinger et al. 2011). At the national level, the MPAs have been established since the mid-70s; Other conservation initiatives include the development of Priority Areas for Biodiversity Conservation (MMA 2007) and the establishment of National

Action Plans (Normative Instruction No. 25/ 2012). Brazil currently protects only 2% of its entire Economic Exclusive Zone (MMA 2013; Schiavetti et al. 2013) while being signatory of the Convention on Biological Diversity - CBD's 10% target for 2020 (Aichi target #11, CBD 2011). The distribution of MPAs in Brazil is quite uneven, both in protection categories as a proportion of protected environments (MMA 2010; Magris et al. 2013; Schiavetti et al. 2013). Reef areas in Brazil are among the places with the highest proportion within MPAs, particularly the shallow, near shore reefs (Prates 2006; MMA 2010).

Studies highlighting the spatial imbalance among where MPAs are established and biodiversity components are important guides to set goals during the first steps of conservation planning (Turpie et al. 2000; Mouillot et al. 2011). In this context, this present study aims to use reef fish hotspots as a case study to inform mismatches with the current MPA network along the Brazilian coast, thus providing a snapshot of reef conservation status. The timing for this assessment is appropriate, since Brazil's government has started to outline a five year National Action Plan for reefs, to guide decision-making at a national level of governance.

METHODS

1 Study area

The study area includes the reef areas from Maranhão to Santa Catarina states to a depth of 50m (Figure 1). In Brazil, there are two main types of reefs, which may be found associated to each other or not: biogenic reefs (formed by calcareous algae, corals and/or rodolith beds) and rocky reeks (beach rocks, granite and/or sandstone) (Castro & Pires 2001; Amado-Filho et al. 2012). The latitudinal gradient in this area encompasses tropical and subtropical weather, with a predominance of biogenic reefs on the lower latitudes which are gradually replaced by rocky reefs on higher latitudes (Castro & Pires 2001; Amado-Filho et al. 2012).

2 Spatial dataset

We used spatial data of MPAs in Brazil available from the Brazilian Ministry of the Environment online database (http://mapas.mma.gov.br/i3geo/datadownload.htm). MPAs were classified in two main groups, according to their level of protection/management in: no-take (*i.e.,* no fishing) and sustainable use (where fishing is allowed with some level of planning/management).

Range distribution maps of 405 species of reef fish were assembled from information on occurrence and distribution areas obtained from various sources (Carvalho-Filho 1999; Floeter et al. 2008; Halpern & Floeter 2008 and updates by the authors), to the maximum depth of 50 m for better data accuracy. We considered reef fish as "any shallow, tropical/subtropical, benthic or benthopelagic fish that constantly associate with hard substrates of coral, calcareous algal, or rocky reefs or that occupy adjacent sand substrate (*i.e.*, using reef structures or the surrounding area for feeding, reproduction, and/or refuge)" (*sensu* Floeter et al. 2008). The extent of occurrence approach was used for all species (Gaston 1994), however, for species with known distribution disjunctions, areas with no occurrences were excluded (Gaston 1994). Each range distribution map (one polygon shapefile/species) was also reviewed by reef fish experts (A. Carvalho-Filho, L.A. Rocha, H.T. Pinheiro).

We listed reef fish species as endemic and/or threatened following Vila-Nova et al. (2011) and Bender et al. (2012, 2013): we considered a species as threatened if it was included within the Critically Endangered, Endangered or Vulnerable categories in local, national and global Red List Inventories (see Bender et al. 2013 for more details on the Red Lists included in this study). Functional groups classification followed that used by Halpern and Floeter (2008), combining biological attributes of maximum depth (very shallow: <10 m; shallow: 10-20 m; medium: 20-50 m; deep: 50-100 m; very deep: >100 m), maximum body size (small: <10 cm; medium-small: 10-25 cm; medium: 25-50 cm; large: >50 cm) and trophic group (herbivore, macro-carnivore, mobile invertivore, sessile invertivore, omnivore, planktivore).

3 Dataset caveats

Reef fish as a surrogate - Ideally, habitat protection should be evaluated to provide estimates of MPAs coverage. However, the total distribution and extent of both biogenic and rocky reefs in Brazil, especially in mesophotic and deeper waters, are still unknown (MMA 2010; Magris et al. 2013). Reef fish, on the other hand, is a group with high richness and such diversity is correlated to other marine groups (*i.e.*, corals, mollusks, crustaceans, Tittensor et al. 2010). In Brazil, reef fish are amongst the most studied marine groups, which provides robust information for the type of study this present work is performing.

The spatial dataset created for this study encompasses the area with the highest data quality available for reef fish in Brazil. The northern part of Brazil (from the state of Maranhão towards the Amazon river mouth) is the least studied area for reef fish, although there are few reports confirming the presence of reef structures in the region. However, the entire area receives strong currents from the Amazon River, which makes surveys in that region a very difficult task. It is a common claim among research groups that this area should be considered as priority for basic research on biodiversity and habitat mapping. Another important area for reef fish not included in our study are the oceanic islands. Although they present much lower richness when compared to the coastal areas, oceanic islands in Brazil are remarkably responsible to host several endemic species, and for this reason should be included in priority policies for marine conservation.

4 Analysis

Both MPAs and fish data were converted to raster format within a Geographic Information System. The resolution (cell size) of rasters was set to 6.25 km² (2.5 x 2.5 km), and a grid containing 39,913 cells was used. The distance between MPAs was measured to identify regions with no protection. We considered hotspots of reef fish richness corresponding to the cells with the highest 10% values (Mouillot et al. 2011). Sum analyses (cell statistics) of reef fish species were performed to identify areas with higher spatial congruence. These analyses were made for total richness, endemic species, threatened species and functional groups. Hotspots (the areas with the highest grid cell co-occurrences) were then compared with the current MPA system; lastly, cells were evaluated if they fell within a MPA and if so, at what protection level.

RESULTS

The MPAs in our study area correspond to a total of 8,189 cells (20.5%), with only 0.8% being no-take MPAs (Fig. 1a). The distribution of MPAs regarding its type and use is also uneven: there is a very small fraction of no-take MPAs whereas approximately 70% of MPAs evaluated are from "sustainable use" categories (Fig. 1a), mainly Areas of Environmental Protection. The highest concentration of MPAs (in number) is located in the state of São Paulo, and the largest area of MPAs lies on the coast of Maranhão (Fig. 1a). A huge spacing among MPAs is also evident, notably with no-take MPAs (Fig. 1b). The northeast region has two no-take MPAs protecting reefs in south Bahia, and the next no-take MPA protecting reefs further north is about 2,000 km away, in the state of Ceará (Fig. 1b). Although there are some small no-take zones within multiple use MPAs in that region, their total area is nearly inexistent when compared to the reef sizes, fishing pressure and other cumulative impacts occuring there. The states of Ceará, Espírito Santo and Rio Grande do Norte have the least amount of MPAs and/or those with a larger spacing between MPAs (Fig. 1a, b).

The hotspots for all species combined were found at the shallow areas (up to ~10 m depth) in the northeast coast (from the state of Paraíba to northern Bahia); 42.4% of hotspots are under some degree of protection, with the noticeable absence of no-take MPAs (Fig. 1c; Table S1). Hotspots for endemic species correspond to regions of shallow depth (~10 m) between the states of Paraíba, Pernambuco, Alagoas, north/central area of Bahia and south of Espírito Santo. In this region, 37.8% of hotspots falls within MPAs, however, no-take MPAs are again absent in this area (Fig. 2a; Table S1). Twenty-six species of reef fish are found under the International Union for Conservation of Nature threat categories (6.4% of the total), and endemic species accounts for 13.3% of the total (N=54). Analyses of reef fish hotspots (10% of the highest scores) showed that, for threatened species, these areas correspond to the state of Espírito Santo; for that region, only 5.3% of the area is under some level of protection, with 1% of no-take MPAs (Fig. 2b; Table S1). Functional groups (N=77) showed a spatial pattern very similar to total richness (Fig. 2c; Table S2), with 37.2% of hotspots within MPAs (>1% being no-take MPAs).

DISCUSSION

This present work highlights, from a fast assessment/biological point of view, which areas more urgently need further evaluation to foster reef conservation in Brazil. With our results, three areas call for special attention regarding reef fish hotspots. In the northeast coast: the area from the state of Paraíba to Alagoas, and the central-north coast of Bahia, were shown as hotspots for total richness, endemic species and functional groups (Fig. 1c; 2a, c; Table S1). This entire region has not a single no-take MPA protecting reefs (Fig. 1b), only other types of MPAs with fragile evidence for reef fish recovery or ineffective management (Gerhardinger et al. 2011). The third area, the state of Espírito Santo, was included as hotspot for both endemic and threatened species (Fig. 2a, b; Table S1), and have a relatively high richness of reef fishes (Fig. 1c), however, it is the least protected region along the Brazilian coast. Southern Espítiro Santo is considered a transitional zone between tropical and subtropical environments (*i.e.*, from biogenic to rocky reefs), which hosts several marine species from both systems. Together with the northern part of Rio de Janeiro, there is a gap of about 200 km without any sort of management (Fig. 1b).

Because MPAs can no longer be considered as a 'quick fix' tool, but rather, a very complex social-political operation (Chuenpagdee et al. 2013), we urge that the MPA network in these most critical areas should be expanded (including more no-take zones and no-take MPAs) within a broader spatial planning to lessen user conflicts (UNEP 2011). With constant reports on the decrease of targeted species stocks (*e.g.*, Freire & Pauly 2010; Freitas et al. 2011), it is most likely to agree that the MPA system in Brazil has still a lot to improve. The spacing large among MPAs observed in many parts of the Brazilian coast (Fig. 1a, b) gives an idea of this alarming reality. When spacing among MPAs is too large, the performance of reserves (*i.e.,* no-take MPAs) can be lowered, especially for harvested species and those with ontogenetic migration (Edwards et al. 2010; Olds et al. 2012). On the other hand, the social component - while not considered in the rapid assessment for this paper, is crucial for the planning process and design of MPAs and should be incorporated in further, more applied evaluation. Brazil and many other coastal countries have a long way to meet global targets of conservation (CBD 2011), and unless these two components are incorporated in the planning process, future MPAs yet to be created to meet the 2020 target will ultimately bring few, if any, results.

Based on the areas with large spacing among MPAs and the hotpots pointed in this study, we suggest areas that are the most critical for urgent mitigating actions for both reef and reef fish conservation in the Brazilian coast (Fig. 1c; 2; Table S1). The mismatches highlighted here, although being part of a low-incremental Ecosystem-based Management approach (UNEP 2011), may instruct further steps towards conservation planning for Brazilian reefs. However In this scenario, well-managed and enforced MPAs would be very useful to provide relevant ecological data and provide protection against over fishing in data poor areas, but appropriate design and implementation is required (Fox et al. 2012; Chuenpagdee et al. 2013). The combination of MPAs distribution and mismatches to relevant areas for biodiversity, *e.g.*, hotspots, are still a reality in many parts of the world (Turpie et al. 2000; Fox & Beckley 2005; Mouillot et al. 2011; Solano-Fernández et al. 2012), and may be seen as a reflect of poor planning in the process of designing and establishing representative areas for protection/management since their step zero

(Chuenpagdee et al. 2013). If stakeholders are not involved from the very beginning of a given MPA's inception, it is most likely that the MPA will not effectively meet its goals once it is formally established.

In the rush to reach conservation targets, governmental top-down decrees establishing protected areas are sometimes used. Such approach, while it appears to give one's government a good status within the international political realm, it often leads to the creation of ineffective paper parks (Gerhardinger et al. 2011). As a result, not only there is the false idea that management is being properly carried out, but biological and social conditions are severely compromised. From the biological side, the need of a proper management of specific groups, such as targeted and/or threatened species, calls for much more complex initiatives: for instance, some reef fish groups, such as top predators and herbivores, when absent often lead to an imbalance or even collapse of the entire system (Lucifora et al. 2011; Rupert et al. 2013). This and other valuable information are a result of long-term ecological studies that are necessary to create a solid baseline for proper, successful conservation actions. In a period of increasing use conflicts in the sea, the integration of different activities in the ocean must be managed together so that they remain sustainable over time (UNEP 2011).

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SUPPORTING INFORMATION

Table S1 (Appendix S1) and table S2 (Appendix 2) are available online. The authors are solely responsible for the content and functionality of this material. Queries (other than absence of the material) should be directed to the corresponding author.

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FIGURE CAPTIONS

Figure 1. (a) Marine Protected Areas along the Brazilian coast. Coastal Protected Areas are also shown with dashed lines, to inform land-ocean connectivity among Protected Areas. (b) No-take Marine Protected Areas in the study area. Important habitats for reef fish with available maps are also show for a better context to MPAs location/content. Coastal No-take Protected Areas are also shown in dashed lines, to inform land-ocean connectivity among No-take Protected Areas. (c) Reef fish richness. States abbreviations: PA = Pará, MA = Maranhão, PI = Piauí, CE = Ceará, RN = Rio Grande do Norte, PB = Paraíba, PE = Pernambuco, AL = Alagoas, SE = Sergipe, BA = Bahia, ES = Espírito Santo, RJ = Rio de Janeiro, SP = São Paulo, PR = Paraná, SC = Santa Catarina.

Figure 2. Reef fish hotspots, quantified as the cells with the highest 10% values: (a) Endemic species. (b) Threatened species. (c) Functional groups. Refer to states abbreviations in Fig. 1.

Figure 1

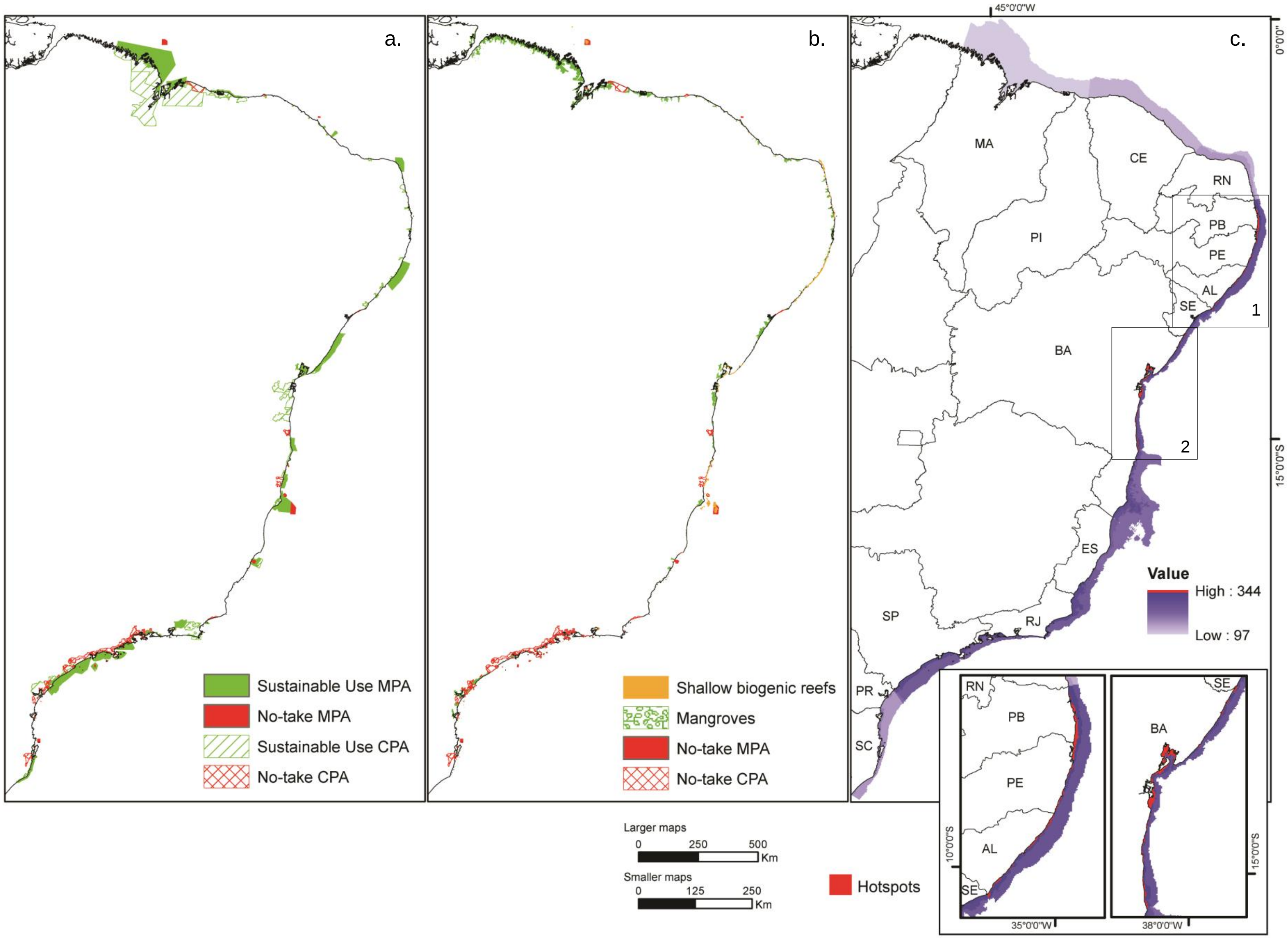
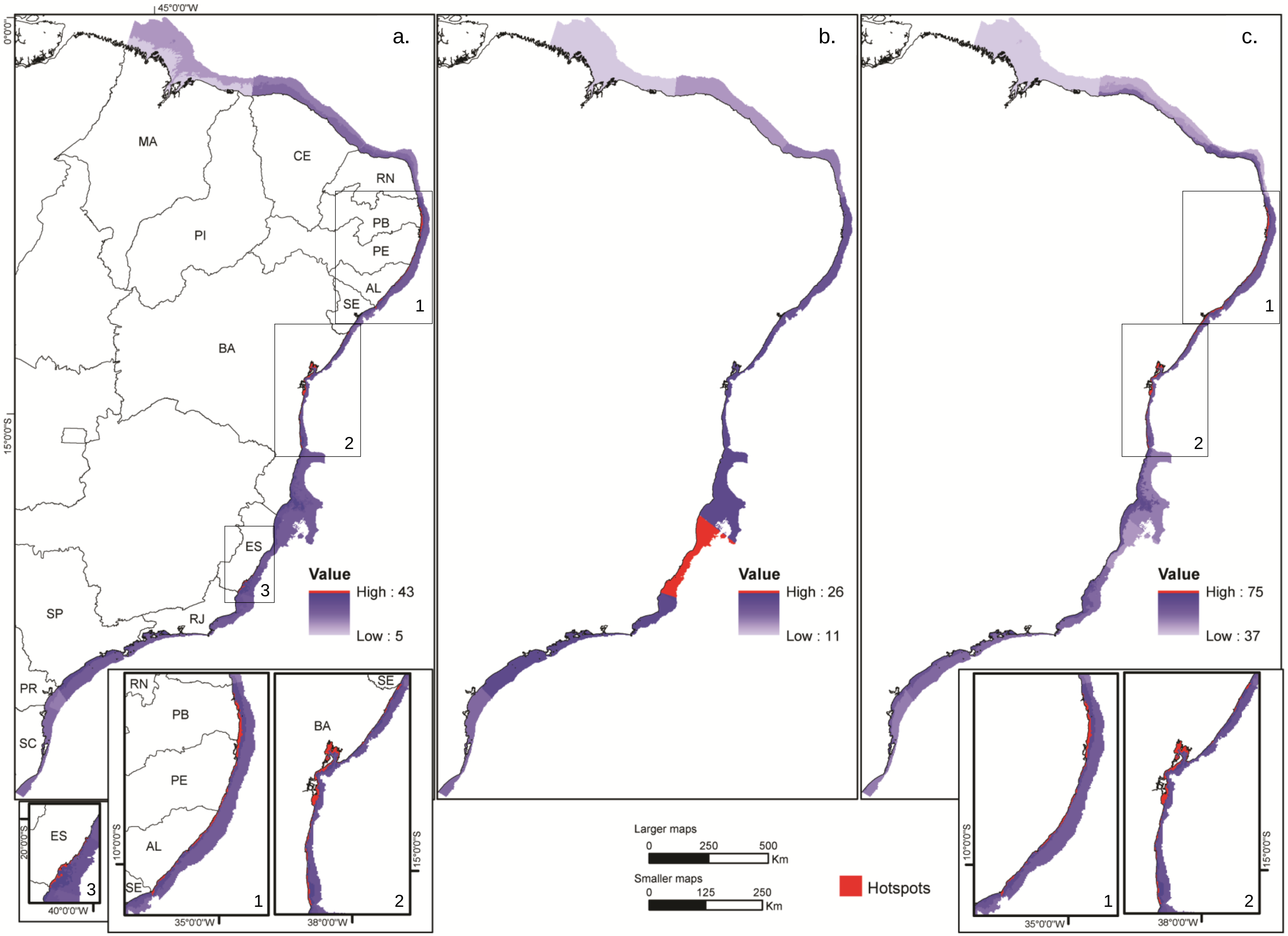

a.
Sustainable Use MPA
No-take MPA
Sustainable Use CPA
No-take CPA
b.
Shallow biogenic reefs
Mangroves
No-take MPA
No-take CPA
c.
45°0'0"W
0°0'0"
15°0'0"S
MA
CE
RN
PB
PE
PI
AL
SE
BA
ES
SP
RJ
PR
SC
1
2
Value
High : 344
Low : 97
Larger maps
0 250 500 Km
Smaller maps
0 125 250 Km
Hotspots
10°0'0"S
35°0'0"W
38°0'0"W

Figure 2


a.
b.
c.
MA
CE
RN
PB
PE
PI
AL
SE
BA
ES
SP
RJ
PR
SC
1
2
3
Value
High : 43
Low : 5
Value
High : 26
Low : 11
Value
High : 75
Low : 37
45°0'0"W
0°0'0"
15°0'0"S
10°0'0"S
20°0'0"S
40°0'0"W
35°0'0"W
38°0'0"W
Larger maps
0 250 500 Km
Smaller maps
0 125 250 Km
Hotspots

Supplement material

Appendix S1

Table S1. Mismatches among Marine Protected Areas and hotspots of reef fish in Brazil continental shelf, from Maranhão to Santa Catarina states.

State	MPA	Type	Protection Level	Has reefs?	Hotspots of reef fish			
					Total richness	Endemics	Threatened	Functional groups
MA	Lençóis Maranhenses	National Park	No-take	No	-	-	-	-
MA	Parcel do Manuel Luiz	State Park	No-take	Yes	-	-	-	-
MA	Baixada Maranhense	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
MA	Delta do Parnaíba	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
MA	Foz Rio Preguiças	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
MA	Reentrâncias Maranhenses	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
MA	Upaon-Açu-Miritiba	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
MA	Delta do Parnaíba	Extractive Reserve	Sustainable-use	No	-	-	-	-
MA	Cururupu	Extractive Reserve	Sustainable-use	No	-	-	-	-
CE	Pedra da Risca do Meio	State Park	No-take	Yes	-	-	-	-
CE	Ponta do Tubarão	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
CE	Batoque	Extractive Reserve	Sustainable-use	Yes	-	-	-	-

CE	Prainha do Canto Verde	Extractive Reserve	Sustainable-use	No	-	-	-	-
RN	Recifes de Corais	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
PB	Areia Vermelha	State Park	No-take	Yes	Yes	-	-	Yes
PE	Acaú-Goiana	Extractive Reserve	Sustainable-use	No	Yes	Yes	-	Yes
PE	Guadalupe	Area of Environmental Protection	Sustainable-use	Yes	Yes	Yes	-	Yes
PE/AL	Costa dos Corais	Area of Environmental Protection	Sustainable-use	Yes	Yes	Yes	-	Yes
AL	Lagoa do Jequiá	Extractive Reserve	Sustainable-use	Yes	Yes	Yes	-	Yes
SE	Santa Isabel	Biological Reserve	No-take	No	-	-	-	-
BA	Recife de Fora	Municipal Park	No-take	Yes	-	-	-	-
BA	Abrolhos	National Park	No-take	Yes	-	-	-	-
BA	Baía de Todos os Santos	Area of Environmental Protection	Sustainable-use	Yes	Yes	Yes	-	Yes
BA	Caraíva/Trancoso	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
BA	Plataforma do Litoral Norte	Area of Environmental Protection	Sustainable-use	Yes	Yes	Yes	-	Yes
BA	Ponta da Baleia/Abrolhos	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
BA	Coroa Vermelha	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
BA	Baía do Iguapé	Extractive Reserve	Sustainable-use	No	-	-	-	-
BA	Canasvieiras	Extractive Reserve	Sustainable-use	No	Yes	Yes	-	Yes
BA	Cassurubá	Extractive Reserve	Sustainable-use	No	-	-	-	-
BA	Corumbau	Extractive Reserve	Sustainable-use	Yes	-	-	-	-
ES	Santa Cruz	Wildlife Refuge	No-take	Yes	-	-	Yes	-

ES	Costa das Algas	Area of Environmental Protection	Sustainable-use	Yes	-	-	Yes	-
RJ	Tamoios	Ecological Station	No-take	Yes	-	-	-	-
RJ	Corais de Armações de Búzios	Municipal Park	No-take	Yes	-	-	-	-
RJ	Grumari	Municipal Park	No-take	No	-	-	-	-
RJ	Ilhas Cagarras	Natural Monument	No-take	Yes	-	-	-	-
RJ	Ilha Grande	State Park	No-take	Yes	-	-	-	-
RJ	Arquipélago de Santana	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
RJ	Cairuçu	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
RJ	Guapi-Mirim	Area of Environmental Protection	Sustainable-use	No	-	-	-	-
RJ	Pau Brasil	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
RJ	Prainha	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
RJ	Tamoios	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
RJ	Grumari	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
RJ	Arraial do Cabo	Extractive Reserve	Sustainable-use	Yes	-	-	-	-
SP	Tupinambás	Ecological Station	No-take	Yes	-	-	-	-
SP	Tupiniquins	Ecological Station	No-take	Yes	-	-	-	-
SP	Ilhabela	State Park	No-take	No	-	-	-	-
SP	Lage de Santos	State Park	No-take	Yes	-	-	-	-
SP	Xixová-Japuí	State Park	No-take	Yes	-	-	-	-
SP	Ilha Anchieta	State Park	No-take	Yes	-	-	-	-

SP	Litoral Centro	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
SP	Litoral Norte	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
SP	Litoral Sul	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
SP	Ilhas Queimada Grande e Queimada Pequena	Area of Relevant Ecological Interest	Sustainable-use	Yes	-	-	-	-
SP	São Sebastião	Area of Relevant Ecological Interest	Sustainable-use	Yes	-	-	-	-
PR	Ilha dos Currais	National Park	No-take	Yes	-	-	-	-
PR	Ilha do Mel	State Park	No-take	Yes	-	-	-	-
SC	Arvoredo	Biological Reserve	No-take	Yes	-	-	-	-
SC	Carijós	Extractive Reserve	No-take	No	-	-	-	-
SC	Acaraí	State Park	No-take	Yes	-	-	-	-
SC	Serra do Tabuleiro	State Park	No-take	Yes	-	-	-	-
SC	Anhatomirim	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
SC	Baleia Franca	Area of Environmental Protection	Sustainable-use	Yes	-	-	-	-
SC	Pirajubaé	Extractive Reserve	Sustainable-use	No	-	-	-	-

Appendix S2

Table S2. List of combinations for functional groups; species were assigned to functional groups by a three variable method (trophic group, maximum body size and maximum depth). Method follows Halpern and Floeter 2008.

Functional groups[1]	Richness
CGP	52
CGD	20
ISD	19
IED	19
IAR	18
ISP	15
IAD	13
IAV	13
CEP	12
ISR	10
IGD	9
IGP	8
IEP	8
IAM	8
IGM	8
ISM	8
CED	7
HEM	6
CGM	6
HSM	6
IEM	6
ISV	5
LSM	5
CGV	5
CSP	5
IER	5

LAD	5
LSD	5
NED	5
OEM	4
CEM	4
CGR	4
CSD	4
IGR	4
LAM	4
HED	3
HGM	3
LED	3
LSR	3
NSD	3
NSM	3
IAP	2
LAP	2
LSP	2
NEM	2
NGM	2
HSD	2
NSP	2
OAM	2
OED	2
OEP	2
OGD	2
OGM	2
OGP	2
OSM	2
OSR	2
HAV	2
CEV	1

CSM	1
CSR	1
CSV	1
HAP	1
HSP	1
IEV	1
LEM	1
LEP	1
LGD	1
LGP	1
NAD	1
NEP	1
NER	1
OAD	1
OAR	1
OAV	1
OEV	1
OGV	1
OSD	1
TOTAL	405

[1]Trophic groups: herbivore ('H'), macro-carnivore ('C'), mobile invertivore ('I'), sessile invertivore ('N'), omnivore ('O'), planktivore ('L'); Maximum body size categories: small (<10 cm; 'A'), medium-small (10-25 cm; 'S'), medium (25-50 cm; 'E'), large (>50 cm; 'G'); Maximum depth categories: very shallow (<10 m; 'V'), shallow (10-20 m; 'R'), medium (20-50 m; 'M'), deep (50-100 m; 'D'), very deep (>100 m; 'P').

Reference for Appendix

Halpern, B.S., and S.R. Floeter. 2008. Functional diversity responses to changing species richness in reef fish communities. Marine Ecology Progress Series **364**: 147-156.

4 ARTIGO III

Where do we bet our future? Towards an ecosystem-based approach for marine conservation in Brazil

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WHERE DO WE BET OUR FUTURE? TOWARDS AN ECOSYSTEM-BASED APPROACH FOR MARINE CONSERVATION IN BRAZIL

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ABSTRACT

Aim – To discuss practices of systematic conservation planning towards marine ecosystem-based management implementation in Brazil; and to provide steps to improve and expand the current system of marine protected areas (MPAs) based on the conceptual ecosystem-based framework, using a case study with coastal reefs.

Location – the Brazilian coastline to a depth of 50 m, from the state of Maranhão to Santa Catarina

Methods – A brief review of previous studies related to ecosystem-based approaches for marine management was performed. A case study for coastal reefs was presented: spatial prioritization analyses using range maps of reef fish (405 spp), algae (207 spp) and hard coral (22 spp), MPAs, and cost layers for industrial and artisanal fishing, ports, oil & gas extraction areas. Outputs were compared to a national assessment published in 2007 by the Ministry of the Environment using qualitative data.

Results – Studies focusing on spatial management of marine ecosystems in Brazil are sparse and not standardized. Also, most of marine ecosystems and habitats remain unmapped, or when they do the extent of such maps are very limited. The spatial prioritization exercise showed the importance of expanding the MPA network, especially in northeast Brazil. These areas match the priority areas for conservation assigned for fishing management and creation/expansion of MPAs proposed by the government.

Main conclusion – The current MPA system is not enough to protect coastal reefs in Brazil. MPA network expansion must be inserted in the context of spatial planning and will help to minimize conflicting uses that could reduce the effectiveness of MPAs. Spatial data for use conflicts are available for national scale assessments; however, habitat and biodiversity spatial data are mostly available at local scales. Such expansion should include areas closed to fishing, whether through no-take MPAs or within no-take zones in multiple-use MPAs.

Keywords: ecosystem-based management, fisheries management, marine spatial planning, MPA network, spatial prioritization, use conflicts, Zonation.

INTRODUCTION

Marine protected areas (MPAs) are a common tool for managing marine resources and ecosystem services, being used mainly to foster conservation, promote sustainable fisheries and macroalgae/invertebrates exploitation (Toropova *et al*., 2010; Kerwath et al., 2013; Riul et al., 2008). However, MPAs have been historically created and designed to meet individual, partitioned goals, which often lead to results that are incapable to thrive long-term expectations and changing activities beyond their boundaries (Halpern et al., 2010). The basic concept of ecosystem-based management (EBM) includes resilience and maintenance of ecosystems, and also considers associated human population and economic/social systems as integral parts of the ecosystem (UNEP, 2006, 2011). Because MPAs are unable to satisfy tangible responses for every single impact on marine ecosystems, several studies are now pointing out the urgent need to incorporate MPAs as a component of EBM initiatives (*e.g.,* Douvere, 2008; Gilliland & Laffoley, 2008; Halpern et al., 2010).

The number and extension of MPAs in the world is still incipient in quantity and efficacy to address management/conservation problems. Currently, less than 3% of the ocean is protected, and a much smaller proportion is within no-take MPAs (where fishing and other extractive activities are forbidden) (IUCN/UNEP-WCMC, 2013). The growing demand for marine resources, coupled with biodiversity losses related to the increase of cumulative impacts caused by various human activities (Martins et al., 2013, Scherner et al., 2013) and climate change (Turra et al., 2013), have demanded for holistic and efficient approaches (such as EBM) to address these issues in both temporal and spatial scales (Toropova et al., 2010; Douvere, 2010). In this sense, MPAs can benefit from being inserted within a broader, comprehensive strategy, rather than being managed isolated from both activities and impacts that may occur within or off-limits (Halpern et al., 2010).

Within the EBM framework, systematic and spatial planning are components used in assessments aiming to minimize use conflicts in the ocean (Margules & Pressey, 2000; Douvere, 2010). The general idea behind is that solutions may be both adequate for biological conservation as well as socially acceptable (Moilanen, 2008). Principles such as comprehensiveness, adequacy, representativeness, and efficiency should also integrate the discussion to implement scientific-based solutions to help aiding marine management deficiencies (Spalding et al., 2013). Therefore, planning for the expansion of a network of MPAs may also include both biological and socioeconomic values, resulting in more realistic scenarios that can be directly applied in decision making (Roberts et al., 2003; UNEP-WCMC, 2008; Spalding et al., 2013). At the Great Barrier Reef, home to the world's largest network of no-take areas combined to other multiple use areas, the comprehensive zoning and spatial management approach used by the Marine Park Authority (GBRMPA) brought both direct and indirect beneficial effects on species, habitats, as well as social and economic enhancements (McCook et al., 2010). The example provided by the GBRMPA administration can contribute with valuable lessons of how comprehensive zoning within MPAs/networks may help promote EBM initiatives in other parts of the world (Halpern et al., 2010; McCook et al., 2010).

This study aims to discuss practices of systematic planning towards marine EBM implementation in Brazil. Following the global trend, marine ecosystems in Brazil have been susceptible to various threats, including coastal areas with high levels of degradation (MMA, 2009, 2010a). Moreover, Brazil currently protects only 2% of its entire Economic Exclusive Zone (MMA, 2013), despite being committed to the Convention on Biological Diversity (CBD) 10% target for 2020 (CBD, 2011). We also present a case study using coastal reefs in Brazil as an example to provide steps to improve and expand the current MPA system based on the conceptual EBM framework.

METHODS

1. Study area and context

The coastal area of Brazil included in this study (from the state of Maranhão to Santa Catarina, Figure 1a) is home of the largest coastal cities in the country, such as Fortaleza (>2.4 mi people), Recife (>1.5 mi people), Rio de Janeiro (>6 mi) and Salvador (>2.6 mi) (IBGE, 2013), which have historically caused the destruction of wide areas on the shoreline, particularly in estuaries, mangrove forests and shallow reefs (McNeill, 1986; Diegues, 1999). The observed unplanned growth of these urban areas promote an important shift in the phytobenthic community structure (Martins et al., 2012; Scherner et al., 2013), compromising the role of these primary producers in these coastal environments, once they represent food, shelter and substrate for a diverse and important associated fauna (Scherner et al., 2012).

Large ports are also found in the study area, including the largest one in Brazil, Porto de Santos, solely responsible for shipping over 60 mi tons of products every year (CODESP, 2014). More recently, user conflicts have escalated, especially after the discovery of one of the largest offshore energy potentials in the world (Hochstetler, 2011). As a result, new and larger ports, plus larger areas for prospection, construction of platforms and ships have greatly increased in the past few years (Figure 1b). Fishing activities are common in the region, with an overall larger influence of artisanal fisheries in the Northeast region (Diegues, 2008), whereas industrial fisheries have a heavier presence further south, especially in the state of Santa Catarina (Isaac et al., 2006), the southernmost limit for reefs and shallow coral species in Brazil (Figure 1c).

The study area also encompasses the area where reefs are most evident throughout the Brazilian coast. Two main types of reefs (inter-connected or not) are described there: biogenic - calcareous algae, corals, rodolith beds - and rocky reefs - granite, sandstone and beach rocks (Castro & Pires, 2001; Amado-Filho et al., 2012; Pascelli et al., 2013). However, the total distribution and extent of these reefs are unevenly known - especially at deeper coastal shelf areas (MMA, 2010; Magris et al., 2013). Shallow coastal biogenic reefs are in its majority included in MPAs (MMA, 2010), but lack of enforcement and poor zoning in many of those protected areas make them as effective as paper parks in the recovery from intensive fishing and other impacting activities (Artaza-Barrios & Schiavetti, 2007; Gerhardinger et al., 2011).

2. Review of practices

We did an online search for the following keywords: ‘ecosystem-based’, ‘adaptive management’, ‘conservation planning’, ‘spatial planning’, each one combined with "AND ‘marine’ AND ‘Brazil’" to evaluate previous studies in Brazil that could be used as a baseline for future conservation planning. Search engines included were Google Scholar, Scopus, and ISI/Web of Science. We selected studies and reports containing a combination of both biological and human use components encompassing the study area.

3. Spatial data

3.a. Biodiversity features

We used biological data of three important surrogates that are responsible for many important functions on the reefs (*e.g.*, Steneck & Dethier, 1994; Godoy & Coutinho, 2002): fish (405spp), algae (207spp) and hard corals (Scleractinians and Milleporids, 22spp). All maps were limited to the maximum depth of 50 m for the sake of data accuracy. We used the extent of occurrence approach (Gaston, 1994) to build range maps for all species, however, for species with known disjunctive distributions (Gaston, 1994), areas with no occurrences were excluded. Inputs of species distribution for all biological groups were assembled from various sources (reef fish - Carvalho-Filho, 1999; Floeter et al., 2008; Halpern & Floeter, 2008 and updates by the authors; algae - Oliveira Filho, 1977; Horta, 2000; Horta et al., 2001 and updates by the authors; corals - Castro & Pires, 2001; Capel, 2012; Souza, 2013).

Biodiversity features weight

Biodiversity features were also classified according to threatened status and endemism. Endemic species were assigned a weight of 1.2, and threatened species were assigned a weight of 1.3 if Vulnerable, 1.4 if Endangered and 1.5 if Critically Endangered. A value of 1 was attributed to a species if it was not assigned as endemic or threatened.

The final value of a single species was given according to the equation:

$$bfw_i = (1/n_{bf}) * end_i * thr_i$$

where bfw_i = biodiversity feature weight; n_{bf} = total number of biodiversity features; end_i = biodiversity feature endemism (weight value: 1.2) or not (value: 1); thr_i = biodiversity feature threat status (vulnerable: 1.3; endangered: 1.4; critically endangered: 1.5) or not threatened (value: 1). Besides the above-mentioned literature, fish data followed the classification in Bender et al. (2012) and corals followed the national red list (Machado et al., 2008). Threatened and endemism status was not available for most algae species, so in this analysis we considered all algae species with a weight value of 1.

3.b. Costs features

The aim for considering costs in this study is to find solutions where there is a balance between marine conservation and human uses. With this, we intend to identify multiple use priorities and to lessen conflicts (Moilanen et al., 2012) by proposing different scenarios for conservation targets. Costs features were given negative values to indicate areas with conflicting uses.

Ports - because of the high risk of species invasion by ballast water discharges , increase of sedimentation, marine debris, dredging and spoil disposal, ports are a potential source for impacts on reefs, as been reported by studies in many parts of the world (*e.g.*, Ferreira et al., 2009; Silva et al., 2011). The point data layer of all Brazilian coastal ports was obtained from the Ministry of the Environment online database (mapas.mma.gov.br/i3geo/datadownload.htm) and a 10 km buffer was generated to indicate an influence core zone of each port.

Oil & Gas - because of the recent increase of Oil & Gas (O&G) areas in Brazil, many concerns have been raised, especially regarding to accidents in platforms and oil spill events. New O&G areas for prospection and extraction near MPAs are also becoming more common. Data layer of O&G areas currently available for prospection and/or exploration was obtained from the National Oil Agency website (brasil-rounds.gov.br).

Industrial fishing - although this practice does not occur over most reefs in Brazil (expect in the South), such activity may have considerable impact (*e.g.*, by-catch) on highly mobile, migratory reef species, such as top fish predators. Data was obtained from the 'National Program for Satellite Tracking of Fishing Vessels' website (www.preps.gov.br) for the following fisheries: squids, pargo (red snapper), pink shrimp, driftnet and dragnet fishing. The density of positions related to the activity of operation was used as a measure of intensity of use of the area for each group of vessels (MPA, 2012).

Artisanal fishing - this may be the human activity with the most direct impact, especially over the most coastal, shallow reefs: the easy access to reefs has already caused a considerable depletion of fish stocks in many areas (Floeter et al., 2006; Francini-Filho & Moura, 2008). Because both registered professional and unregistered citizens might undertake this activity, an accurate number of artisanal fishermen may be hard to define. Moreover, information on the extent of each artisanal fishing vessel is also unlikely to be reported, because of the various discrepancies of vessels and fishing gear. Here we projected the information of registered artisanal fishermen from all coastal cities on the marine area until the 12 nautical miles limit, which is the area under the coastal cities jurisdiction (*i.e.*, the territorial sea), as determined by the National Plan for Coastal Management (CIRM, 1997). This proxy was used because it provides an idea on the influence of each coastal city to this activity. Data of registered fishermen was obtained at the Ministry of Fishing and Aquiculture website (http://sinpesq.mpa.gov.br/rgp/).

Other impacting, conflicting activities could have been listed here (*e.g.*, aquiculture, shrimp farming, game fishing), however, spatial data for such activities are not available for the entire extent of the study area. At local scales, different conflicting activities can also be listed, exposing a multiple-use condition throughout the coast that varies within regions and cultural backgrounds. For this first spatial prioritization exercise, we focused on relevant human activities that have also shown to create substantial impacts on coastal reefs when not managed properly.

3.c. Mask layer

A mask layer determines the removal hierarchy of cells and can be used in conservation prioritization when some predetermined information about zoning (*i.e.*, the presence of MPAs) exists (Moilanen et al., 2012). The grid corresponding to the study area has 20.5% of cells as MPAs (not necessarily in reef areas), being 0.8% no-take MPAs (mostly in reef areas) (Figure 1a). We use a mask layer in analysis so that cells that are not inserted in MPAs (*i.e.*, with the lowest mask level = 0) are removed first, followed by MPAs for sustainable use (mask level = 1) and lastly, no-take MPAs (*i.e.*, highest mask level = 2), which are removed last. Because the latter are only removed after there are no more cells with lower mask level values left, they remain within the top fraction of the solution (Moilanen et al., 2012). Data of MPAs were obtained from the Ministry of the Environment online database (mapas.mma.gov.br/i3geo/datadownload.htm).

4. Analyses

The study area was divided into fine scale (0.2 decimal degrees) grid cells (total of 34,775 cells). Analyses of spatial prioritization for reefs in Brazil were done using Zonation v3.1.11. We built three different scenarios for discussion: a. only biodiversity features – to highlight areas with highest overlap of species; b. both biodiversity and human use features with the MPAs mask layer – to measure the extent to which biodiversity features protection have been achieved by existing conservation areas; c. both biodiversity and human use features with a mask layer containing only no-take MPAs– because most of no-take MPAs in the study area encompasses reefs, this analysis would show how to expand the MPA network based on current reef protection. We divided outputs showing areas with the highest 10% and 30% scores, which are the figures 'ideally' proposed by both political (MMA, 2010) and ecological (Svancara et al., 2005) targets, respectively. Results were compared to the outputs from the document 'Priority Areas for Conservation, Sustainable Use and Benefit Sharing of Brazilian Biological Diversity' (MMA, 2007) (Figure 1d). One of the goals reported in this document was to design a system of MPAs (MMA, 2007), however, very few MPAs were created since its release. Spatial data of this document was obtained from the Ministry of the Environment online database (mapas.mma.gov.br/i3geo/datadownload.htm). The spatial data from this document was adapted to show the actions proposed that match use conflicts included in our study (Figure 1d).

RESULTS

The existing data that could contribute for marine EBM development and implementation in Brazil is sparse and not standardized (Table 1). Also, most of marine ecosystems and habitats remain unmapped, or when they do the extent of such maps are very limited (Table 1). There is a significant amount of spatial data for various human uses available at a national level, whereas spatial data for biological features are mostly local (Table 1). Additionally, studies focusing on spatial management of reefs are usually also very local, but with a good representation of different sectors that could benefit and/or have conflicts with conservation tools such as MPAs (Table 1).

Analyses of spatial prioritization for reefs in Brazil showed similar results for both the scenario with only biodiversity features and the scenario with biodiversity features, costs and no-take MPAs combined (Figure 2a, 2b). Some of the areas with the highest scores for biodiversity features overlap to areas near ports, cities with medium to high artisanal fishing and O&G activities (Figures 1b, 1c). For these two scenarios, the northeast region was the most representative, and it corresponds to areas assigned for MPA creation/expansion and fisheries regulations in the Priority Areas for Conservation document (Figure 1d).

The analysis with the scenario considering all existing MPAs showed the highest scores in areas within or near existing MPAs throughout the coast (Figure 2c). Besides the human activities described for the previous scenarios above, this scenario also overlaps with areas for industrial fishing (Figure 1c). Priority areas from this analysis also correspond to areas designated for MPA creation/expansion and fisheries regulations, as well as for other arrangements (Figure 1d).

DISCUSSION

Here we present the first comprehensive spatial conservation portfolio for shallow reefs at the Brazilian coastline, comparing biodiversity features to human use conflicts, existing MPAs and priority areas proposed by the government. Considering the distribution of biodiversity features we believe that current MPAs are insufficient for protecting reef organisms at the Brazilian coast (Figure 1a, Figure 2). The similar result for scenarios with only biodiversity features and the combination of biodiversity features, costs and no-takes is due to the low number of no-take MPAs along the coast (Figure 2a, 2b). Our results also points out a crucial need for EBM implementation in Brazil: there is a considerable gap in spatial data for marine ecosystems and habitats (Table 1; Magris et al., 2013). The region encompassing the Abrolhos banks (Figure 1a) may be the most comprehensively mapped reef area in Brazil to date, with both human uses and ecosystem data available at a fine resolution (see Moura et al., 2013). However, use conflicts, especially resulting from fishing and new Oil and Gas prospection areas, have risen to the point that even a recent proposal for MPA network expansion at the Abrolhos region was postponed with no convincing reason (MMA, 2012b; Angelo, 2012). Another detail worth noticing is that there are some spots within the priority areas with great potential for conflicts with the O&G industry and ports (Figure 1d). This example represents an alarming reality in Brazil’s marine governance: regardless of a good existing legal framework with plenty of room for EBM (Seraval, 2010), the compliance of current laws still needs substantial improvement.

Despite the fact that the Brazilian legal/political framework include, in more or less intensity, the concepts of an ecosystem-based management approach (*e.g.*

CIRM, 1997; MMA, 2006, 2007a; Seraval, 2010), in reality they are still disconnected to many components of marine conservation in the country, including MPAs. The legal existing instruments that mention the protection/conservation of coastal and marine natural resources are the National Plan on Coastal Management and the Sectorial Plan for Sea Resources (Law number 7661/1998 and decree number 6678/2008, respectively). The neglect in orchestrating together both focuses and actions among different sectors suggests that the legal framework is still not substantially implemented. There is currently a federal law proposal that attempts to integrate both uses and management practices within one comprehensive legislation in Brazil, called the 'Law of the Sea' (Law proposal number 6969/2013). This proposal aims to involve a wide audience of stakeholders (at local, regional, national levels) in what will probably become the most important management tool for the sea and coastal zone in Brazil.

Moreover, there are high quality spatial data available from various human uses throughout the entire Brazilian Exclusive Economic Zone, especially in more coastal areas (Table 1). Having such information freely accessible as spatial layers for any research group, non-profit agencies and the civil society is a huge advance towards EBM that the Brazilian government is reaching. This type of data can benefit EBM implementation from local to national levels, besides help promoting dissemination and stakeholder engagement in the holistic view that EBM attains (Ehler & Douvere, 2009).

Reefs may be the most studied marine ecosystem in Brazil, and while being inserted in MPAs of various levels of protection and use, they are still under several threats (*e.g.*, Floeter et al., 2006; Francini-Filho & Moura, 2008). Studies and applications of EBM have been applied to reefs in Brazil before (Table 1), but this present study is the first attempt of doing so at a more comprehensive, national level. The spatial prioritization exercise presented here reassures the importance to implement the proposals stated in the ‘Priority Areas for Conservation, Sustainable Use and Benefit Sharing of Brazilian Biological Diversity’ (MMA, 2007) document (Figure 1d, Figure 2). It is clear that the current MPA system needs to be enlarged at a national level, and the exercise of MPAs expansion in coastal reefs areas presented here can be used as a reference in other ecosystems to implement EBM.

The use of decision science tools to apply EBM methods will ultimately form the basis for adequate management of marine ecosystems and resources (Crowder

& Norse, 2008). Currently, existing MPAs throughout the world are not of enough help in EBM implementation because they are too few, in number and size, to guarantee long-term results in the light of growing demands and impacts (Halpern et al., 2010; IUCN/UNEP-WCMC, 2013). Paradoxically, sufficient information and experience are evident in many scales that may contribute to further an ecosystem-based approach towards management, although there is still room to increase the knowledge of both social and ecological components of marine systems (Leslie & McLeod, 2007). In this context, marine spatial planning (MSP) may help meet existing commitments for supporting biodiversity, restoring ecosystem components, advancing integrated management while addressing human impacts, and establishing MPA networks (McCook et al., 2010; UNEP, 2011).

As a continuous, iterative and adaptive system, MSP may play a crucial role in EBM implementation in Brazil, especially when planning for long-term results (Douvere, 2008). Because spatial management tools include multiple areas and objectives, inserting the MPA system expansion within the context of MSP will help minimize outside features that could reduce MPA effectiveness (Halpern et al., 2010). An important next step that must be emphasized is to organize stakeholder participation where priority areas were proposed (Figure 1d; Figure 2), to coordinate the sustainable use of resources in the area and engage stakeholders in the process even at the earliest stages of planning - whether local, regional or national scales (Gilliand & Laffoley, 2008). This is crucial as Brazil still have to quintuple its current MPA area to achieve government commitments (CBD, 2011; MMA, 2013).

Recent claims suggest that optimal marine conservation will ultimately be achieved with large, old, enforced and isolated no-take MPAs (Edgar et al., 2014). This bold statement reassures previous scientific reports affirming that for every marine habitat there should be around 20-30% of strictly protected areas (*i.e.*, no-take MPAs) (*e.g.*, IUCN, 2003; Lubchenco et al., 2003). While such statements are extremely relevant for current and future MPAs calibration, the benefit of inserting MPAs within the EBM context is that multiple goals can be fulfilled and conflicting activities can be adequately addressed rather than being merely displaced (Halpern et al., 2010). In this context, our findings provide useful information for the expansion of MPAs along the Brazilian coastline, including no-take MPAs (Figure 2). An interesting next step here would be addressing specific problems and particularities of the priority areas appointed in this study (Figure 2). For instance, other conflicting uses that were not available for this analysis at a national scale should be easier to be included at a more local level. Promoting stakeholder engagement at more local scales should also be more feasible, especially when addressing issues related to artisanal fishing areas and the empowerment of local communities.

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FIGURE CAPTIONS

1. Study area (in black) encompasses the Brazilian coastline (≤50m) from the state of Maranhão (MA) to Santa Catarina (SC). Light grey marine boundaries indicate a country's Exclusive Economic Zone. a. Marine Protected Areas inserted within the study area; b. Areas for Oil and Gas prospection/exploration activities, and ports; c. Intensity of fishing activities, both artisanal and industrial; d. Government action strategies adapted from 'Priority Areas for Conservation, Sustainable Use and Benefit Sharing of Brazilian Biological Diversity', published by the Brazilian Ministry of the Environment (MMA, 2007).

Figure 2. Spatial prioritization of shallow (≤50m) marine areas at the Brazilian coastline. Colored areas indicate priority areas to meet 10% (red) and 30% (yellow) protection scenarios (*i.e.*, maintaining at least 90% and 70% of biodiversity in the region, respectively). a. Biodiversity features only (reef fish, corals and algae species); b. Biodiversity features, human uses and no-take MPAs combined; c. Biodiversity features, human uses and all MPAs combined.

TABLE LEGEND

Table 1. Review of practices: examples of spatial components from studies and reports with the potential to foster marine EBM implementation in Brazil.

Figure 1.

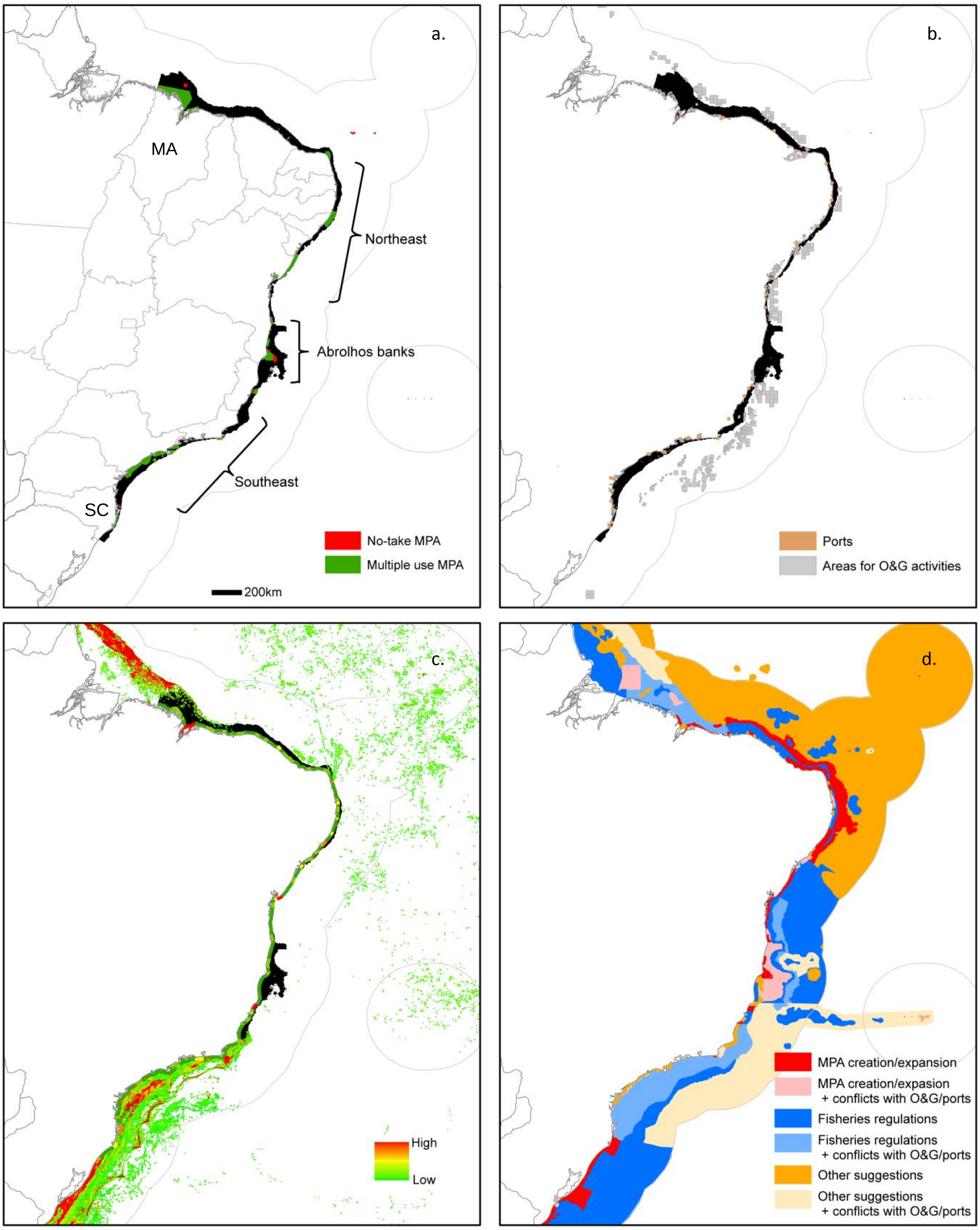
a.
MA
Northeast
Abrolhos banks
Southeast
SC
No-take MPA
Multiple use MPA
200km
b.
Ports
Areas for O&G activities
c.
High
Low
d.
MPA creation/expansion
MPA creation/expasion
+ conflicts with O&G/ports
Fisheries regulations
Fisheries regulations
+ conflicts with O&G/ports
Other suggestions
Other suggestions
+ conflicts with O&G/ports

Figure 2.

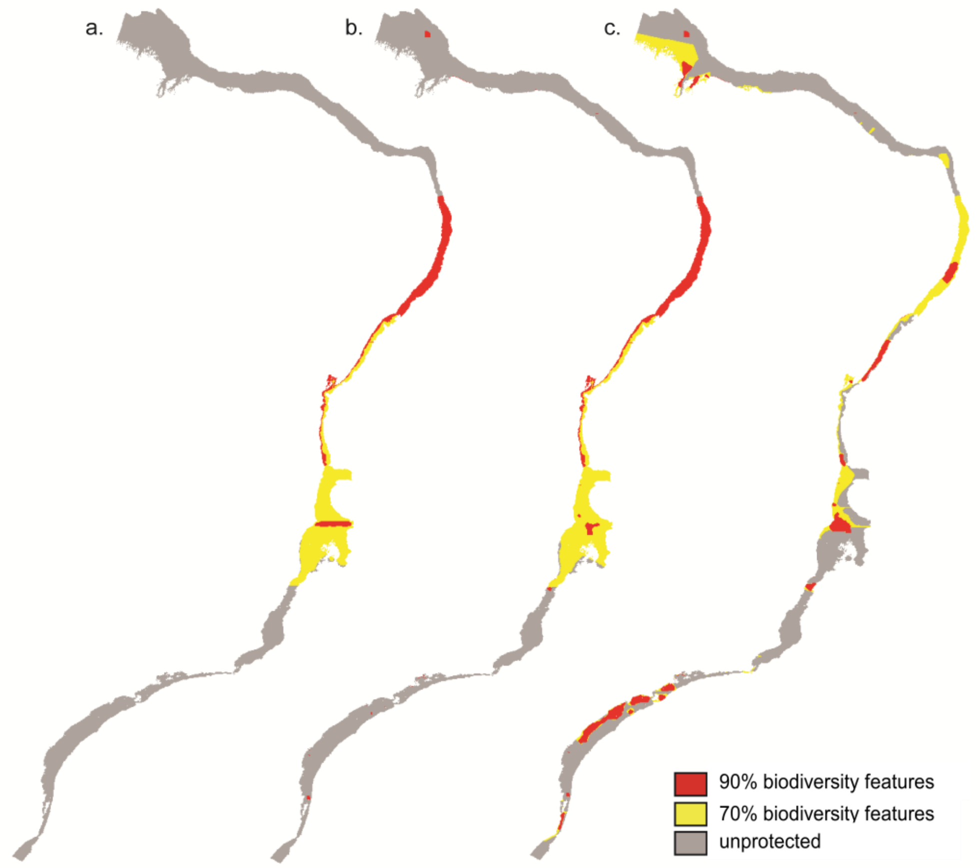
a.
b.
c.
90% biodiversity features
70% biodiversity features
unprotected

Table 1.

Study region	Ecosystem/habitat/species	EBM level?[1]	Spatial component	Sector(s)	References
Salvador (Bahia)	Reef	Incremental	Spatial prioritization	MPAs, not specified socio-economic sectors	Cruz et al., 2013
Bahia	Reef, mangrove	Incremental	Bio/geo/physical features mapping	MPAs, artisanal fishing	Carvalho & Kikuchi 2013
Abrolhos bank (Bahia)	Reef, rhodolith beds	Comprehensive	Benthic mapping (sonar, remotely operated vehicle)	MPAs, O&G extraction areas, mining, dredging, artisanal and trawling fishing	Moura *et al*. 2013
Bahia and Espírito Santo	Humpback whale	Incremental	Risk analysis	MPAs, ship traffic, harbors and ports, O&G extraction areas	Martins et al., 2013
Espírito Santo	Reef habitats	Incremental	TEK[2], Sonar	MPA, artisanal fishing	Teixeira et al., 2013
Santos (São Paulo)	Mangrove, estuary	Comprehensive	Biological + socio-economic mapping	Marinas, game fishing, diving areas, mining, artisanal fishing, industrial and military facilities	Sartor et al., 2007
Ubatuba (São Paulo)	Fishing grounds	Incremental	FEK[3] mapping	MPA, artisanal fishing	Leite & Gasalla 2013
Babitonga bay (Santa Catarina)	Goliath grouper	Low	FEK mapping	Artisanal fishing	Gerhardinger et al., 2009
National	Seabirds	Low	Spatial prioritization	MPAs	Machado et al., 2013
National	All marine[4]	Low	Gap analysis	MPAs	Magris et al., 2013
National	All coastal and marine ecosystems	Comprehensive	Spatial prioritization	MPAs, artisanal and industrial fishing, other not specified socio-economic sectors	MMA 2007a
National	All coastal and most marine ecosystems	Comprehensive	Biological + socio-economic mapping	MPAs, Marinas, game fishing, diving areas, mining, artisanal fishing, industrial and military facilities, ports, O&G extraction areas (…)	MMA 2004, 2007b, 2010, 2012a
National	All coastal and most marine ecosystems	Comprehensive	Biological + socio-economic mapping	Socio-economic data for coastal cities, game fishing, diving areas, mining, artisanal fishing, industrial and military facilities, ports	MMA 2009

[1]EBM levels can be assigned as: Low – individual species or single sector management and/or restrict scale, short-term perspective; Incremental – groups of species and at least two sector management, coordinate management, medium-term perspective; Comprehensive – whole ecosystems and all sectors that impact/are impacted are managed, long-term perspective (UNEP 2011). Disclaimer: here we consider the potential use of each study/report at different EBM levels, not necessarily that EBM practices are currently being implemented at the given region/level.

[2]TEK = Traditional Ecological Knowledge

[3]FEK = Fishermen Ecological Knowledge
[4]With the exception of shallow biogenic reefs and mangroves, bathymetry was used as a proxy to define ecosystems.

5 CONCLUSÃO GERAL

Num contexto global a maioria dos países, notoriamente os emergentes, apresentam um baixo número de áreas marinhas protegidas (AMPs). Brasil, China, Índia, Indonésia, México e África do Sul apresentam entre 1 e 2% de proteção do seu território marinho e, com poucas exceções, estas AMPs são manejadas de forma ineficiente. Um efeito disso pode ser observado na grande quantidade de recifes altamente impactados (BURKE *et al.,* 2011), ainda que este ambiente esteja entre os mais contemplados por AMPs quando comparado com outros habitats (TOROPOVA *et al.,* 2010, WOODS *et al.,* 2010). O número de áreas fechadas para pesca (seja em reservas marinhas ou AMPs de proteção integral, ou ainda dentro de AMPs de múltiplo uso) deve ser aumentado principalmente pela importância destas áreas mais restritivas para a recuperação de espécies exploradas comercialmente (TOROPOVA *et al.,* 2010; HALPERN *et al.,* 2010; ABURTO-OROPEZA *et al.,* 2011; GRAHAM *et al.,* 2011) e para ajudar a manter a resiliência de ambientes frágeis como os recifes (COTE & REYNOLDS, 2005; WOODS *et al.,* 2010). Esforços conjuntos entre comunidades locais e o governo precisam ser expandidos para que alvos prioritários de conservação sejam atingidos e políticas sustentáveis sejam utilizadas.

No Brasil, as AMPs correspondem a 2% do território marinho brasileiro (MMA, 2013). Além disso, existe um número muito superior de AMPs de uso sustentável e poucas AMPs de proteção integral (e poucas áreas fechadas pra pesca dentro de AMPs de uso múltiplo). O estudo feito observando as incompatibilidades entre hotspots de peixes recifais e AMPs revelou que a costa do nordeste e o estado do Espírito Santo são as regiões mais críticas para medidas de conservação de peixes recifais. Uma vez que AMPs não podem mais ser consideradas como uma ‘medida paliativa’, mas sim uma operação sócio-política bastante complexa, é necessário que a rede de AMPs nestas regiões críticas sejam expandidas (CHUENPAGDEE *et al.,* 2013); Tal expansão deve incluir áreas fechadas pra pesca, seja por meio de AMPs de proteção integral ou no zoneamento das AMPs de uso múltiplo, dentro de um planejamento espacial extensivo para minimizar conflitos (HALPERN *et al.,* 2010; UNEP, 2011).

Esse trabalho também apresenta o primeiro conjunto de análises de priorização espacial abrangendo ambientes recifais em toda a costa Brasileira, comparando componentes biológicos com conflitos de uso, AMPs existentes, e as áreas prioritárias para conservação estabelecidas pelo governo (MMA, 2007), dentro do contexto de manejo com base em ecossistema (EBM). Os recifes são provavelmente o ecossistema marinho mais estudado no Brasil, e mesmo estando inseridos em áreas marinhas protegidas de vários níveis de proteção e uso (PRATES, 2006; MMA, 2010), eles ainda estão sob várias ameaças (BURKE *et al.,* 2011). Os ecossistemas marinhos de forma geral ainda permanecem não mapeados, ou quando são, a extensão do mapeamento é bastante limitada (*e.g.* MOURA *et al.,* 2013; MAGRIS *et al.,* 2013). Mais especificamente, os estudos com foco na gestão espacializada de ambientes recifais no Brasil são geralmente locais, porém com uma boa representação de variados setores que se beneficiam/têm conflito com as estratégias de conservação tais como as AMPs (*e.g.*, CRUZ *et al.,* 2013; TEIXEIRA *et al.,* 2013).

Os exercícios de priorização espacial aqui apresentados reforçam a importância de implementar as propostas estabelecidas no documento 'Áreas Prioritárias para Conservação, Uso Sustentável e Repartição de Benefícios da Biodiversidade Brasileira' (MMA, 2007). É evidente que o atual sistema de AMPs precisa ser ampliado em nível nacional, e o exercício de expansão das AMPs em áreas com recifes costeiros aqui apresentados pode ser usado como referência em outros sistemas marinhos para integrar as AMPs numa abordagem ecossistêmica. Um próximo passo importante que deve ser enfatizado é o de organizar a participação dos outros atores onde as áreas prioritárias foram propostas (GILLIAND & LAFFOLEY, 2008).

O uso de métodos e ferramentas que englobam o EBM tem o potencial de formar a base para uma gestão adequada dos recursos e ecossistemas marinhos no Brasil (CROWDER & NORSE, 2008). Por ser um sistema contínuo, interativo e adaptativo, o planejamento espacial pode desempenhar um papel crucial na implementação do EBM no Brasil, especialmente quando se planeja para resultados a longo prazo (DOUVERE, 2008). Como as ferramentas de gestão espaciais incluem múltiplas áreas e objetivos, inserir a expansão do sistema de AMPs no contexto do planejamento espacial irá contribuir para minimizar influências externas que poderiam reduzir a eficácia das AMPs (HALPERN *et al.,* 2010). É importante destacar que já existem dados espaciais de alta qualidade disponíveis para diversos tipos de atividades espalhadas por toda a Zona Econômica Exclusiva brasileira, especialmente na região costeira. Tais informações, de livre acesso para qualquer grupo de pesquisa, organizações sem fins lucrativos e da sociedade civil, é um grande avanço para implementar iniciativas de EBM no Brasil. Isto é pertinente, uma vez que o Brasil ainda precisa quintuplicar sua atual área de AMPs para alcançar compromissos governamentais para a conservação marinha (CBD, 2011).

É necessário destacar que reivindicações recentes sugerem que o formato de conservação marinha ideal só será alcançado com AMPs grandes, antigas, isoladas e de proteção integral (EDGAR 2014). Essa afirmação confirma sugestões prévias para proteger de forma integral (ou seja, fechada para a pesca/extração de recursos) aproximadamente 20-30% de todos os habitats marinhos (IUCN, 2003; LUBCHENCO *et al.,* 2003). Nesse contexto, os resultados apresentados nesse trabalho podem ser de extrema relevância na expansão de AMPs na costa brasileira, incluindo AMPs onde a pesca é proibida. Embora tais afirmações sejam extremas, e ainda relevantes para a calibração das AMPs atuais e futuras, o benefício da inserção de áreas marinhas protegidas no contexto do EBM é que metas múltiplas podem ser cumpridas, e as atividades conflitantes podem ser tratadas de forma adequada ao invés de serem apenas mudadas de lugar (HALPERN *et al.,* 2010).

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