UNIVERSIDADE ESTADUAL DE SANTA CRUZ
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA E CONSERVAÇÃO DA BIODIVERSIDADE

CUSTOS DE OPORTUNIDADE E PERMUTAS (“TRADEOFFS”) NO PLANEJAMENTO ESPACIAL MARINHO

JOÃO BATISTA TEIXEIRA

ILHÉUS – BAHIA
Abril de 2016

JOÃO BATISTA TEIXEIRA

CUSTOS DE OPORTUNIDADE E PERMUTAS (“TRADEOFFS”) NO PLANEJAMENTO ESPACIAL MARINHO

Tese apresentada à Universidade Estadual de Santa Cruz para obtenção do título de doutor em Ecologia e Conservação da Biodiversidade. Área de concentração: Biodiversidade

Orientador: Dr. Rodrigo Leão de Moura

Co-orientadora: Dra. Deborah Faria

Supervisoras do estágio na University of Queensland, Austrália: Dra. Carissa Klein e Dra. Morena Mills

ILHÉUS – BAHIA

T266 Teixeira, João Batista
Custos de oportunidade e permutas (“tradeoffs”) no planejamento espacial marinho / João Batista Teixeira. – Ilhéus, BA: UESC, 2016.
74 f.: il.

Orientador: Rodrigo Leão de Moura.
Dissertação (Mestrado) – Universidade Estadual de Santa Cruz. Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade.
Inclui referências.

1. Biodiversidade marinha – Conservação. 2. Abrolhos, Arquipélago dos (BA). 3. Pesca – Pesquisa. 4. Habitat (Ecologia) – Conservação. I. Título.

CDD 333.95

ATA DA DEFESA PÚBLICA **Nº 05 - B** – TESE DE **JOÃO BATISTA TEIXEIRA** NO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA E CONSERVAÇÃO DA BIODIVERSIDADE – **DOUTORADO**

Aos vinte e oito dias do mês de abril do ano de dois mil e dezesseis, **João Batista Teixeira**, sob a orientação do(a) **Dr.(ª) Rodrigo Leão de Moura** e co-orientação do(a) **Dr(a) Deborah Maria de Faria**, apresentou a este programa a versão revisada de sua tese intitulada "**SUBSÍDIOS DE PLANEJAMENTO SISTEMÁTICO PARA CONSERVAÇÃO NO CENTRO-OESTE DO ATLÂNTICO SUL**" para última análise pelos membros da Comissão Examinadora que haviam emitido parecer "Necessita revisão – NR", a saber, os doutores **ALEX CARDOSO BASTOS, GILBERTO MENEZES AMADO FILHO, FERNANDO COREIXAS MORAES** e **DEBORAH MARIA FARIA**, conforme Ata de Defesa Pública Nº 05, de vinte e oito de março de dois mil e dezesseis. Após a avaliação da nova versão da tese e emissão de quatro pareceres favoráveis à sua aprovação, que somados a um parecer favorável à aprovação da primeira versão, a saber, do Dr. **FÁBIO DOS SANTOS MOTTA**, totalizaram cinco pareceres favoráveis, chegou-se à conclusão que a tese está **aprovada**. Sendo assim, o candidato passa a ter o título de doutor em Ecologia e Conservação da Biodiversidade, pela Universidade Estadual de Santa Cruz. Nada mais havendo a ser tratado, eu, Dr.ª **Deborah Maria de Faria**, lavrei a presente ata que será assinada por mim.

Campus Prof. Soane Nazaré de Andrade, Ilhéus, Bahia, 01 de junho de 2016.

Prof.(ª) Dr.(ª) Deborah Maria de Faria – Co-Orientador(a), UESC

Aos meus queridos pais, Janice e Waldemar, que me apoiaram incondicionalmente com perseverança, amor e fé, sem os quais eu nada seria.

AGRADECIMENTOS

À Renata Costa Carvalho, por compartilhar amizade, amor, carinho e cuidado nos piores e melhores momentos desta jornada.

À minha família que me valoriza não pelo que sou agora, mas pelo que sempre fui.

Aos meus amigos, irmãos, da vida, do trabalho, da UFES, da UESC, da Bahia, da Barra, do céu, da mata, da cachoeira e do mar, pelos risos, aventuras e ensinamentos imprescindíveis.

Ao meu filho Davi Luiz, pela luz que me transmite.

Aos meus mestres Rodrigo, Morena, Deborah, Carissa, Chris Brown, Matt e Hugh Possingham, por me guiarem na ciência.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), à Universidade Estadual de Santa Cruz, à Rede Abrolhos (SISBIOTA), ao Projeto PELD Abrolhos, à Conservação Internacional (CI-Brasil), à ECOMAR, ao *Centre of Excellence for Environmental Decisions* e à *University of Queensland* – Austrália, por viabilizarem a realização deste trabalho.

CUSTOS DE OPORTUNIDADE E PERMUTAS (“TRADEOFFS”) NO PLANEJAMENTO ESPACIAL MARINHO

RESUMO

Os países signatários da Convenção da Diversidade Biológica da Organização das Nações Unidas (CDB/ONU) reconheceram o cenário precário de proteção da biodiversidade marinha global e assumiram o compromisso de proteger 10% das suas Zonas Econômicas Exclusivas (ZEE). O Brasil é o primeiro signatário da CDB e está comprometido com o acordo. Entretanto, o atual estado da conservação marinha brasileira, aliado à política de desenvolvimento acelerado, gera um cenário desafiador para o atingimento efetivo dessa meta. O Planejamento Sistemático para Conservação (PSC) é a abordagem conceitual e matemática que busca otimizar de processos criação de áreas protegidas atingindo metas de proteção da biodiversidade e possibilitando a redução dos custos envolvidos de forma eficiente, replicável e justa. Os impactos socioeconômicos causados por restrições de acesso aos recursos naturais representam custos de oportunidade fundamentais para o desenvolvimento de um PSC. No entanto, considerar tais custos em regiões com pobreza de dados representa um desafio contemporâneo para a ciência devido à carência de dados socioeconômicos históricos, abrangentes e espacialmente explícitos. No Atlântico Sul, a região do Banco dos Abrolhos, sul da Bahia e norte do Espírito Santo, é uma área prioritária para conservação devido à sua relevância biológica e socioeconômica. Recentemente, uma importante iniciativa de PSC foi paralisada na região devido à intervenção do setor pesqueiro que alegou falta de representatividade e alto impacto das áreas marinhas protegidas propostas. Diante do exposto, o presente trabalho fornece uma revisão sobre a problemática da representatividade e abrangência dos custos de oportunidades para a pesca (Capitulo I), apresenta um novo método para estimar camadas heterogêneas de custos de oportunidade, baseado na distribuição dos habitats dos recursos pesqueiros (Capítulo II) e um modelo de PSC para o Banco dos Abrolhos que permite analisar permutas (tradeoffs) entre a proteção da biodiversidade e a exploração de recursos naturais (Capítulo III). Os resultados apresentados, assim como os dados e modelos produzidos, trazem novas perspectivas para o avanço do conhecimento sobre a incorporação de custos socioeconômicos em PSC e para a solução de um problema prático de conservação da biodiversidade marinha brasileira.

Palavras-chave: Banco dos Abrolhos, planejamento sistemático para conservação, custo de conservação, habitats, biodiversidade, pesca.

OPPORTUNITY COST AND TRADEOFF IN MARINE SPATIAL PLANNING

ABSTRACT

The signatory countries of the United Nations Convention on Biological Diversity (CDB) recognized the poor scenario of the global biodiversity protection assuming a commitment to protect 10% of the Economic Exclusive Zones. Brazil is the first signatory, however, the actual condition of the Brazilian marine conservation, combined with the accelerated development police, generates a big challenge scenario to achieve the CDB targets. The Systematic Conservation Planning (PSC) is a mathematic approach that allows optimizing the selection process to design protected areas achieving biodiversity targets while minimizing the costs in an efficient, replicable and fair way. The socioeconomic impact of the access restriction of natural resources represents the opportunity cost necessary to be incorporated in the PSC process. However, considering that cost in a data poor condition is a contemporaneous challenge because it demands a historically, comprehensively and spatially explicit database. The Abrolhos Bank, in the south of Bahia and north of Espírito Santo (South Atlantic), is a priority area for conservation because its biologic and socioeconomic relevance. Recently, an important PSC initiative in this region was stoped by the fishing sector that claimed for representativeness and pointed the high opportunity cost for fishing in the proposal marine protected areas. This thesis provides a review about opportunity costs' representativeness and comprehensiveness for fishing (Chapter I), a novel approach to estimate heterogeneous layers of opportunity cost for fisheries (Chapter II) and a PSC model to Abrolhos Bank that allow to analyse the tradeoffs between the achievement of targets to biodiversity protection and the exploration of natural resources (Chapter III). The presented results, database and models bring a new perspective to move forward with the knowledge about integrating socioeconomic costs in the PSC process and to solve a practical problem of the Brazilian marine biodiversity conservation.

Keywords: Abrolhos Bank, systematic conservation planning, cost of conservation, biodiversity, habitats, fishing.

SUMÁRIO

INTRODUÇÃO GERAL

1. ÁREAS MARINHAS PROTEGIDAS (AMPS): UMA NECESSIDADE GLOBAL

Em 2050 a população mundial alcançará 9,7 bilhões de habitantes (United Nations, 2015). A concentração humana próximo ao litoral implica em necessidades de expansão da infraestrutura portuária, pesqueira, industrial e habitacional, transformado rápida e drasticamente as paisagens costeiras.. A política econômica desenvolvimentista, que busca maximizar o retorno de investimentos em curto prazo, precisa estar aliada a conservação dos ecossistemas para assegurar, em longo prazo, o provimento dos bens e serviços proporcionados pela biodiversidade, a resiliência dos ecossistemas frente a estressores antropogênicos e climáticos, e a qualidade de vida das populações costeiras (Balmford et al., 2002).

A intensa exploração do Oceano nos últimos 50 anos tem causado alterações significativas nos ecossistemas marinhos (Pauly et al., 1998). Em sistemas comunais de extrativismo, envolvendo os recursos naturais não privatizados das áreas costeiras e marinhas, a necessidade de implementação de medidas de conservação é premente, em função da concorrência pela máxima extração (Hardin, 1968). Com muitos ecossistemas e estoques pesqueiros à beira do colapso, os gestores têm planejado investimentos crescentes em Áreas Marinhas Protegidas (AMPs), visto que podem representar ferramentas efetivas para restauração de ambientes degradados, ordenamento territorial, e até mesmo aumento na produtividade pesqueira (Palumbi, 1999; Boersma & Parrish, 1999; Lindeman et al., 2000; Sanchirico et al., 2002).

Em escala global, os países signatários da Convenção da Diversidade Biológica (CDB) da Organização das Nações Unidas (ONU) comprometeram-se com a proteção de pelo menos 10% dos oceanos mundiais até 2020, as denominadas Metas de Aichi (CDB, 2010). Entretanto, em 2010, as cerca de 6 mil AMPs existentes cobriam apenas 1,7% da superfície oceânica (Toropova et al., 2010). Além disso, parte significativa destas AMPs foi estabelecida de maneira oportunista ou com base na opinião de especialistas (planejamento *ad hoc;* Stewart et al., 2003). A inefetividade na alocação de recursos para decretação de AMPs que pouco contribuem para a conservação da biodiversidade, ou cujas características e processo de delineamento são considerados injustos pelos afetados e/ou beneficiários, resulta em "parques de papel" (*paper-parks*; Rife et al., 2013).

O planejamento de novas AMPs deve considerar, conjuntamente, os usos existentes ou futuros (custos da conservação) e o alcance de metas que representem a conservação da biodiversidade (benefícios da conservação) de uma dada região. Portanto, a representação das informações deve ser equitativa, tanto para biodiversidade quanto para os atores sociais que podem perder oportunidades econômicas. A sistematização das informações existentes e o planejamento adequado qualifica as discussões junto à sociedade, um dos passos fundamentais para aumentar a aceitação e aderência a novos regimes de uso do espaço costeiro e marinho.

2. PLANEJAMENTO SISTEMÁTICO PARA CONSERVAÇÃO (PSC)

O PSC é uma abordagem que pode ser aplicada pelos gestores responsáveis por conduzir os processos decisórios que envolvem AMPs. Trata-se de um ciclo que vai desde a pesquisa até a tomada de decisão sobre as ações de conservação, incluindo consultas suficientes para envolvimento dos diversos atores e setores envolvidos (*stakeholders*). O arcabouço conceitual do PSC obedece aos seguintes princípios, postulados por Pressey et al. (1993):

I. Insubstituibilidade - representação de alvos insubstituíveis para biodiversidade;
II. Complementaridade - complementar áreas protegidas existentes;
III. Flexibilidade - possibilitar combinações variadas entre elementos de biodiversidade e metas de conservação;
IV. Vulnerabilidade - considerar ameaças futuras à biodiversidade;
V. Representatividade - representar os níveis hierárquicos da biodiversidade desde a variabilidade genética até a diversidade funcional; e
VI. Persistência - manter a integridade dos alvos em longo prazo.

Além desses princípios, o PSC deve ser participativo e representar os *stakeholders* do princípio ao fim. Em função dessa complexidade, o PSC demanda a utilização de ferramentas de suporte à decisão para priorizar a seleção dos locais mais adequados para o atingimento de metas de conservação, considerando os custos envolvidos. Tais ferramentas podem se basear em duas abordagens distintas: 1) *minimum set*, que visa o alcance de metas de conservação da biodiversidade ao menor custo possível; e 2) *maximum coverage,* que maximiza a cobertura de proteção da biodiversidade a um determinado custo fixo. Dentre os softwares de suporte à tomada de decisão mais amplamente utilizados, tanto em estudos conceituais e simulações quanto em situações reais de PSC, destacam-se: ResNet (Kelley et al., 2002); Marxan (Ball & Possingham, 2000); Zonation (Moilanen et al., 2005); C-Plan (Pressey et al., 2009); e Marxan with Zones (Watts et al., 2009). A aplicação desses algoritmos, que são computacionalmente intensivos, possibilita a análise conjunta das informações sobre metas, benefícios e custos da conservação, auxiliando os tomadores de decisão na busca por soluções espacialmente explícitas capazes de maximizar os objetivos de conservação frente as limitações existentes.

As limitações existentes são proporcionais à complexidade dos problemas de priorização, principalmente quando envolvem múltiplas formas de uso dos recursos e diversos tipos de AMPs (Klein et al., 2010). O software Marxan with Zones foi desenvolvido para suprir a demanda de priorização por zonas com alvos, metas e custos específicos (Watts et al., 2009). Trata-se do algoritmo com maiores possibilidades de utilização em problemas reais de conservação em ambientes costeiros e marinhos, pois permite encontrar soluções para zonas de uso múltiplo e para diversas categorias de AMPs, simultaneamente.

Outra limitação do planejamento espacial marinho diz respeito à qualidade das informações espaciais para representação dos valores sociais, que mudam ao longo do tempo e do espaço e diferem entre os diferentes atores (Ives & Kendal, 2014). Para serem comparados diretamente, os valores precisam ser reduzidos a uma escala simples que utilize um padrão comum (e.g. dinheiro). A análise de permutas (*tradeoffs*) entre os valores ambientais e socioeconômicos podem contribuir nesse sentido (Klein et al. 2010), ainda que bens e serviços culturais ou ecossistêmicos sejam difíceis de monetizar, por serem intangíveis (Chan et al. 2012; Ives & Kendal 2014). Quando múltiplos custos são importantes para a tomada de decisão, a combinação de diversos dados socioeconômicos em uma só camada de custos, homogênea, afeta a robustez das soluções. Além disso, dados de diferentes naturezas não podem ser combinados matematicamente (e.g. recursos pesqueiros e valores culturais), tornando necessária a composição e análise individual de cada uma das múltiplas camadas de custo (Ban & Klein, 2009; Klein et al., 2008b; Mace et al., 2007; Possingham et al., 2002).

3. PROBLEMÁTICA DE CONSERVAÇÃO NO BANCO DOS ABROLHOS

A porção centro-oeste da Zona Econômica Exclusiva (ZEE) brasileira possui características singulares em termos de biodiversidade marinha, destacando-se como feições mais proeminentes o Banco dos Abrolhos e a Cadeia de Montes Submarinos Vitória-Trindade (CVT). A plataforma continental na região dos Abrolhos abriga os maiores e mais ricos recifes coralíneos do Atlântico Sul, bem como um mosaico de ambientes complexos e interligados (Dutra et al., 2005; Moura et al., 2013). Abrolhos é também a região mais piscosa do Nordeste (Costa et al., 2005), possuindo enorme importância socioeconômica (Freitas et al., 2011). Além dos atributos de biodiversidade e do fornecimento de bens e serviços ecossistêmicos (e.g. Amado Filho et al., 2012), a região está sob usos conflitantes (e.g. pesca artesanal, pesca industrial, exploração mineral). Apesar da relevância biológica, social e econômica, a cobertura de AMPs em Abrolhos ainda é incipiente, havendo também poucas medidas para embasar o uso sustentável dos recursos naturais, a despeito dos subsídios para implementação de medidas simples de gestão da pesca (e.g. Moura et al., 2009, 2013; Freitas et al. 2011, 2014; Previero et al. 2011). A ocupação desordenada da zona costeira e a degradação das drenagens fluviais pela expansão urbana, agrícola e industrial agravam o quadro regional (Dutra et al., 2006) tornando premente a realização de estudos que possam embasar o planejamento espacial marinho.

Como país signatário da Convenção da Diversidade Biológica das Nações Unidas (CDB), o Brasil se comprometeu a expandir sua rede de AMPs que, no momento, cobre apenas 1,52% das águas sob jurisdição nacional (ICMBio, 2011). O histórico de criação de AMPs no Brasil demonstra a completa ausência de um esforço coordenado e sistematizado no sentido do estabelecimento de uma rede nacional representativa, funcional, e socialmente justa. Em uma tentativa improvisada de atender as metas da CDB, a região do Banco dos Abrolhos, foi alvo de um processo de criação de AMPs sem observância dos princípios do PSC, em 2011. O processo foi considerado injusto por diversos atores e foi interrompido no momento das consultas públicas, quando boa parte do setor da pesca revelou não ter participado do planejamento.

4. JUSTIFICATIVAS DO TRABALHO

A necessidade de expansão da cobertura global de AMPs e o compromisso brasileiro com a CDB, juntamente com a necessidade de aprimoramentos metodológicos e conceituais nos métodos de representação e incorporação de custos socioeconômicos em processos de PSC marinho, foram as principais justificativas para o desenvolvimento do trabalho aqui apresentado.

5. OBJETIVOS

O objetivo geral foi subsidiar o PSC marinho em cenários com escassez de dados espacialmente explícitos sobre custos socioeconômicos. Os objetivos específicos foram: 1) revisar a literatura científica sobre custos de conservação, com foco no custo de oportunidade para o setor pesqueiro (Capítulo I); desenvolver e avaliar uma metodologia para quantificar custos de oportunidade que representem diferentes grupos de pescadores (Capítulo II); 3) realizar um exercício de zoneamento múltiplo para Abrolhos, disponibilizando um modelo para análise de permutas (*tradeoffs*) entre a conservação da biodiversidade e a exploração de recursos naturais (Capítulo III).

6. CONTRIBUIÇÕES CIENTÍFICAS

O presente trabalho apresenta uma abordagem inovadora para estimar o custo de oportunidade para pesca e minimizar a dependência de dados espaciais. A metodologia desenvolvida é baseada na distribuição dos habitats bênticos das espécies-alvo da pesca (recursos pesqueiros), combinando a disponibilidade, a importância e a acessibilidade dos mesmos. Essa nova abordagem representa uma mudança de perspectiva para estimativas de custo, que é endereçada através dos recursos, ao invés de ser baseada em retratos atuais das pescarias, inevitavelmente difíceis de alcançar. A disponibilização dos modelos gerados amplia as possibilidades de negociação com o setor pesqueiro no PSC marinho em Abrolhos, podendo contribuir para a retomada do processo de ampliação das AMPs brasileiras. O trabalho também consolida uma extensa base de dados produzida por pesquisadores que se dedicaram a expandir o conhecimento sobre o Banco dos Abrolhos nos últimos anos (www.abrolhos.org). Em especial, a publicação desse trabalho interessa aos cientistas que compartilharam dados e "insights" sobre a temática, às agências públicas e privadas que aportaram recursos financeiros para sua execução, e às comunidades locais que vêm sofrendo com a paralisia do processo de ordenamento espacial marinho da região.

7. REFERÊNCIAS

Amado-Filho, G.M., Moura, R.L., Bastos, A.C., Salgado, L.T., Sumida, P.Y., Guth, A.Z., Francini-Filho, R.B., Pereira-Filho, G.H., Abrantes, D.P., Brasileiro, P.S., Bahia, R.G., Leal, R.N., Kaufman, L., Kleypas, J.A., Farina, M., Thompson, F.L., 2012. Rhodolith beds are major CaCO3 bio-factories in the tropical South West Atlantic. PLoS One 7, e35171. doi:10.1371/journal.pone.0035171

Ball, I.R., Possingham H., 2000. Marxan (V1.8.2): marine reserve design using spatially explicit annealing, a manual. Available from www.uq.edu.au/marxan/docs/marxan manual 1 8 2.pdf.

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., Turner, R.K., 2002. Economic reasons for conserving wild nature. Science 297, 950–3. doi:10.1126/science.1073947

Ban, N.C., Klein, C.J., 2009. Spatial socioeconomic data as a cost in systematic marine conservation planning. Conserv. Lett. 2, 206–215. doi:10.1111/j.1755-263X.2009.00071.x

Boersma, P.D., Parrish, J.K., 1999. Limiting abuse: marine protected areas, a limited solution. Ecological Economics 31, 287–304. doi:10.1016/S0921-8009(99)00085-3.

CBD. 2010. Convention on biological diversity target 11, Aichi biodiversity targets. http://www.cbd.int/sp/targets/ (accessed September 2014).

Chan, K.M.A., Satterfield, T., Goldstein, J., 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecol. Econ. 74, 8–18. doi:10.1016/j.ecolecon.2011.11.011

Costa, P., Olavo, G., Martins, A., 2005. Áreas de pesca e rendimentos da frota de linheiros na região central da costa brasileira entre Salvador-BA e o Cabo de São Tomé-RJ, in: Pesca e Potenciais de Exploração de Recursos Vivos na Região Central da Zona Econômica Exclusiva Brasileira. pp. 57–70.

Dutra, G.F, Allen, G.R, Werner, T., McKenna, S.A., 2005. A rapid marine biodiversity assessment of the Abrolhos Bank, Bahia, Brazil. RAP Bulletin of biological assessment 38:155.

Dutra, L.X.C., Kikuchi, R.K.P., Leão, Z.M.A.N., 2006. Effects of sediment accumulation on reef corals from Abrolhos, Bahia, Brazil. Journal of Coastal Research (Royal Palm Beach) 39, 639–644.

Freitas, M.O., Moura, R.L, Francini-Filho, R.B., Minte-Vera, C.V., 2011. Spawning patterns of commercially important reef fish (Lutjanidae and Serranidae) in the tropical western South Atlantic. Sci. Mar. 75, 135–146. doi:10.3989/scimar.2011.75n1135

Freitas, M.O., Rocha, G.R.A., Chaves, P.D.T.D.C., Moura, R.L., 2014. Reproductive biology of the lane snapper, *Lutjanus synagris*, and recommendations for its management on the Abrolhos Shelf, Brazil. J. Mar. Biol. Assoc. United Kingdom 94, 1711–1720. doi:10.1017/S0025315414001088

Hardin, G. 1968. The Tragedy of the Commons. Science 162, 1243-1248. doi: 10.1126/science.162.3859.1243

ICMBio, 2011. Proposição de Unidades de Conservação na Região dos Abrolhos. Brasília-DF, pp. 27. Available from http://www.icmbio.gov.br/portal/images/stories/o-que-fazemos/Propostas_UCs_Banco_Abrolhos_0512_novo2.pdf (accessed February 2015).

Ives, C.D., Kendal, D., 2014. The role of social values in the management of ecological systems. J. Environ. Manage. 144, 67–72. doi:10.1016/j.jenvman.2014.05.013

Kelley, C., Garson, J., Aggarwal, A., Sarkar, S., 2002. Place prioritization for biodiversity reserve network design: a comparison of the SITES and ResNet software packages for coverage and efficiency. Divers. Distrib. 8, 297–306.

Klein, C.J., Chan, A., Kircher, L., Cundiff, A.J., Gardner, N., Hrovat, Y., Scholz, A., Kendall, B.E., Airam, S., 2008b. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. Conserv. Biol. 22, 691–700. doi:10.1111/j.1523-1739.2008.00896.x

Klein, C.J., Steinback, C., Watts, M., Scholz, A.J., Possingham, H.P., 2010. Spatial marine zoning for fisheries and conservation. Front. Ecol. Environ. 8, 349–353. doi:10.1890/090047

Lindeman, K.C., Pugliese, R., Waugh, G.T., Ault, J.S., 2000. Developmental patterns within a multispecies reef fishery: management applications for essential fish habitats and protected areas. Bulletin of Marine Science 66, 929–956.

Mace, G., Possingham, H., Leader-Williams, N., 2007. Prioritizing choices in conservation. in: MacDonald, D.W., Service, K. (Eds.), Key topics in conservation biology. Blackwell Publishing, Malden, MA, pp. 17–34.

Moilanen, A., Franco, A.M., Early, R.I., Fox, R.,Wintle, B., Thomas, C.D., 2005. Prioritizing multiple-use landscapes for conservation: methods for large multi-species planning problems. Biol. Sci. 272, 1885–1891.

Moura, R.L., Minte-Vera, C.V., Curado, I.B., Francini-Filho, R.B., Rodrigues, H.D.C.L., Dutra, G.F., Alves, D.C., Souto, F.J.B., 2009. Challenges and prospects of fisheries co-management under a marine extractive reserve framework in Northeastern Brazil. Coast. Manag. 37, 617–632. doi:10.1080/08920750903194165

Moura, R.L., Secchin, N.A., Amado-Filho, G.M., Francini-Filho, R.B., Freitas, M.O., Minte-Vera, C.V., Teixeira, J.B., Thompson, F.L., Dutra, G.F., Sumida, P.Y.G., Guth, A.Z., Lopes, R.M., Bastos, A.C., 2013. Spatial patterns of benthic megahabitats and conservation planning in the Abrolhos Bank. Cont. Shelf Res. 70, 109–117. doi:10.1016/j.csr.2013.04.036

Palumbi, S.R., 2001. The ecology of marine protected areas. In: Bertness, M., Gaines, S., Hay, M. (Eds.), Marine community ecology. Sinauer Press, Sunderland, MA, pp. 509–529.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres, F., 1998. Fishing down marine food webs. Science 279, 860–3.

Possingham, H.P., Andelman, S.J., Burgman, M.A., Medellín, R.A., Master, L.L., Keith, D.A., 2002. Limits to the use of threatened species lists. Trends in Ecology & Evolution 17, 503–507.

Pressey, R.L., Humphries, C.J., Margules, C.R., Vane-wright, R.I., Williams, P.H., 1993. Beyond opportunism: key principles for systematic reserve selection. Trends Ecol. Evol. 8, 124–128.

Pressey, R.L.,Watts, M.E., Barrett, T.W., Ridges, M.J., 2009. The C-Plan conservation planning system: origins, applications and possible futures. In: Moilanen, A., Possingham, H.P., Wilson, K.A. (Eds.), Spatial conservation prioritization, quantitative methods and computational tools. Oxford University Press, Oxford, UK, pp. 211–234.

Previero, M., Minte-Vera, C., Moura, R., 2013. Fisheries monitoring in Babel: fish ethnotaxonomy in a hotspot of common names. Neotrop. Ichthyol. 11, 467–476.

Rife, A.N., Erisman, B., Sanchez, A., Aburto-Oropeza, O., 2013. When good intentions are not enough … Insights on networks of “paper park” marine protected areas. Conserv. Lett. 6, 200–212. doi:10.1111/j.1755-263X.2012.00303.x

Sanchirico, J.N., Cochran, K.A., Emerson, P.M., 2002. Marine protected areas: economic and social implications. Resour. Futur. May 2002, 02–26.

Stewart, R.R., Noyce, T., Possingham, H.P., 2003. Opportunity cost of ad hoc marine reserve design decisions: an example from South Australia. Mar. Ecol. Prog. Ser. 253, 25–38.

Toropova, C., Meliane, I., Laffoley, D., Matthews, E., Spalding, M. (Eds.), 2010. Global ocean protection: present status and future possibilities. Agence des aires marines protegees, IUCN-WCPA, UNEP-WCMC, TNC, UNU, WCS, Brest, France; Gland, Switzerland; New York, USA; Washngton D.C.; Cambridge, U.K.; Arlington, USA.; Tokyo, Japan, pp. 96.

United Nations, 2015. World population prospects: the 2015 revision, key findings and advance tables. Department of economic and social affairs, Population division. Working Paper No. ESA/P/WP.241.

Watts, M.E., Ball, I.R., Stewart, R.S., Klein, C.J., Wilson, K., Steinback, C., Lourival, R., Kircher, L., Possingham, H.P., 2009. Environmental modelling & software Marxan with Zones: Software for optimal conservation based land- and sea-use zoning. Environ. Model. Softw. 24, 1513–1521. doi:10.1016/j.envsoft.2009.06.005

CAPÍTULO I

CUSTO DE OPORTUNIDADE PARA PESCA NA CONSERVAÇÃO MARINHA: O CASO DO BANCO DOS ABROLHOS

Resumo

A crescente pressão antrópica sobre os ambientes marinhos tem gerado uma demanda paralela de ações de planejamento, recuperação de ecossistemas e conservação da biodiversidade. No entanto, como os recursos alocados à conservação são limitados e frequentemente competem com outras demandas sociais e econômicas, a priorização das ações de conservação deve ser feita de maneira eficiente, levando-se em conta o compromisso entre ganhos biológicos e os custos de oportunidade envolvidos. O Planejamento Sistemático em Conservação (PSC) é a abordagem que traz este arcabouço para a conservação, prevendo uma priorização de ações de maneira eficiente, i.e. alocando recursos a partir de um processo transparente que objetiva maximizar benefícios e minimizar custos. A transparência no processo de planejamento, o uso de ferramentas específicas, a abrangência adequada de participação de atores e a inclusão dos custos envolvidos ajudam, portanto, a minimizar conflitos existentes entre os diferentes atores. Uma das limitações neste processo, porém, tem sido a obtenção de informações acerca dos custos associados à atividade de pesca. Pela natureza da atividade envolvida estes custos são dinâmicos e podem sofrer flutuações espaço-temporais de acordo com as condições de acessibilidade, disponibilidade e demanda de recursos. Geralmente os custos de oportunidade para o setor pesqueiro são estimados a partir de dados espacializados de captura e esforço de pesca. Entretanto, principalmente em larga escala, as limitações em abrangência e representatividade destes dados pode comprometer a qualidade das estimativas, devido ao potencial impacto em grupos que não foram considerados no processo. Este capítulo traz os principais conceitos e exemplos relacionados à consideração dos custos da conservação de ambientes marinhos, ressaltando o problema de representação dos diferentes grupos de pesca que atuam no banco dos abrolhos.

Palavras-Chave: Planejamento espacial marinho; áreas marinhas protegidas; pescadores; participação social.

1. CUSTOS DA CONSERVAÇÃO

A incorporação de considerações sociais e ecológicas no processo decisório é um critério fundamental para efetividade do Planejamento Sistemático para Conservação (PSC) (Ban et al., 2013). Com essa premissa atendida, é possível realizar um balanço efetivo entre a conservação da biodiversidade e a viabilidade prática para implementação das ações pretendidas (Klein et al., 2008a; Richardson et al., 2006; Stewart & Possingham, 2005; Sala et al., 2002). Esta análise se faz necessária uma vez que as ações de conservação competem com outros interesses legítimos da sociedade. Além disso, embora cada ação pretendida tenha benefícios associados à conservação, a implementação destas ações não ocorre de maneira gratuita. O foco exclusivo em benefícios biológicos da conservação, sem a incorporação explícita dos custos associados, leva a planejamentos com pouca viabilidade prática na sua implementação. Embora exista ainda uma tendência generalizada em atribuir maior importância ao uso de variáveis ligadas aos benefícios de conservação em si (i.e. informações acerca das espécies-alvo, hábitats ou outras métricas de biodiversidade), qualquer espaço alocado para conservação implica em uma restrição de uso, e portanto em um custo com consequências econômicas para a sociedade.

Em uma acepção geral, custos representam aquilo que é "dado, requerido ou pedido para viabilizar a obtenção de algo em particular". Especificamente em conservação existem uma série de diferentes custos envolvidos, sendo os principais definidos por Naidoo et al. (2006) como:

- Custo de aquisição – refere-se aos valores para adquirir total ou parcialmente o direito de propriedade, o que geralmente não se aplica ao ambiente marinho;
- Custo de transação – aquele relacionado aos processos de negociação, desde a procura por proprietários até a transferência dos títulos, envolvendo tempo e pessoal nos trâmites burocráticos. No ambiente marinho ocorre quando existe sistema de cotas de pesca;
- Custo de gestão – aquele associado aos gastos com infraestrutura, materiais e pessoal no estabelecimento e manutenção de áreas protegidas;
- Custo de danos – representa as perdas econômicas de atividades existentes nas vizinhanças das áreas protegidas, como o caso de animais silvestres invadirem e causarem prejuízos às propriedades privadas ou ataques diretos aos seres humanos.

- Custo de oportunidade – aquele relacionado às perdas de oportunidades econômicas em função da impossibilidade direta de exploração de recursos naturais ou aos prejuízos para atividades tradicionalmente realizadas ou pretendidas por *stakeholders*. No caso dos ambientes marinhos, está relacionado principalmente com atividades de pesca, exploração de óleo e gás, mineração, navegação e/ou infraestrutura portuária.

Em estudos focados especificamente na proposição de Áreas Marinhas Protegidas (AMPs), as ações planejadas envolvem explicitamente a imposição de limites ao acesso aos recursos pesqueiros ou ao desenvolvimento deste setor produtivo e, ainda que tal exclusão seja temporária, este custo de oportunidade se torna fundamental no planejamento (James et al., 2001). Dada a importância dos recursos pesqueiros, tanto sob o ponto de vista econômico quanto o social, os custos relacionados ao setor pesqueiro geralmente são considerados como informações mais relevantes para o delineamento eficiente de estratégias de conservação marinha (Ban & Klein, 2009).

2. CUSTO DE OPORTUNIDADE PARA PESCA

Em todo o mundo, as pessoas diretamente envolvidas no setor pesqueiro temem a criação de AMPs quando estas áreas restringem o acesso aos recursos que muitas vezes sustentam populações tradicionais. Há, portanto, um receio de que a atividade pesqueira sofra com os custos associados ao possível fechamento das áreas de pesca (Sanchirico et al., 2002). De fato, a tentativa de convencer os pescadores de que as perdas dos rendimentos de curto prazo poderão ser compensadas pela implementação das AMPs é muitas vezes dificultada pelas expectativas de ganhos imediatos e pela falta de compreensão dos mecanismos biológicos que geram esta expectativa de melhora futura.

Da maneira similar, as expectativas biológicas de aumento de biomassa de pescados pelo efeito da transferência de peixes adultos ou juvenis de dentro para fora das AMPs (efeito de "*spillover*") são limitadas espacialmente (Gell & Roberts, 2003; Francini-Filho & Moura, 2008) e em função do tempo de resposta (Bohnsack, 1998). Mesmo quando a implantação das AMPs gera possibilidades de geração alternativa de renda, como no caso do turismo, é frequente que esta mudança da base econômica tradicional seja percebida de forma negativa, representando muitas vezes a inversão de valores tradicionais da comunidade. Em contrapartida, as implicações da redução das áreas de pesca são mais perceptíveis aos pescadores. Estas perdas incluem a redução de rendimento, o adensamento do esforço de pesca nas áreas remanescentes, o aumento dos custos em combustível e equipamentos, assim como os conflitos entre diferentes tipos de pescarias (Sanchirico et al., 2002). Portanto, enquanto os defensores das AMPs procuram mostrar que elas ajudarão na sustentabilidade das capturas futuras, os pescadores argumentam o declínio perceptível dos rendimentos em curto-prazo. Tal percepção pode variar, todavia, em função das abordagens acerca dos custos de oportunidade, do estado atual dos estoques e do plano de manejo futuro (Smith et al., 2010; White et al., 2010).

No contexto das considerações socioeconômicas, é preciso incorporar dados espacialmente explícitos em escalas apropriadas nas ferramentas de suporte à decisão (Ban & Klein, 2009). Entretanto, tanto os alvos de conservação (elementos que representam a biodiversidade) quanto a distribuição dos custos geralmente não estão dispersos de maneira homogênea na região de planejamento. Tal carência de informações espacialmente explicitas, assim como discrepâncias na correlação espacial entre custos e benefícios, implica em ineficiência no planejamento para conservação (Ferraro et al. 2003; Stewart & Possingham 2005; Naidoo et al. 2006; Adams et al. 2011). Estudos mostram que planos de conservação que incorporam a variação espacial de custos podem ser até 10 vezes mais eficientes (Polasky & Solow 2001; Naidoo et al. 2006). Apesar da significativa contribuição dessas informações para maior eficiência e viabilidade de planos de conservação, ainda persiste uma grande carência de entendimento sobre a variabilidade espacial dos custos (Klein et al. 2008b; Adams et al. 2010, 2011).

Neste sentido são empregadas diferentes metodologias para estimar de maneira mais acurada os custos de oportunidade. A seguir, estão apresentadas as principais informações encontradas na literatura que sustentam os cálculos de custos de oportunidade para pesca no PSC, acompanhadas das respectivas vantagens e limitações:

Captura e esforço de pesca: dados de captura e esforço, obtidos de monitoramentos de desembarques ou registros a bordo, são as fontes mais comuns usadas em cálculos do custo de pesca. A principal vantagem desses dados é a possibilidade de representar diretamente os rendimentos financeiros das áreas de pesca combinando-os com valores monetários (Klein et al., 2010; Wood & Dragicevic, 2007). Entretanto, as raras iniciativas de monitoramentos de capturas e/ou esforço, principalmente para pesca artesanal, enfrentam problemas de padronização, espacialização e representação das diferentes pescarias. As ferramentas de suporte à decisão podem gerar resultados equivocados a partir destes dados devido às falsas áreas “não pescadas” (Stewart & Possingham, 2005; Game et al., 2008) ou à variabilidade não computada destes custos no tempo e no espaço (Manson & Die, 2001). Modelos estocásticos de rendimento bioeconômico e esforço são de particular importância para gestores por estimarem informações de longo prazo (Grafton et al., 2004). Em contrapartida, demandam dados históricos de qualidade, além de apresentarem complexidade de obtenção e representação de pescarias proporcionais a escala do planejamento.

Número de pescadores ou de barcos: são bastante utilizados em função da falta de dados de captura e esforço (e.g. Green et al., 2004). Em outros dois estudos, realizados por Sala et al. (2002) e Weeks et al. (2010), a densidade de barcos por unidade de área foi relevante para a parametrização de modelos de priorização em escala regional. Os estudos ressaltam que a redistribuição das frotas após a criação das AMPs e a complexidade em se representar espacialmente o número de pescadores podem comprometer a qualidade dessas informações.

Conhecimento tradicional local: os custos socioeconômicos também podem ser representados utilizando abordagens empíricas (Ban & Klein, 2009). Caso haja um consenso entre os atores sobre áreas a serem incluídas ou excluídas em sistemas de AMPs, estas preferências podem ser usadas diretamente nas ferramentas de suporte à decisão (Klein et al., 2008b). Estes tipos de modelos empíricos podem tanto representar os custos de pesca, em curto prazo, quanto projetá-los em longo prazo, mas o consenso deve respeitar a heterogeneidade dos atores, já que quem tem mais a perder ou a ganhar tende a dominar os resultados (Smith et al., 2010). A possibilidade de solucionar conflitos durante a fase de planejamento, devido ao conhecimento dos valores relevantes para os atores, é a principal vantagem dessa abordagem (Ives & Kendal, 2014).

Distância da costa ou de portos: a acessibilidade para as áreas de planejamento pode refletir bem os custos para os pescadores, afinal, quanto mais longa for a jornada em busca dos recursos, mais insumos e combustível serão gastos. Contudo, é possível que uma área mais distante seja mais importante no que se refere a extração do recurso pesqueiro e represente maior custo de conservação, tendo em vista sua produtividade. Dessa forma, essas distâncias só se tornam úteis quando combinadas com outra informação que represente a importância relativa das áreas, como os dados de captura, esforço ou habitats dos recursos.

Diante do exposto, fica claro que as estimativas dos impactos de AMPs para pescadores são extremamente dependentes da avaliação do tipo, da qualidade e do método de coleta dos dados. Uma estimativa mais acurada pode aumentar a palatabilidade dos planos de conservação e, portanto, seu sucesso de implementação no mundo real (Klein et al., 2008b; Stelzenmüller et al., 2013). A abrangência espacial dos dados que gerarão os custos da atividade de pesca deve ser compatível com a região de planejamento. Modelos multivariados podem predizer capturas em áreas com dados indisponíveis (Ban et al., 2009), entretanto, a representatividade dos diferentes sistemas de pesca ainda será fundamental para efetividade das negociações no processo de planejamento. É preciso, portanto, desenvolver estimativas de custos que compatibilizem tanto a variabilidade espacial do tipo de recurso capturado e as diferentes técnicas de pesca.

3. O CASO DO BANCO DOS ABROLHOS

O Banco dos Abrolhos é um alargamento da plataforma continental de aproximadamente 200 km, entre os Estados da Bahia e do Espírito Santo, que abriga os maiores e mais ricos recifes coralíneos do Atlântico Sul. Até o momento menos de 1% de sua área está protegida integralmente (IUCN I e II) e cerca de 10% em reservas de uso múltiplo (IUCN III e IV). Os riscos e pressões impostos aos recifes nessa região tanto pela pressão de pesca quanto pela atividade de exploração de petróleo são sérios o suficiente para justificar a ampliação dos esforços de conservação (Leão & Kikuchi, 2005).

A ação de Organizações Não Governamentais e da Academia tem provocado o governo a tomar medidas de conservação adequadas à importância de Abrolhos. Assim, um processo de PSC foi conduzido pelo órgão governamental responsável pela criação e gestão de áreas protegidas (ICMBio – Instituto Chico Mendes de Biodiversidade) e interrompido por setores que utilizam a região de forma pouco planejada para exploração de recursos naturais. Neste processo, produziu-se um relatório contendo as áreas de elevada insubstituibilidade e importantes sugestões para os próximos passos antes das audiências públicas para criação oficial de novas AMPs no Banco dos Abrolhos. Um olhar crítico a este relatório aponta como fragilidade a necessidade de uma avaliação da influência do fechamento das áreas tradicionais de pesca para as frotas atuantes na região, principalmente aquelas provenientes do Estado do Espírito Santo, que não foram consideradas nas análises (ICMBio, 2011). Destaca-se que o Banco dos Abrolhos possui cerca de 20.000 profissionais da pesca, que juntos representam cerca de 10% do valor gerado pela pesca marinha do Brasil (ICMBio, 2011). Trata-se da região pesqueira mais produtiva do nordeste brasileiro (Costa et al., 2005) que vem sustentando diversas pescarias de média escala, inclusive de frotas sediadas em estados vizinhos (Isaac et al., 2006).

Além dos vieses relacionados à consideração de custos pouco abrangentes e a limitada representação dos grupos de pescadores, a baixa participação do setor acadêmico no final do processo enfraqueceu o respaldo técnico das propostas. Mesmo assim, o governo brasileiro decidiu prosseguir com a decretação de novas unidades de conservação no Banco dos Abrolhos. O setor pesqueiro, liderado por representantes do Estado do Espírito Santo, declarou desconhecer previamente as propostas do ICMBio e, usando este argumento, conseguiu impedir a continuação das audiências públicas e interromper todo processo.

4. DESAFIOS CORRENTES

Embora o efeito desse fracasso tenha aumentado a dificuldade de ações conservacionistas na região, a demanda de proteção da biodiversidade devido às crescentes ameaças ao Banco dos Abrolhos persiste. Segundo (Grantham et al., 2010), o planejamento para conservação precisa ser adaptativo e considerar, além dos resultados obtidos, o aprendizado adquirido ao longo do processo a fim de tornar tais iniciativas cada vez mais eficazes. As novas propostas de priorização deverão considerar ainda mais cuidadosamente os custos da pesca de forma abrangente e representativa. As instituições pesqueiras deverão ser envolvidas em todos os estágios do desenvolvimento das novas AMPs (Manson & Die, 2001). Além disso, os novos planos devem considerar o problema do uso múltiplo desde o princípio e utilizar a ferramenta mais apropriada para dar suporte ao processo de decisão.

Neste contexto, ainda é preciso considerar que o Brasil, apesar da sua grande área costeira, tem um histórico muito pobre na gestão de pescarias (Moura et al., 2009). O déficit de recursos humanos e materiais, a descontinuidade dos programas de pesquisa e a frágil estatística pesqueira restringem o avanço do conhecimento sobre a realidade da pesca brasileira (Isaac et al., 2006). Caso as perdas econômicas de grupos ou setores da sociedade sejam consideradas injustas nas propostas de AMPs, o processo pode se estender demasiadamente em discussões desprovidas de dados. Quando múltiplos custos são importantes para a tomada de decisão, a combinação de diversos dados socioeconômicos em uma só camada de custos corretamente especializados representa um desafio para a eficiência do plano de conservação, sendo que análises individualizadas de cada uma das camadas de custo tornam-se mais adequadas (Possingham et al., 2002; Ban & Klein, 2009; Klein et al., 2008b; Mace et al., 2007). Desta forma, a deficiência de dados de pesca, disponíveis de forma espacializada e representativa para os diferentes grupos de pescadores, é um dos principais riscos para o PSC de Abrolhos em particular, e para a conservação marinha e geral.

5. REFERÊNCIAS

Adams, V.M., Mills, M., Jupiter, S.D., Pressey, R.L., 2011. Improving social acceptability of marine protected area networks: A method for estimating opportunity costs to multiple gear types in both fished and currently unfished areas. Biological Conservation 144:350–361.

Adams, V.M., Pressey, R.L,, Naidoo. R., 2010. Opportunity costs: who really pays for conservation? Biological Conservation 143:439–448.

Ban, N.C., Hansen, G.J.A., Jones, M., Vincent, A.C.J., 2009. Systematic marine conservation planning in data-poor regions: socioeconomic data is essential. Mar. Policy 33, 794–800. doi:10.1016/j.marpol.2009.02.011

Ban, N.C., Klein, C.J., 2009. Spatial socioeconomic data as a cost in systematic marine conservation planning. Conserv. Lett. 2, 206–215. doi:10.1111/j.1755-263X.2009.00071.x

Ban, N.C., Mills, M., Tam, J., Hicks, C.C., Klain, S., Stoeckl, N., Bottrill, M.C., Levine, J., Pressey, R.L., Satterfield, T., Chan, K.M., 2013. A social–ecological approach to conservation planning: embedding social considerations. Front. Ecol. Environ. 11, 194–202. doi:10.1890/110205

Bohnsack, J., 1998. Application of marine reserves to reef fisheries management. Aust. J. Ecol. 23, 298–304.

Costa, P., Olavo, G., Martins, A., 2005. Áreas de pesca e rendimentos da frota de linheiros na região central da costa brasileira entre Salvador-BA e o Cabo de São Tomé-RJ, in: Pesca e Potenciais de Exploração de Recursos Vivos na Região Central da Zona Econômica Exclusiva Brasileira. pp. 57–70.

Ferraro, P.J., 2003. Assigning priority to environmental policy interventions in a heterogeneous world. J. Policy Anal. Manag. 22, 27–43. doi:10.1002/pam.10094

Francini-Filho, R.B., Moura, R.L., 2008. Evidence for spillover of reef fishes from a no-take marine reserve: an evaluation using the before-after control-impact (BACI) approach. Fish. Res. 93, 346–356. doi:10.1016/j.fishres.2008.06.011

Game, E.T., Watts, M.E., Wooldridge, S., Possingham, H.P., 2008. Planning for persistence in marine reserves: a question of catastrophic importance. Ecol. Appl. 18, 670–680.

Grafton, R., Kompas, T., Schneider, V., 2004. The bioeconomics of marine reserves: a selected review with policy implications. Univ. Otago Econ. Discussion Paper, 1–30.

Grantham, H.S., Bode, M., McDonald-Madden, E., Game, E.T., Knight, A.T., Possingham, H.P., 2010. Effective conservation planning requires learning and adaptation. Front. Ecol. Environ. 8, 431–437. doi:10.1890/080151

Gell, F.R., Roberts, C.M., 2003. Benefits beyond boundaries: the fishery effects of marine reserves. Trends Ecol. Evol. 18, 448–455.

Green, S.J., Flores, J.O., Dizon-Corrales, J.Q., Martinez, R.T., Nuñal, D.R.M., Armada, N.B., White, A.T., 2004. The fisheries of Central Visayas, Philippines: status and trends. Coastal resource management project of the department of environment and natural resources and the bureau of fisheries and aquatic resources of the Department of Agriculture, Cebu City, Philippines, pp. 159.

ICMBio, 2011. Proposição de Unidades de Conservação na Região dos Abrolhos. Brasília-DF, pp. 27. Available from http://www.icmbio.gov.br/portal/images/stories/o-que-fazemos/Propostas_UCs_Banco_Abrolhos_0512_novo2.pdf (accessed February 2015).

Isaac, V.J., Martins, A.S., Haimovici, M., Castello, J.P., Andriguetto, J.M., 2006. Síntese do estado de conhecimento sobre a pesca marinha e estuarina do Brasil, in: Isaac, V.J. A pesca marinha e estuarina do Brasil no início do século xxi: recursos, tecnologias, aspectos socioeconômicos e institucionais. pp. 181–186.

Ives, C.D., Kendal, D., 2014. The role of social values in the management of ecological systems. J. Environ. Manage. 144, 67–72. doi:10.1016/j.jenvman.2014.05.013

James, A., Gaston, K.J., Balmford, A., 2001. Can we afford to conserve biodiversity? Bioscience 51, 43. doi:10.1641/0006-3568(2001)051[0043:CWATCB]2.0.CO;2

Klein, C., Steinback, C., Scholz, A.J., Possingham, H.P., 2008a. Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in

California. Conserv. Lett. 1, 44–51. doi:10.1111/j.1755.263X.2008.00005.x

Klein, C.J., Chan, A., Kircher, L., Cundiff, A.J., Gardner, N., Hrovat, Y., Scholz, A., Kendall, B.E., Airam, S., 2008b. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. Conserv. Biol. 22, 691–700. doi:10.1111/j.1523-1739.2008.00896.x

Klein, C.J., Steinback, C., Watts, M., Scholz, A.J., Possingham, H.P., 2010. Spatial marine zoning for fisheries and conservation. Front. Ecol. Environ. 8, 349–353. doi:10.1890/090047

Leão, Z.M.A.N., Kikuchi, R.K.P., 2005. A relic coral fauna threatened by global changes and human activities, Eastern Brazil. Mar. Pollut. Bull. 51, 599–611. doi:10.1016/j.marpolbul.2005.04.024

Mace, G., Possingham, H., Leader-Williams, N., 2007. Prioritizing choices in conservation. in: MacDonald, D.W., Service, K. (Eds.), Key topics in conservation biology. Blackwell Publishing, Malden, MA, pp. 17–34.

Manson, F.J., Die, D.J., 2001. Incorporating commercial fishery information into the design of marine protected areas. Ocean Coast. Manag. 44, 517–530. doi:10.1016/S0964-5691(01)00063-1

Moura, R.L., Minte-Vera, C.V., Curado, I.B., Francini-Filho, R.B., Rodrigues, H.D.C.L., Dutra, G.F., Alves, D.C., Souto, F.J.B., 2009. Challenges and prospects of fisheries co-management under a marine extractive reserve framework in Northeastern Brazil. Coast. Manag. 37, 617–632. doi:10.1080/08920750903194165

Naidoo, R., Balmford, A., Ferraro, P.J., Polasky, S., Ricketts, T.H., Rouget, M., 2006. Integrating economic costs into conservation planning. Trends Ecol. Evol. 21, 681–7.

Polasky, S., Solow, A.R., 2001. The value of information in reserve site selection. Nature 1051–1058.

Possingham, H.P., Andelman, S.J., Burgman, M.A., Medellín, R.A., Master, L.L., Keith, D.A., 2002. Limits to the use of threatened species lists. Trends in Ecology & Evolution 17, 503–507.

Richardson, E.A., Kaiser, M.J., Edwards-Jones, G., Possingham, H.P., 2006. Sensitivity of marine-reserve design to the spatial resolution of socioeconomic data. Conserv. Biol. 20, 1191–1202. doi:10.1111/j.1523-1739.2006.00426.x

Sala, E., Aburto-Oropeza, O., Paredes, G., Parra, I., Barrera, J.C., Dayton, P.K., 2002. A general model for designing networks of marine reserves. Science 298, 1991–3. doi:10.1126/science.1075284

Sanchirico, J.N., Cochran, K.A., Emerson, P.M., 2002. Marine protected areas: economic and social implications. Resour. Futur. May 2002, 02–26.

Smith, M.D., Lynham, J., Sanchirico, J.N., Wilson, J.A. 2010. Political economy of marine reserves: understanding the role of opportunity costs. Proc. Natl. Acad. Sci. U. S. A. 107, 18300–5. doi:10.1073/pnas.0907365107

Stelzenmüller, V., Lee, J., South, A., Foden, J., Rogers, S.I., 2013. Practical tools to support marine spatial planning: A review and some prototype tools. Mar. Policy 38, 214–227. doi:10.1016/j.marpol.2012.05.038

Stewart, R.R., Possingham, H.P., 2005. Efficiency, costs and trade-offs in marine reserve system design. Environmental Modeling & Assessment 10, 203–213.

Weeks, R., Russ, G.R., Bucol, A.A., Alcala, A.C., 2010. Shortcuts for marine conservation planning: The effectiveness of socioeconomic data surrogates. Biol. Conserv. 143, 1236–1244. doi:10.1016/j.biocon.2010.02.031

White, J.W., Botsford, L.W., Moffitt, E. a, Fischer, D.T., 2010. Decision analysis for designing marine protected areas for multiple species with uncertain fishery status. Ecol. Appl. 20, 1523–41.

Wood, L.J., Dragicevic, S., 2007. GIS-based multicriteria evaluation and fuzzy sets to identify priority sites for marine protection. Biodivers. Conserv. 16, 2539–2558. doi:10.1007/s10531-006-9035-8

CAPÍTULO II

A NOVEL HABITAT-BASED APPROACH TO PREDICT IMPACTS OF MARINE PROTECTED AREAS ON FISHERS

João B. Teixeira[1,2], Rodrigo L. Moura[1,2,*], Morena Mills[3], Carissa Klein[4], Christopher J. Brown[5], Vanessa M. Adams[3], Hedley Grantham[6,3], Matthew Watts[3], Gilberto M. Amado-Filho[7], Alex C. Bastos[8], Deborah M. Faria[2], Reinaldo Lourival[3,9], Hugh P. Possingham[3].

1- Instituto de Biologia and SAGE/COPPE, Universidade Federal do Rio de Janeiro. Rio de Janeiro RJ 21941-599 Brazil. Corresponding author: moura.uesc@gmail.com

2- Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade, Universidade Estadual de Santa Cruz. Ilhéus BA 45650-000 Brazil.

3- The School of Biological Sciences, The University of Queensland, St. Lucia, Qld 4072, Australia

4- The School of Geography, Planning, and Environmental Management, The University of Queensland, St. Lucia, Qld 4072, Australia

5- Australian Rivers Institute, Griffith University, Nathan, QLD 4111, Australia

6- Conservation Science and Solutions, Wildlife Conservation Society, 750 9th St., NW, Suite 525, Washington, DC 20001, USA

7- Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. Rio de Janeiro RJ 22460-030 Brazil

8- Departamento de Oceanografia, Universidade Federal do Espírito Santo. Vitória 29090-600 ES Brazil.

9- Universidade Federal de Mato Grosso do Sul/UFMS-FUNDECT. Campo Grande, 79070-900 MS Brazil.

Acknowledgements

We thank the fisherfolks from the Extractive Reserves of Corumbau and Cassurubá for the continued support to our fieldwork, and the Colônias dos Pescadores (Fishing Guilds) from the municipalities of Porto Seguro, Prado, Alcobaça, Caravelas, Nova Viçosa, Conceição da Barra, Linhares e Aracruz. Logistical and financial support was provided by the ICMBio, Conservation International, A Voz da Natureza, CNPq, FAPES, FAPERJ, CAPES, PELD-Abrolhos (www.abrolhos.org) and ANP/Brasoil.

A NOVEL HABITAT-BASED APPROACH TO PREDICT IMPACTS OF MARINE PROTECTED AREAS ON FISHERS

Abstract

A growing human population and expanding coastal development is resulting in dramatic worldwide increase for marine resources and ocean degradation. The rate at which marine protected areas (MPAs) are being declared is steadily increasing with a global commitment to protect 10% of the world's ocean by 2020. While MPAs can simultaneously contribute to biodiversity conservation and fisheries management, the global network is heavily biased towards particular ecosystem types and is often poorly managed. These two problems are a consequence of MPAs being established in an ad hoc fashion, often with low public participation and support. Therefore, MPAs are failing to deliver their expected biological and socioeconomic benefits. One essential component for efficient MPA design lies in the integration of socioeconomic and ecological factors, including the optimization of trade-offs between biodiversity benefits and socio-economic values. In this regard, it is critical to account for lost opportunities by people whose activities will be shifted or restricted by MPAs. One reason this is often neglected is the lack of spatial socioeconomic data for entire planning regions. Existing approaches for collecting such data are costly as they are based on socioeconomic surveys, and thus prohibitive for many planning processes. Here we present a novel habitat-based approach to estimate the opportunity cost to fishers in data poor regions, assuming that the most accessible areas have higher values to fishers, and their designation as MPAs represents increased loss of fishing opportunities. We apply our approach to the Abrolhos Bank, Brazil, which is recognized by the global Convention on Biological Diversity (CDB) as an "Ecologically or Biologically Significant Area". The resulting opportunity cost approach improve our understanding of the tradeoffs among different stakeholder groups and can be directly used to support conservation planning, or as a standalone tool, to facilitate community consultation.

Keywords: Opportunity cost; Abrolhos Bank; Small-scale fisheries, Conservation planning

INTRODUCTION

Given the overall degraded state of marine biodiversity and associated fisheries (Pauly & Zeller, 2016), marine spatial planning (MSP) is an important tool for marine conservation and management (Sala et al. 2002; Wood et al. 2008). MSP consists of a public process of analyzing and allocating human activities, including marine protected areas (MPAs), in order to achieve ecological, economic and social objectives specified through a social and political process (Douvere, 2008; Douvere et al. 2007; Stelzenmüller et al. 2013).

The global targets from the Convention of Biological Diversity (CBD) known as the Aichi targets are fuelling declarations of new MPAs globally (Toropova et al. 2010). By 2020, CBD signatories aim to increase MPA coverage from the current ~2% up to 10% of the ocean (Aichi Biodiversity Targets, CBD 2010). While MPAs can contribute simultaneously to biodiversity conservation and fisheries management (Alcala & Russ 2006; Fox et al. 2012), the existing global MPA network is biased towards particular geographies and ecosystems (Klein et al. 2015) and was established with low stakeholder participation (Devillers et al. 2014; Mills et al. 2015). As a result, MPAs often fail to deliver on their biological and socioeconomic objectives (Edgar et al. 2014).

The process of locating and configuring MPA networks is increasingly being supported by decision support software designed to identify priority areas for different types of management (Watts et al. 2009). This systematic approach for designing MPAs uses data representing both the features of interest and the opportunities and limitations for implementation (Teh et al. 2012). A key component of spatial prioritization is minimizing economic impacts to stakeholders. Therefore, assessing spatial variation in the relative cost of management is a critical component of MSP, not only for optimizing always scarce conservation funds, but also because it reduces social conflict by minimizing overlaps between competing activities (Ban & Klein 2009; Deas et al. 2014; Weeks et al. 2010b). Socioeconomic costs typically included in MSP are management (e.g. implementation, ongoing enforcement costs) and opportunity (forgone economic opportunities) costs (Ban & Klein 2009). Although long-term non-extractive values may exceed lost opportunities of extractive uses (Sanchirico et al. 2002), loss of fishing grounds is an important opportunity cost to be considered when planning for MPAs (Ban & Klein 2009). The inclusion of data obtained from stakeholders is particularly important in the context of developing countries, where data are limited and social acceptance critical (Adams et al. 2010; Ban et al. 2009; Johannes 1998). The balance between minimizing opportunity costs to fishers while creating no-take and other restrictive zoning types can increase their support and compliance (Weeks et al. 2010b).

Estimates of opportunity costs to fishermen can be derived from different data types and sources. Catch-and-effort data can represent fisheries revenues (Klein et al. 2010; Wood & Dragicevic 2007), but spatial gaps in such data are frequent and can result in unexploited areas being wrongly mapped as fished and vice-versa (Adams et al. 2011; Stewart & Possingham 2005). Multivariate stochastic bioeconomic models may overcome such gaps (Ban et al. 2009; Grafton et al. 2004), but demand high-resolution catch-and-effort historical data that are rarely available, especially for small-scale fisheries (Richardson et al. 2006). Density of boats or fishers' numbers can be used as regional surrogates (Ban et al. 2009; Green et al. 2009; Sala et al. 2002), but distribution of fleet data within fishing grounds is elusive. In addition, fleet mobility beyond seasonal and diel patterns may severely constrain its accuracy (Sala et al. 2002; Weeks et al. 2010b). Finally, fishers may directly provide relevant cost information (Scholz et al. 2004; Ban & Klein 2009; Teixeira et al. 2013; Yates et al. 2013), but consultation processes often fail to represent the heterogeneous social landscape. Biases are stronger when fishing activity is gender and age structured, or when small-scale fisheries coexist with recreational and industrial fisheries, escalating urbanization, and industrial activities. In such situations, outspoken groups with the largest rewards or losses tend to be disproportionally influential (Smith et al. 2010).

While methods to estimate opportunity costs in terrestrial environments are well developed (e.g. probability of land conversion and agricultural rents) (Naidoo & Adamowicz 2006; Naidoo & Iwamura 2007), similar methods for the marine environment are limited (but see Adams et al. 2011). Here, we present an easily reproducible approach developed in order to estimate the opportunity cost to fishers. Our method for calculating opportunity costs is based on simple catch data, which is often available, and is developed as an R software script. We demonstrate its application in a data-poor region under a MSP initiative (Abrolhos Bank, Brazil), where data is limited to a coarse-scale benthic habitat map (Moura et al. 2013) and a snapshot of fishery landings (1 year).

METHODS

Study area and datasets

The Abrolhos Bank is a 200 km wide portion of the tropical Brazilian continental shelf, with about 50,000 km^2, located between the States of Bahia and Espírito Santo. It represents the most biodiverse marine area in the South Atlantic (Dutra et al. 2005; Moura et al. 2013) and is recognized as a global "Ecologically or Biologically Significant Area" (https://www.cbd.int/ebsa/). Nearly 300 species of fish and 20 species of reef-building corals are recorded in its benthic mosaic of rhodolith beds, reefs, soft bottom, mangroves and vegetated sandbanks (Amado-Filho et al. 2012; Moura et al. 2013). Despite limited spatial coverage, MPAs are the main fisheries management tool in this region: 1.7% of the shelf is covered by one no-take MPA (Abrolhos National Park, 880 km2) and 3.7% are covered by two MPAs that allow extractive uses (Corumbau Extractive Reserve, 895 km2 and Cassurubá Extractive Reserve, 1,000 km^2). A largest (3,400 km2) multiple-use MPA under Bahia State jurisdiction has had no enforcement or management since its declaration in 1993 (Fig. 1a-d). For the analyses presented herein, the entire planning region was divided into a 1 km^2 grid, from the estuaries to the shelf edge (200 m isobath), resulting in 50,762 *Planning Units* (*PUs*).

Abrolhos' small-scale fisheries account for more than half of Northeastern Brazil's landings (Freitas et al. 2011). We obtained catch (total landings: kg$*$year^{-1}) and first commercialization price (in Brazilian Reais - R$) from three projects funded by the Ministério da Pesca e Aquicultura in 2011 (since then fisheries monitoring were halted countrywide; see Pinheiro et al. 2015). The first dataset (ES) was obtained by the Universidade Federal do Espírito Santo and covers the main ports in Espírito Santo State (Silva & Soares 2013). The second dataset (BA) was obtained by the Non-Governmental Organization (NGO) *ECOMAR* and covers the ports of Prado, Alcobaça, Caravelas, Nova Viçosa and Mucuri, in the southern coast of Bahia State (unpublished). The third dataset (ER) was obtained by NGO Conservation International and covers the ports within the Extractive Reserves of Corumbau and Cassurubá, also in Southern Bahia State (unpublished). The three datasets were treated as different Groups of Ports, in which different *Vessel Types* operate (gear/target species and boat size obtained from <http://sinpesq.mpa.gov.br/rgp>).

Opportunity costs

In order to estimate opportunity costs of fishers' displacement by no-take reserves we introduce a simple approach, the "FishCake" model (Fig. 2), herein provided as an R 3.1.0 script (R Core Team 2014) (Supporting Information). The model is based on fishers' accessibility (distance between Ports and planning units, see below) and the relative importance of each Area (resource's fishing ground) to each Group of Ports and their respective Vessel Types (estimated from habitat and/or catch data). This approach is based on three main assumptions. First, Areas with greater co-occurrences of Resources (target species our species' groups) have higher opportunity costs, as fishers can target multiple species (e.g. Aswani 1998). Second, we assume that the habitat of the most important Resources (i.e. those with higher yields or price) are associated with higher opportunity costs. Finally, Areas nearer to ports are cheaper to fish and therefore have higher opportunity costs (e.g. Adams et al. 2011). The core components used in FishCake (habitat maps, resources' importance, accessibility) are detailed below.

The three datasets included 142 fish taxa (Supporting Information), four species of lobsters (Panulirus argus, P. echinatus, P. laevicauda and Scyllarides brasiliensis), two octopus genera (Octopus and Eledone), two species and one genus of crabs (Goniopsis cruentata, Ucides cordatus and Callinectes spp.), and five species of shrimps (Litopenaeus schimitti, Farfantepenaeus brasiliensis, F. paulensis, F. subtilis, Xiphopenaeus kroyeri). Some taxa were lumped as resources, according to the records in the database (e.g. parrotfishes – 6 spp., groupers – 4 spp., shrimps – 5 spp.). Resources' distributions were mapped based on habitat- and depth-associations (estuary, unconsolidated bottom, reefs, and rhodolith beds) obtained from field guides (e.g. Lessa & Nóbrega 2000) and Fishbase (Froese & Pauly 2013).

Catch data ($kg*year^{-1}$) and first commercialization prices were used to inform the importance of each *Resource* among the three *Groups of Ports* (BA, ES and ER). Total catch was divided by the catch of each resource and multiplied by its price, in order to estimate an individual importance factor (*Imp)*. In the few absences of catch and/or price data, *Imp* was obtained through stakeholder consultation, through a ranking process.

Opportunity costs in fishing grounds nearer to ports are higher, and the size and shape of the planning region also implies a nonlinear cost decrease as distance from ports increases. Therefore, we calculated an Accessibility Factor based on a function that uses two parameters: the rate of cost decline (α) and a minimum cost multiplier (β). The Accessibility Factor, $Af(d)$, is given by the function:

$$Af(d) = \left(e^{(d \times \alpha)} + \beta\right) - \left(e^{(d \times \alpha)}\ \beta\right) \qquad \text{eq. (1)}$$

Where d is the distance from a port to the PU; α is the rate of cost decline with distance; β is the minimum cost multiplier. $Af(d)$ takes values in $\{\beta\text{-}1\}$. The purpose of is β to ensure that all areas, even those far from ports are accounted some importance to fishers.

The opportunity cost for fisheries in planning unit i, C_i, is given by:

$$C_i = \left(\sum_j^n \frac{a_{i,j}}{A_j}\ Imp_j\right) Af(d)_i \qquad \text{eq. (2)}$$

Where: $a_{i,j}$ is the area of resource j in planning unit $i;A_j$ is the total area (habitat) of the resource j and Imp_j is the Importance Factor for resource j.

We made separate calculations of opportunity costs for each Group of Ports (ES, BA and ER), conservatively setting α at - 0.000009 and β at 0.1. Vessel type (shrimp trawling and vessels using passive gears) was used to further refine opportunity cost layers. Colinearity among cost layers was assessed using a pairs plot, with relationships illustrated as LOESS smoothers and corresponding Pearson's correlation coefficients. For each Group of Ports we evaluated the correlation of cost layers with: catch (kg); catch∗distance function (kg∗f(d)); catch∗price (kg∗$); and catch∗price∗distance function (kg∗$∗f(d)). Highly uncorrelated costs (<90%) were grouped, resulting in a general '*Full Cost*' layer. Conversely, cost layers for ER∗trawling and BA∗trawling were identical, resulting in a total of six cost layers retained for the development of conservation scenarios.

Conservation scenarios

We used Marxan (Ball et al. 2009) to explore tradeoffs in six conservation scenarios based on the different cost layers. Each scenario targeted full protection against fisheries in 30% of each benthic habitat (estuary, unconsolidated bottom, shallow reefs, mesophotic reefs, rhodolith beds, and continental slope) (Fig. 1b). We set Marxan to find 100 good solutions for each scenario. The *Boundary Length Modifier* (*BLM*), a parameter that controls fragmentation of selected areas, was set to 0 in order to isolate the effect of costs on solutions to the problem. The *Species Penalty Factor* (*SPF*) was calibrated for each scenario following Ardron et al. (2010), in order to keep shortfalls consistent and to make results comparable.

Relationships among Marxan solutions were evaluated with hierarchical clusters and nMDS biplots based on a Jaccard resemblance matrix, following Harris et al. (2014). Analyses were performed with R (R Development Core Team 2014) using the *hclust*, *metaMDS* and *vegdist* functions of the Vegan package (Oksanen et al. 2013). In addition, an *envfit* analysis was performed to determine which explanatory variables are best correlated across the nMDS ordinations. Explanatory variables included the following parameters (continuous vectors) of each Marxan solution: number of selected *PUs*; score; cost; minimum proportion of target met (MPM); penalty; and missing value. Significantly correlated variables (a= 0.05) were plotted as axes on the main bidimensional nMDS diagram. We also evaluated how much each *Best Solution* (smallest objective function score over 100 runs) costs for each scenario, in total and for each group of stakeholders (Adams et al. 2011). Databases, shapefiles and R codes are available from https://www.dropbox.com/s/0yktpajy7znu2bo/FishCake_Cost_Estimator.zip?dl=0 (Supporting Information).

RESULTS

The FishCake model revealed a heterogeneous mosaic of opportunity costs within the planning region, as the opportunity costs of fishers' displacement by reserves differ among *Groups of Ports* (ES, BA, ER). The three Groups of Ports encompass distinct vessel sizes and gears (Fig. 3a, b), target distinct resources, and present highly different catches (ES ~6,590 ton, BA ~850 ton and ER ~120 ton) (Fig. 3c).

The registered regional fishing fleet by port includes; 961 gillnet vessels (55% ES, 21% BA, 24% ER), 884 trawling vessels (37% ES, 46% BA, 18% ER), 739 longline vessels (80% ES, 10% BA, 10% ER), 675 line vessels (27% ES, 35% BA, 38% ER), and 146 diving vessels (27% ES, 48% BA, 25% ER). Despite such complexity, scenarios using all vessel types and resources result in high correlation between ES and ER opportunity cost layers (ES *vs* ER=

0.76; BA *vs* ER= 0.68; $p<0.0001$). The cost correlation between ES and BA ports was also significant but weaker (ES *vs* BA= 0.37; $p<0.0001$), regardless of the variables used to calculate the resources importance factor and distance function [$kg*\$*f(d)$].

Our habitat-based approach also highlights the effects of each opportunity cost for different types of fisheries on Marxan solutions, when used to find areas of high conservation priority (Fig. 4). Despite the overall high correlation between cost layers (Fig. 5a), the multivariate analysis of Marxan outputs showed significant differences among conservation solutions for the six scenarios (Fig 5b, c). Shrimp is the main *Resource* from ES and ER groups. Due to regional bias towards shrimp trawling, we contrasted conservation scenarios with and without shrimp yields, producing the biggest differences between solutions. The BA and ER Trawling scenarios were identical due to shared fishing grounds, and therefore S5 represents both groups. Scenarios considering coastal trawling vessel types tended to select offshore PUs for conservation. For instance, the S5 solution (BA/ER Trawling) had a higher concentration of selected *PUs* in the south of the planning region, contrasting with other solutions (e.g. S4 using ES Trawling cost). The Full Cost scenario (S6) reflects a selection pattern primarily driven by higher value fisheries (e.g. shrimp trawling) and resulted in the smallest global opportunity costs (S6) (Fig. 5d).

DISCUSSION

The diversity of stakeholders that use coastal and marine ecosystems should all have a say in MSP, in order to improve the robustness and resilience of conservation decisions and deliver reasonably equitable outcomes (Klein et al. 2008). Fishers, due to their wide presence, dependency and role in contemporary marine ecosystems (Jackson et al. 2001), represent a crucial stakeholder group to be considered in MSP. This is particularly true in the coastal zones of developing countries where alternative livelihoods are not an option in the foreseeable future. Opportunity cost models, using catch and effort data, provide accurate estimates of potential fishing losses from no-take zoning of MPAs (Adams et al. 2011), but they depend on high resolution data, that is often unavailable (Deas et al. 2014; Richardson et al. 2006). Here, we present an alternative habitat-based approach to predict impacts to different groups of fishers under the data-limited contexts typical of developing countries.

Data on catch distribution of small-scale fisheries is generally scarce and its collection can be costly and time-consuming (Adams et al. 2011; Deas et al. 2014; Leopold et al. 2014; Weeks et al. 2010b). Under such circumstances, socio-economic data may represent alternative surrogates to represent opportunity costs (Ban & Klein 2009; Deas et al. 2014; Weeks et al. 2010b). However, crude generalizations based on surrogates that are arbitrarily exchanged among sites may lead to inefficient solutions, and the improvement of surrogates is a major need of MSP (Christensen et al. 2009; Deas et al. 2014). When substituting coarse-resolution data (e.g. population census, number of fishers or boats) to fine resolution and empirical fishing effort distribution, the variation in spatial precision is reduced (Adams et al. 2011; Deas et al. 2014; Richardson et al. 2006; Weeks et al. 2010b). However, the use of this kind of data is still associated to spatial-temporal biases and high costs associated to data collection. Our approach offers an alternative and more precise method for data poor regions. Habitat maps may be costly and time-consuming to produce, however can be readily and accurately acquired from local knowledge, as demonstrated (Teixeira et al. 2013). The FishCake algorithm is an R script to assist MSP within data poor contexts, and is easily adaptable during consultation processes, allowing for fine-tuning the importance of species for different stakeholder groups as additional information is gradually updated. The maps produced can also be validated by local stakeholders when opportunities arise during planning.

Thus, rather than focusing on assessing the current extractive effort, the FishCake algorithm considers the variation in the spatial distribution of important resources, similar to Adams et al. (2011), relying only on habitat maps and landing data to distinguish the relative importance of *PUs* for different stakeholder groups. The resulting opportunity cost layers thus do not necessarily identify the most fished areas, but provide a useful starting point for guiding reserve design to avoid the most accessible areas with high availability of important resources in multi-species fisheries.

Assumptions and caveats

Given limited data availability, some assumptions on fish distribution were inevitable. Our model assumes that fishing yield within a given habitat is homogeneous. While habitats are homogeneously related to particular species, density of target species may vary within habitats (Manson & Die 2001). In addition, only species that can be related to a particular benthic habitat were considered. While demersal and reef-associated species strongly respond to depth (distance offshore), relief and benthic community structure (Beger et al. 2003), the distribution of several pelagic and migratory species may be harder to infer from benthic habitat and depth. Our model relies only on depth and benthic habitat associations and its comprehensiveness in terms of biodiversity representation is therefore limited.

Additionally, we assumed stability in the importance factor, a parameter that distinguishes stakeholder groups. Accordingly, we acknowledge that there are limitations from snapshot assessment of landings and prices, as these parameters can fluctuate due to environmental forcing (e.g. climate anomalies), markets, and fishing techniques/technology (Adams et al. 2011; van de Geer et al. 2013). Historical catch data, when available, can be used to provide more reliable importance ranks for the resources exploited by each stakeholder group. Despite such limitations, our model serves as a starting point for stakeholder consultation aiming to identify important resources with low spatial-temporal variability (Weeks et al. 2010b), a critical step for building trust among local communities that will be impacted by MSP (e.g. Moura et al. 2009). Finally, we remark that artisanal fisheries in developing countries are driven by resource availability, risk aversion, travelling distances, update of fishing gears/boats and cultural identity (Béné & Tewfik 2001; Daw 2008; Deas et al. 2014; Pet-Soede et al. 2001; Salas & Gaertner 2004; van de Geer et al. 2013, Maire et al. 2016), and such factors remain to be explicitly considered in spatial planning algorithms.

FishCake in a real world application

Recently, the Brazilian Protected Areas Agency (ICMBio) and environmental NGOs proposed a mosaic of new MPAs to expand marine protection in the Abrolhos Bank, considering a single homogeneous cost layer for fishers (ICMBio, 2011). Local fishers broadly rejected this proposal, as the planning process was not transparent and did not address opportunity costs for fisheries. Here, we revisited the Abrolhos' MPA planning challenge, demonstrating that the process may be considerably improved if opportunity costs represent the different groups of ports (ES, BA and ER) and fisheries (Trawling and Passive Gears). Despite being the main fishing area for ES and ER fishers (shrimp trawling grounds), the nearshore southern part of the study region was assigned to a high selection frequency to receive a no-take MPA, based on information on both costs and benefits, in the rejected MPA proposal (ICMBio, 2011). Cost layers are a prerequisite for robust spatial planning, such as

Marxan, in which the goal is to minimize the combination costs of the reserve network, whilst meeting a set of biodiversity targets (Ball et al. 2009). However, when homogeneous opportunity cost layers are used as a shortcut in the planning process, they fail to represent all stakeholders, ultimately leading to inequitable distribution of costs, and lack of support by local communities (Deas et al. 2014).

FishCake allows for the much-needed assignment of importance ranks for each *PU* and stakeholder group, allowing for a more explicit assessment of tradeoffs. If such a multidimensional and heterogeneous opportunity cost landscape is not considered, the resulting solutions can be very cheap for one group and extremely expensive to another. Contrasts between the FullCost scenario (minimum global opportunity cost) and solutions that consider each stakeholder group individually are a potential starting point for receiving inputs from stakeholders, allowing for datasets fine-tuning and consequently more equitable solutions. Opportunity cost layers obtained from FishCake can be used to assist data input in decision support systems such as Marxan and Marxan with Zones (Ball et al. 2009; Watts et al. 2009). Moreover, it can be simply employed as a tool to facilitate community consultation (Adams et al. 2011), adding an alternative approach to methods based on opportunity costs in data poor regions.

SUPPORTING INFORMATION

Maps resulting from distance function explorations (Appendix S1), R scripts and Marxan datasets (Appendix S2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

LITERATURE CITED

Adams VM, Mills M, Jupiter SD, Pressey RL. 2011. Improving social acceptability of marine protected area networks: a method for estimating opportunity costs to multiple gear types in both fished and currently unfished areas. Biological Conservation **144**:350–361.

Adams VM, Pressey RL, Naidoo R. 2010. Opportunity costs: who really pays for conservation? Biological Conservation **143**:439–448.

Alcala AC, Russ GR. 2006. No-take marine reserves and reef fisheries management in the Philippines: a new people power revolution. Ambio **35**:245–254.

Amado-Filho GM et al. 2012. Rhodolith beds are major CaCO3 bio-factories in the tropical south west Atlantic. PLoS ONE **7**:e35171.

Ardron JA, Possingham HP, Klein CJ. 2010. Marxan good practices handbook, version 2. Pacific Marine Analysis and Research Association.

Aswani S. 1998. Patterns of marine harvest effort in southwestern New Georgia, Solomon Islands. Ocean & Coastal Management **40**:207–235.

Ball IR, Possingham HP, Watts ME. 2009. Marxan and relatives: software for spatial conservation prioritization. Spatial conservation prioritisation: quantitative methods and computational tools. Oxford University Press, Oxford.

Ban NC, Hansen GJA, Jones M, Vincent ACJ. 2009. Systematic marine conservation planning in data-poor regions: socioeconomic data is essential. Marine Policy **33**:794– 800.

Ban NC, Klein CJ. 2009. Spatial socioeconomic data as a cost in systematic marine conservation planning. Conservation Letters **2**:206–215.

Beger M, Jones GP, Munday PL. 2003. Conservation of coral reef biodiversity: a comparison of reserve selection procedures for corals and fishes. Biological Conservation **111**:53–62.

Béné C, Tewfik A. 2001. Fishing effort allocation and fishermen's decision making process in a multi-species small-scale fishery: analysis of the conch and lobster fishery in Turks and Caicos. Human Ecology **29**:157–186.

CBD. 2010. Convention on biological diversity target 11, Aichi biodiversity targets. http://www.cbd.int/sp/targets/ (accessed September 2014).

Christensen V, Ferdaña Z, Steenbeek J. 2009. Spatial optimization of protected area placement incorporating ecological, social and economical criteria. Ecological Modelling **220**:2583–2593.

Daw TM. 2008. Spatial distribution of effort by artisanal fishers: exploring economic factors affecting the lobster fisheries of the Corn Islands, Nicaragua. Fisheries Research **90**:17– 25.

Deas M, Andréfouët S, Léopold M, Guillemot N. 2014. Modulation of habitat-based conservation plans by fishery opportunity costs: a New Caledonia case study using fine- scale catch data. PloS ONE **9**:e97409.

Devillers R, Pressey RL, Grech A, Kittinger JN, Edgar GJ, Ward T, Watson R. 2014. Reinventing residual reserves in the sea: are we favouring ease of establishment over need for protection? Aquatic Conservation: Marine and Freshwater Ecosystems **25**:480– 504.

Douvere F. 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Marine Policy **32**:762–771.

Douvere F, Maes F, Vanhulle A, Schrijvers J. 2007. The role of marine spatial planning in sea use management: the Belgian case. Marine Policy **31**:182–191.

Dutra GF, Allen GR, Werner T, McKenna SA. 2005. A rapid marine biodiversity assessment of the Abrolhos Bank, Bahia, Brazil. RAP Bulletin of biological assessment **38**:155.

Edgar GJ et al. 2014. Global conservation outcomes depend on marine protected areas with five key features. Nature **506**:216–220.

Fox HE et al. 2012. Reexamining the science of marine protected areas: linking knowledge to action. Conservation Letters **5**:1–10.

Freitas MO, Moura RL, Francini-Filho RB, Minte-Vera CV. 2011. Spawning patterns of commercially important reef fish (Lutjanidae and Serranidae) in the tropical western South Atlantic. Scientia Marina **75**:135–146.

Froese R. Pauly D. 2011. FishBase. Available from www.fishbase.org (accessed July 2013).

Grafton RQ, Kompas T, Schneider V. 2004. The bioeconomics of marine reserves: a selected review with policy implications. Journal of Bioeconomics **7**:161–178.

Green A et al. 2009. Designing a resilient network of marine protected areas for Kimbe Bay, Papua New Guinea. Oryx **43**:488.

Harris LR, Watts ME, Nel R, Schoeman DS, Possingham HP. 2014. Using multivariate statistics to explore trade-offs among spatial planning scenarios. Journal of Applied Ecology **51**:1504–1514.

ICMBio. 2011. Proposição de Unidades de Conservação na Região dos Abrolhos. Brasília- DF, pp. 27. Available from http://www.icmbio.gov.br/portal/images/stories/o-que- fazemos/ Propostas_UCs_Banco_Abrolhos_0512_novo2.pdf (accessed February 2015).

Jackson JB et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science **293**: 629–37.

Johannes R. 1998. The case for data-less marine resource management: examples from tropical nearshore finfisheries. Trends in Ecology & Evolution **13**:243–246.

Klein CJ, Brown CJ, Halpern BS, Segan DB, McGowan J, Beger M, Watson JE. 2015. Shortfalls in the global protected area network at representing marine biodiversity. Scientific Reports 5.

Klein CJ, Chan A, Kircher L, Cundiff AJ, Gardner N, Hrovat Y, Scholz A, Kendall BE, Airamé S. 2008. Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. Conservation Biology **22**:691–700.

Klein CJ, Steinback C, Watts M, Scholz AJ, Possingham HP. 2010. Spatial marine zoning for fisheries and conservation. Frontiers in Ecology and the Environment **8**:349–353.

Leopold M, Guillemot N, Rocklin D, Chen C. 2014. A framework for mapping small-scale coastal fisheries using fishers' knowledge. ICES Journal of Marine Science **71**:1781– 1792.

Lessa R, Nóbrega M. 2000. Programa REVIZEE/SCORE-NE-Guia de identificação de peixes marinhos da região Nordeste. Recife, UFRPE-DIMAR, 128p.

Maire E et al. 2016. How accessible are coral reefs to people? A global assessment based on travel time. Ecology Letters **19**: 351–360.

Manson FJ, Die DJ. 2001. Incorporating commercial fishery information into the design of marine protected areas. Ocean & Coastal Management **44**:517–530.

Mills M, Weeks R, Pressey RL, Gleason MG, Eisma-Osorio R-L, Lombard AT, Harris JM, Killmer AB, White A, Morrison TH. 2015. Real-world progress in overcoming the challenges of adaptive spatial planning in marine protected areas. Biological Conservation **181**:54–63.

Moura RL et al. 2013. Spatial patterns of benthic megahabitats and conservation planning in the Abrolhos Bank. Continental Shelf Research **70**:109–117.

Moura RL, Minte-Vera CV, Curado IB, Francini-Filho RB, Rodrigues HDCL, Dutra GF, Alves DC, Souto FJB. 2009. Challenges and prospects of fisheries co-management under a marine extractive reserve framework in Northeastern Brazil. Coastal Management **37**:617–632.

Naidoo R, Adamowicz WL. 2006. Modeling opportunity costs of conservation in transitional landscapes. Conservation Biology **20**:490–500.

Naidoo R, Balmford A, Ferraro PJ, Polasky S, Ricketts T, Rouget M. 2006. Integrating economic costs into conservation planning. Trends in Ecology and Evolution **21**:681– 687.

Naidoo R, Iwamura T. 2007. Global-scale mapping of economic benefits from agricultural lands: Implications for conservation priorities. Biological Conservation **140**:40–49.

Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Wagner H. 2013. Package "vegan." Community ecology package, version 2.

Pauly D, Zeller D. 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Nature Communications **7**:10244.

Pet-Soede C, Van Densen WLT, Hiddink JG, Kuyl S, Machiels MAM. 2001. Can fishermen allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia. Fisheries Management and Ecology **8**:15–36.

Pinheiro HT, Di Dario F, Gerhardinger LC, de Melo MRS, de Moura RL, Reis RE, Vieira F, Zuanon J, Rocha LA. 2015. Brazilian aquatic biodiversity in peril. Science **350**:1043–4.

Richardson EA, Kaiser MJ, Edwards-Jones G, Possingham HP. 2006. Sensitivity of marine- reserve design to the spatial resolution of socioeconomic data. Conservation Biology **20**:1191–1202.

Sala E, Aburto-Oropeza O, Paredes G, Parra I, Barrera JC, Dayton PK. 2002. A general model for designing networks of marine reserves. Science **298**:1991–1993.

Salas S, Gaertner D. 2004. The behavioural dynamics of fishers: management implications. Fish and Fisheries **5**:153–167.

Sanchirico JN, Cochran KA, Emerson PM. 2002. Marine protected areas: Economic and social implications. Resources for the Future **May 2002**:24.

Scholz A, Bonzon K, Fujita R, Benjamin N, Woodling N, Black P, Steinback C. 2004. Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. Marine Policy **28**: 335–349.

Silva MH, Soares GSS. 2013. Boletim estatístico da pesca do Espírito Santo: ano 2011.

Smith MD, Lynham J, Sanchirico JN, Wilson JA. 2010. Political economy of marine reserves: Understanding the role of opportunity costs. Proceedings of the National Academy of Sciences **107**:18300–18305.

Stelzenmüller V, Lee J, South A, Foden J, Rogers SI. 2013. Practical tools to support marine spatial planning: A review and some prototype tools. Marine Policy **38**:214–227.

Stewart RR, Possingham HP. 2005. Efficiency, costs and trade-offs in marine reserve system design. Environmental Modeling & Assessment **10**:203–213.

Teh LCL, Teh LSL, Pitcher TJ. 2012. A tool for site prioritisation of marine protected areas under data poor conditions. Marine Policy **36**:1290–1300.

Teixeira JB, Martins AS, Pinheiro HT, Secchin NA, Moura RL, Bastos AC. 2013. Traditional ecological knowledge and the mapping of benthic marine habitats. Journal of Environmental Management **115**:241–250.

Toropova C, Meliane I, Laffoley D, Matthews E, Spalding M. 2010. Global ocean protection: present status and future possibilities. IUCN.

van de Geer C, Mills M, Adams VM, Pressey RL, McPhee D. 2013. Impacts of the Moreton Bay Marine Park rezoning on commercial fishermen. Marine Policy **39**:248–256.

Watts ME, Ball IR, Stewart RS, Klein CJ, Wilson K, Steinback C, Lourival R, Kircher L, Possingham HP. 2009. Marxan with Zones: Software for optimal conservation based land- and sea-use zoning. Environmental Modelling & Software **24**:1513–1521.

Weeks R, Russ GR, Bucol AA, Alcala AC. 2010. Shortcuts for marine conservation planning: the effectiveness of socioeconomic data surrogates. Biological Conservation **143**:1236–1244.

Wood LJ, Dragicevic S. 2007. GIS-based multicriteria evaluation and fuzzy sets to identify priority sites for marine protection. Biodiversity and Conservation **16**:2539–2558.

Wood LJ, Fish L, Laughren J, Pauly D. 2008. Assessing progress towards global marine protection targets: shortfalls in information and action. Oryx **42**:340–351.

Yates KL, Schoeman DS. 2013. Spatial access priority mapping (SAPM) with fishers: a quantitative GIS method for participatory planning. PLoS ONE **8**: e68424.

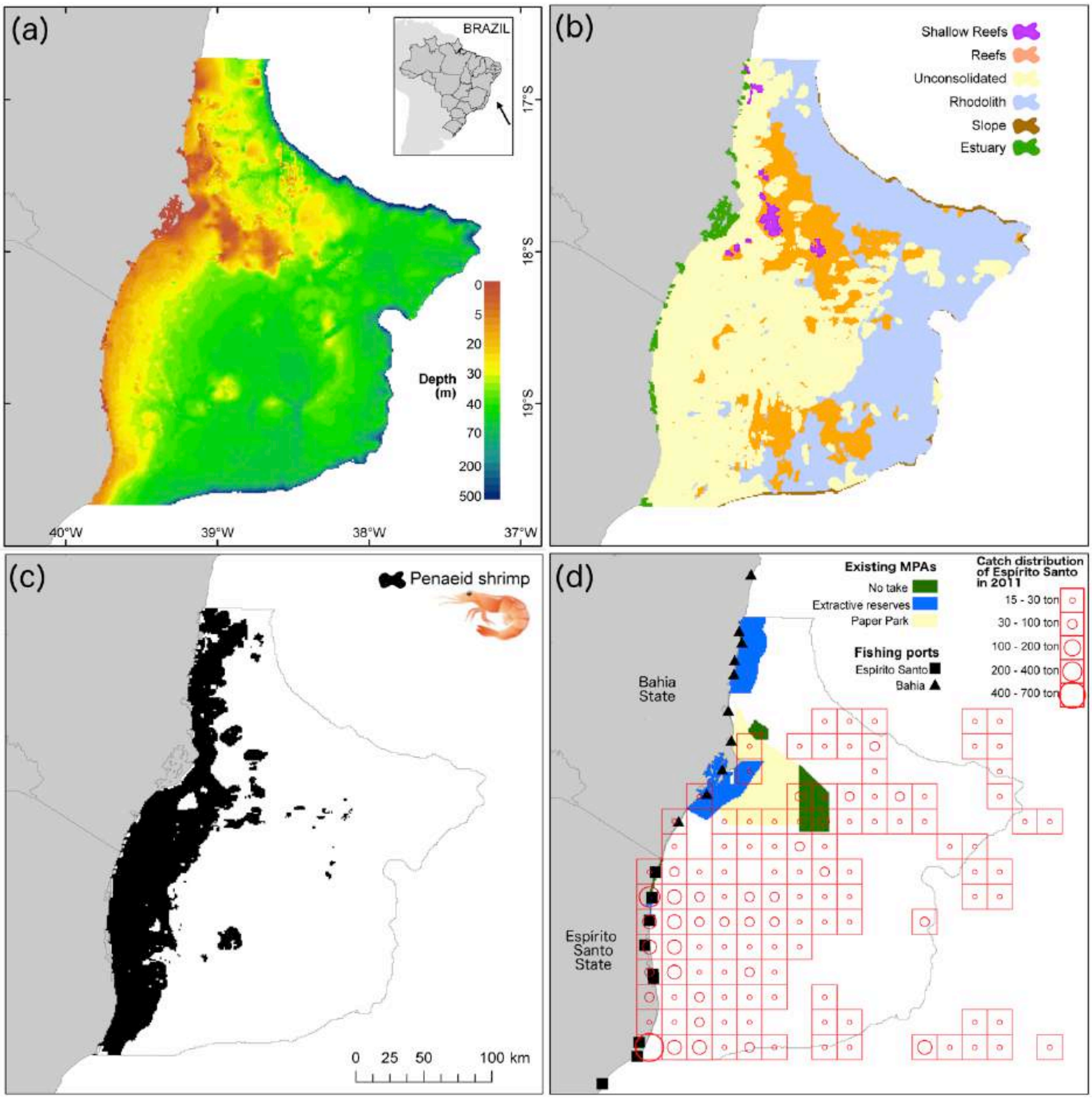


Figure 1. The Abrolhos Bank shelf, Brazil (inset): (a) detailed bathymetric profile; (b) benthic megahabitats; (c) potential distribution of penaeid shrimp fishing grounds (from bathymetric and benthic habitat data); (d) Fishing ports, existing MPAs and catch data for Espírito Santo State fleets (ES).

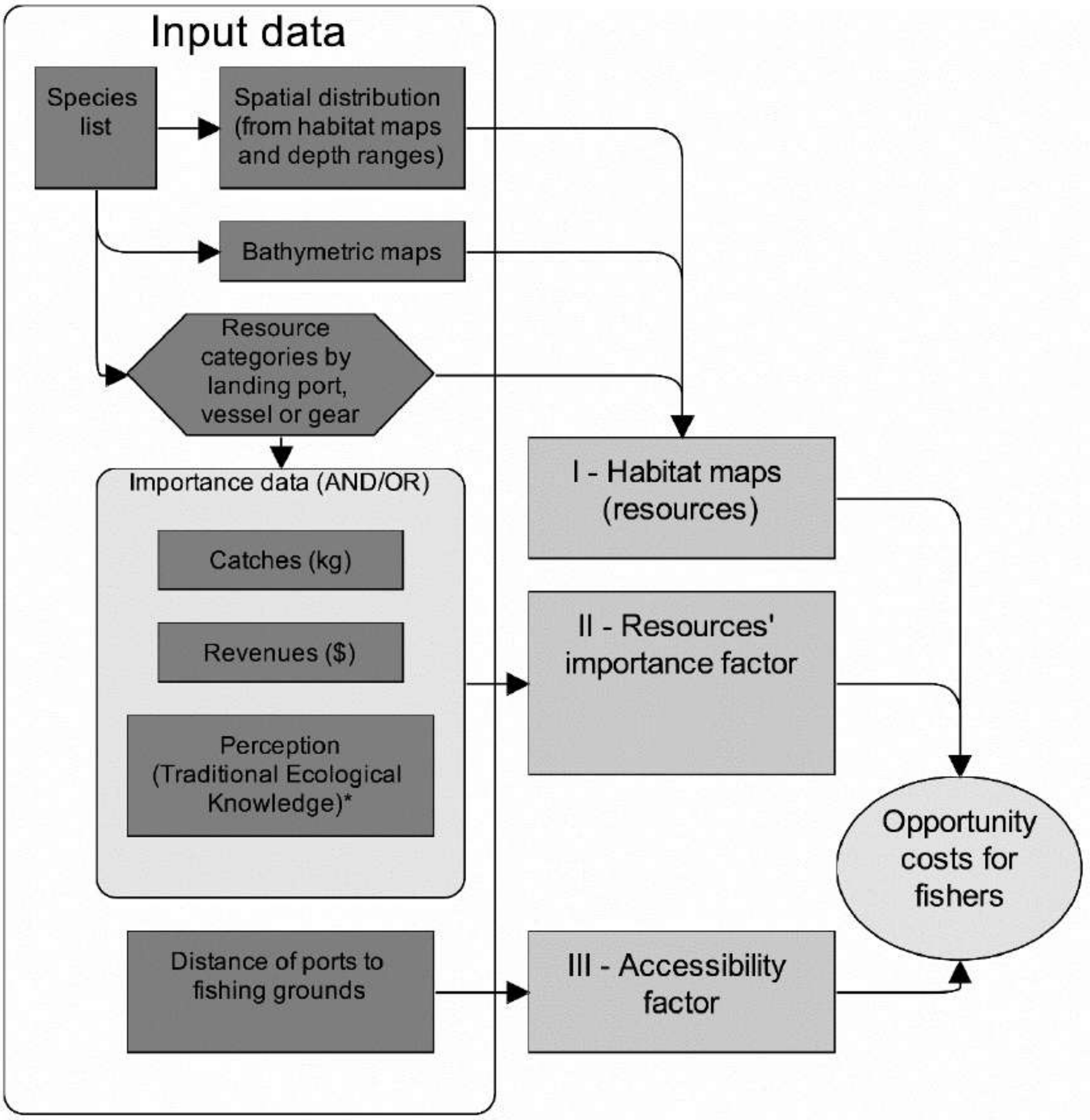


Figure 2. Conceptual model used to estimate the opportunity cost for fisheries in the Abrolhos Bank shelf (FishCake). *Not used.

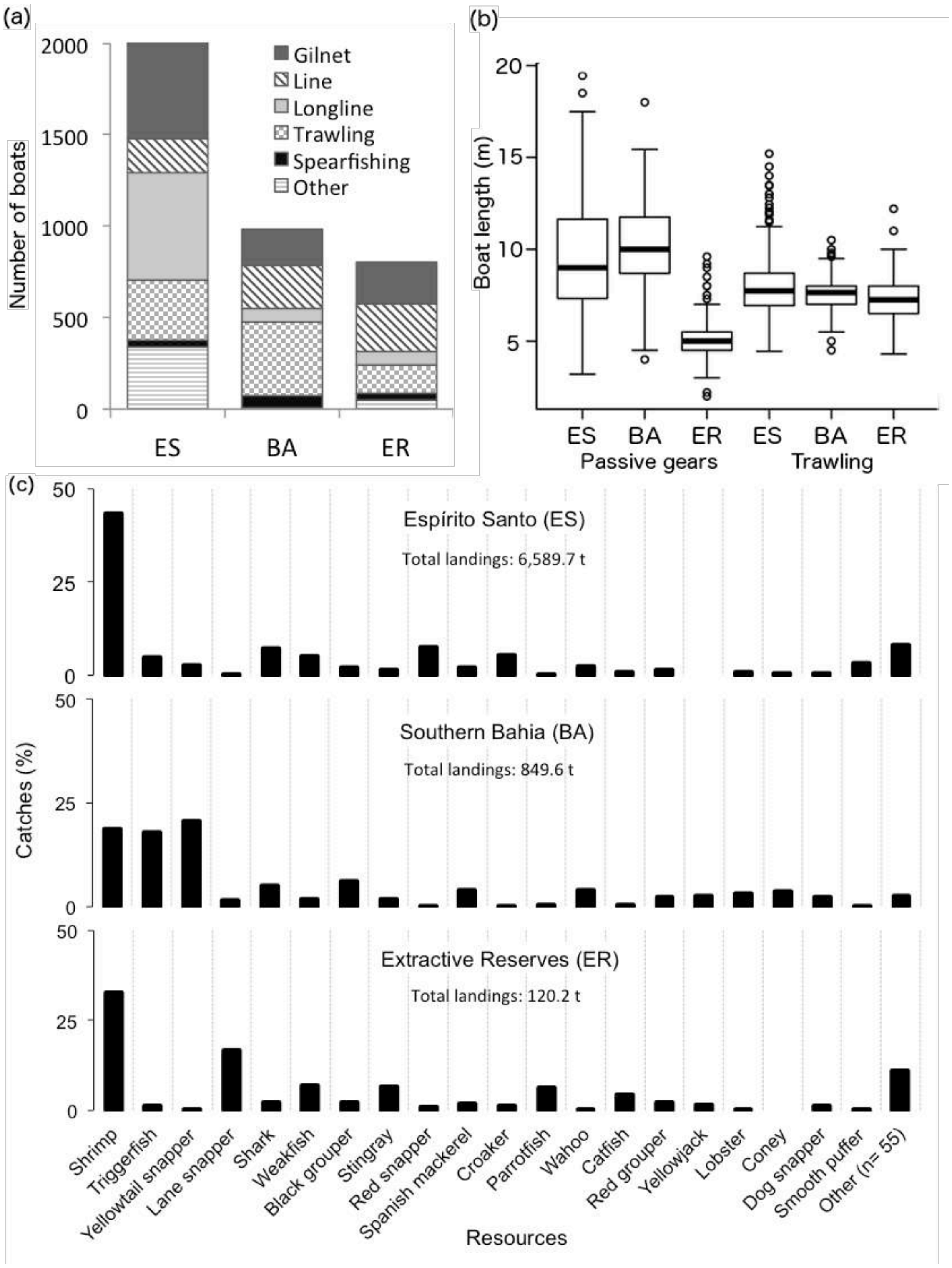


Figure 3. Characteristics of the fishing fleets that operate in the Abrolhos Bank and relative importance of the main fisheries resources landed in each Group of Ports: (a) gear types; (b) boat size; (c) landings. ES= Espírito Santo State; BA= Bahia State; ER= Extractive Reserves. Species represented as Resources are listed in the Supplementary Material.

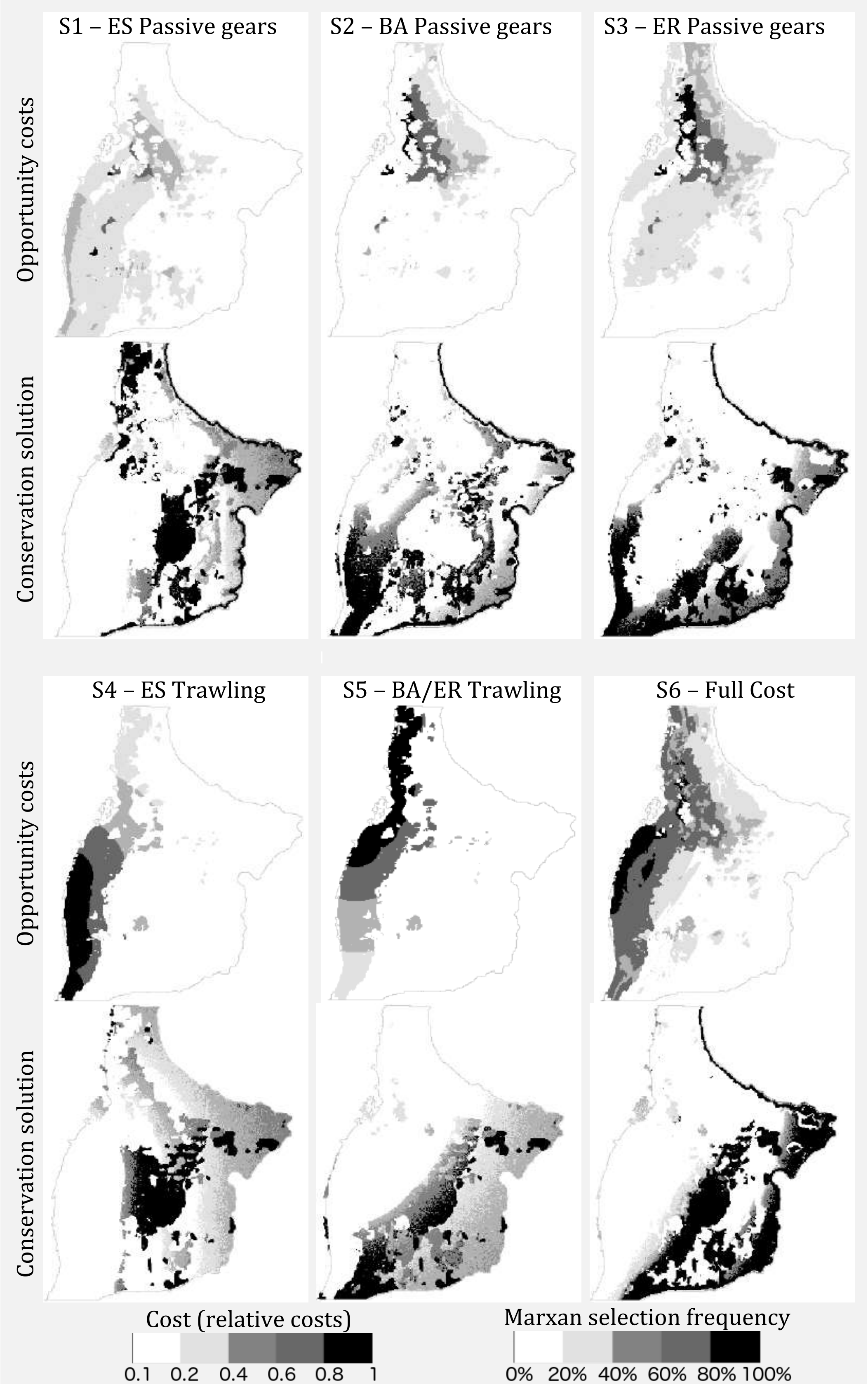


Figure 4. Spatial distribution of opportunity costs and respective Marxan selection frequencies (100 replicated runs, targets comprising 30% of each habitat) for the six planning scenarios, S1-S6 (one for each of the five ports/vessel groups, and a Full Cost scenario).

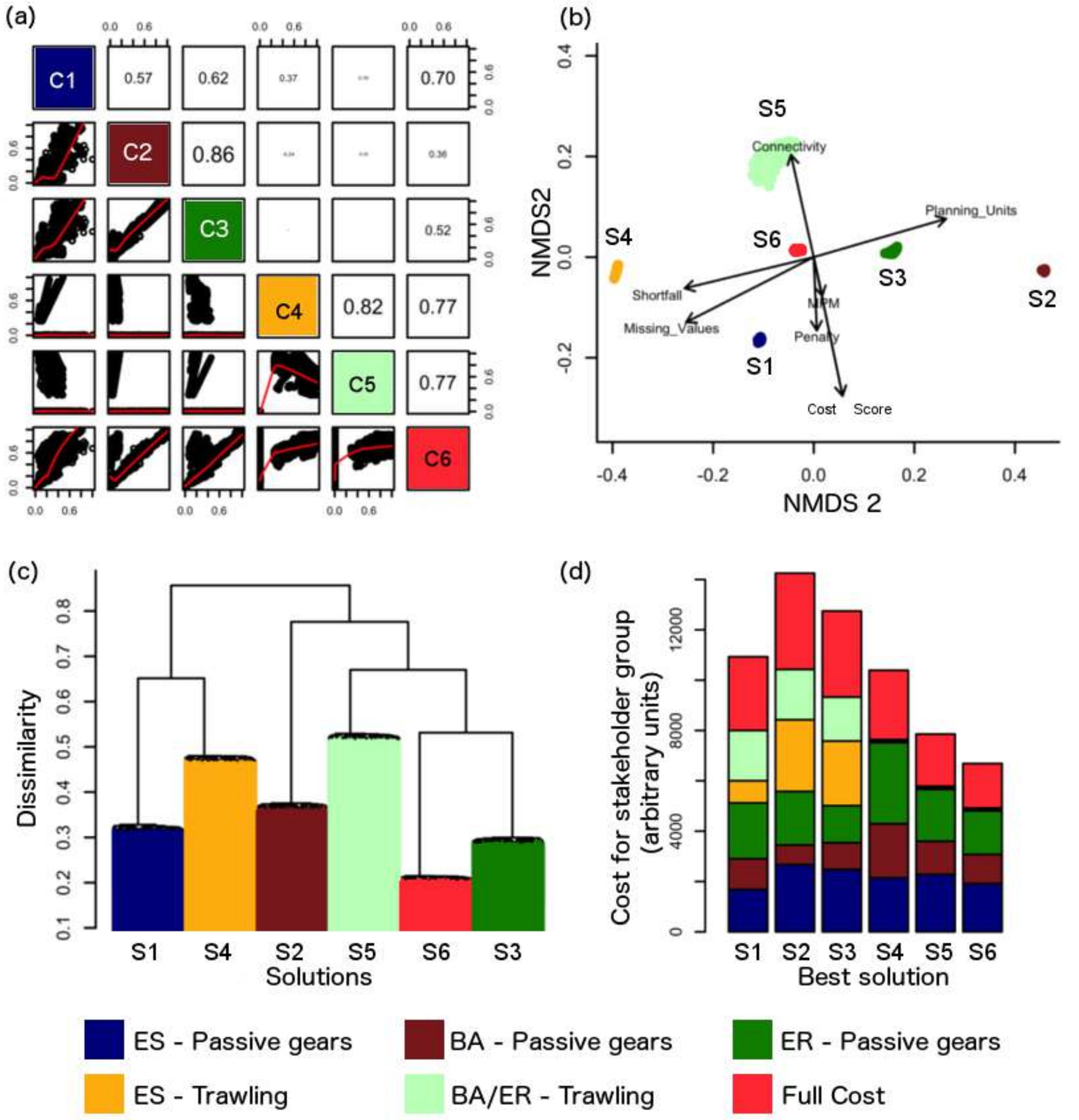
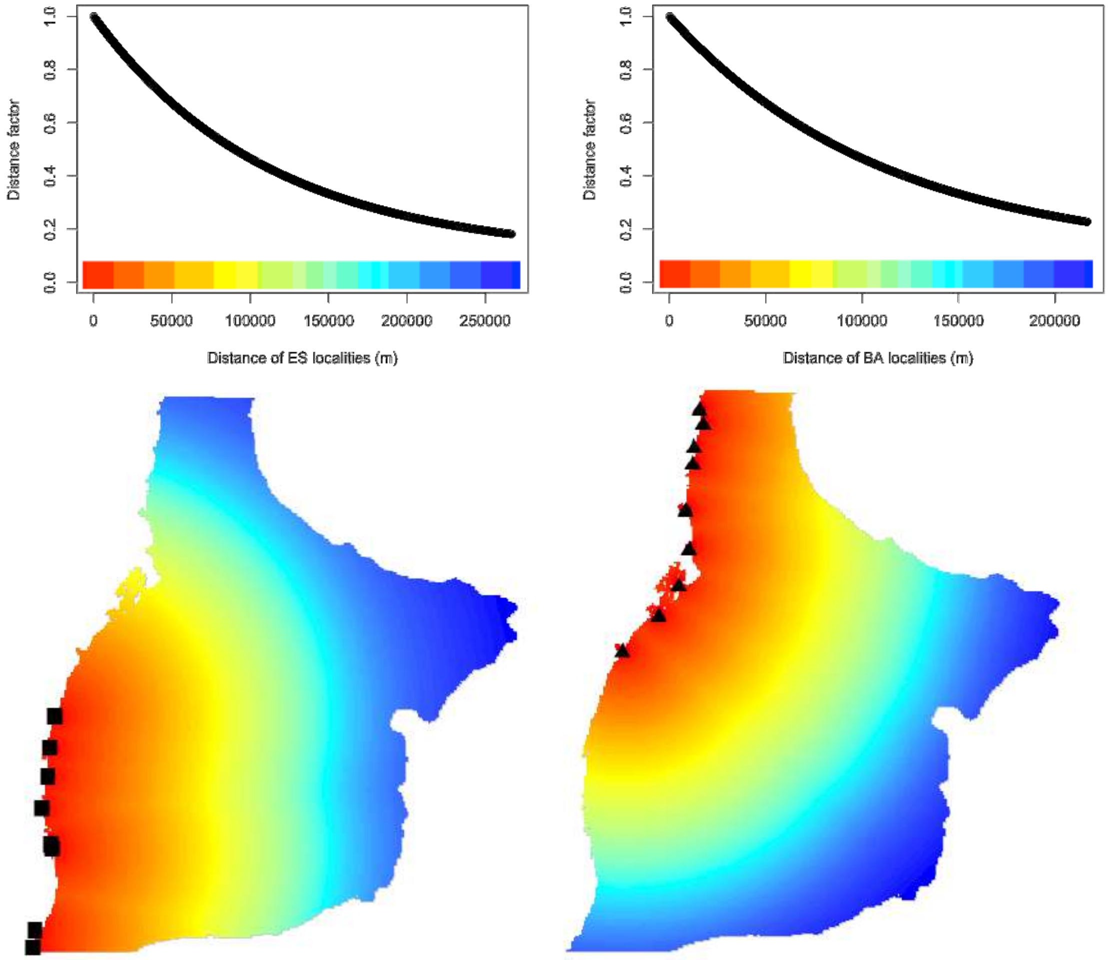


Figure 5. Multivariate analyses of opportunity cost layers (C1-C6) and Marxan selection frequencies for planning scenarios (S1-S6): (a) correlations among cost layers plotted as scatterplots with LOESS smoother (below diagonal) and corresponding Pearson´s coefficients (above diagonal). (b) Multidimensional scaling plots (NMDS) of Marxan solutions with vectors representing significant model output parameters. (c) Dendrogram showing the similarity among Marxan solutions (each bar contains 100 solutions). (d) Opportunity costs of Marxan's best solution for each of the five port/vessel groups and for the full-cost scenario.

Supporting Information:



Appendix S1: The distance function (f(d)) applied to fishing cost estimates. The left graph and map shows the result of distances from Espírito Santo (ES) ports. The same function was applied to Bahia ports (right graph and map), including the Southern Bahia (BA) and Extractive Reserves (ER) groups.

CAPÍTULO III

CONSERVATION PLANNING IN A SEA OF SMALL BOATS: TRADEOFFS BETWEEN BIODIVERSITY CONSERVATION AND RESOURCE EXPLOITATION IN EASTERN BRAZIL

João B. Teixeira[1, 2,], Morena Mills[3], Rodrigo L. Moura[1, 2], Gilberto M. Amado-Filho[4], Alex C. Bastos[5], Deborah M. Faria[2].

1- Instituto de Biologia and SAGE/COPPE, Universidade Federal do Rio de Janeiro. Rio de Janeiro RJ 21941-599 Brazil. Corresponding author: moura.uesc@gmail.com

2- Programa de Pós-Graduação em Ecologia e Conservação da Biodiversidade, Universidade Estadual de Santa Cruz. Ilhéus BA 45650-000 Brazil.

3- The School of Biological Sciences, The University of Queensland, St. Lucia, Qld 4072, Australia

4- Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. Rio de Janeiro RJ 22460-030 Brazil

5- Departamento de Oceanografia, Universidade Federal do Espírito Santo. Vitória 29090-600 ES Brazil.

Acknowledgements

We thank the fisherfolks from the Extractive Reserves of Corumbau and Cassurubá for the continued support to our fieldwork, and the Colônias dos Pescadores (Fishing Guilds) from the municipalities of Porto Seguro, Prado, Alcobaça, Caravelas, Nova Viçosa, Conceição da Barra, Linhares e Aracruz. Logistical and financial support was provided by the ICMBio, Conservation International, A Voz da Natureza, CNPq, FAPES, FAPERJ, CAPES, PELD-Abrolhos (www.abrolhos.org) and ANP/Brasoil.

CONSERVATION PLANNING IN A SEA OF SMALL BOATS: TRADEOFFS BETWEEN BIODIVERSITY CONSERVATION AND RESOURCE EXPLOITATION IN EASTERN BRAZIL

Abstract

The rapid urbanization and expansion of fishing, port and industrial infrastructure negatively affects the goods and services provided by marine biodiversity. Establishment of Marine Protected Areas (MPAs) can complement fisheries management by mitigating impacts from fishing and destructive use of gears, maximizing the benefits from biodiversity conservation. However, MPA establishment often involves conflicts with fishers and other stakeholders that either depend or benefit from open access regimes (e.g. mining, shipping and tourism sectors). Conflicts are likely when planning focuses on biodiversity objectives only, ignoring the social and economic dimensions of the planning regions. A first attempt of expanding the Abrolhos Bank MPAs failed implementation as fishers considered the potential impacts of the proposal inequitable. Besides being South Atlantic’s most biodiverse area, Abrolhos yields the highest fishing landings in the entire Northeastern Brazil. MPA establishment invariably implies in displacements and restrictions to fisheries; therefore planners must consider the tradeoffs between biodiversity protection and losses of economic activities. Here, we explore trade-offs between economic activities and biodiversity conservation in Abrolhos, and how the impact of different MPA scenarios varies across stakeholder groups. We present an MPA proposal that aims to achieve conservation objectives while minimizing socioeconomic impacts in the Abrolhos region. Our results are expected to help catalyze the re-establishment of the Abrolhos’ spatial planning initiative under more equitable conceptual foundations and praxis.

Keywords: conservation systematic planning, trade off, habitat, biodiversity, fishing.

1. INTRODUCTION

Globally, population growth is concentrated near the coast and is accompanied by rapid expansion of fishing, port, industrial, and urban infrastructure. The search for hydrocarbons and minerals is also escalating, resulting in deep transformations at all seascapes and negative effects in the goods and services provided by marine biodiversity [1]. Economic development is focused on the rapid maximization of financial return, resulting in the degradation of ecosystems and life quality of the most vulnerable coastal communities [2,3].

Currently, Marine Protected Areas (MPAs) are the cornerstones of marine biodiversity conservation [4,5]. Also, they can complement fisheries management measures such as size-season-gear-catch limits, as fisheries resources and their larvae may spill over from no-take reserves (NTRs) into adjacent fishing grounds [6]. Due to such immense potential, the signatory countries of the Convention on Biological Diversity (CBD) have committed to protect 10% of the oceans until 2020 [7]. However, accomplishing this target requires an additional 10 million km^2 of MPAs, or a 360% increase in the MPA area established in the last decade [8], enclosing wide expanses of ocean that are used by fishers and other stakeholder groups that depend upon natural resources' extraction for survival.

A representative and functional global MPA network depends on planning frameworks that are able to integrate the social and ecological dimensions of the targeted regions, avoiding further allocation of resources in low-cost residual MPAs, "paper parks", and negative social impacts [9–11]. Recent increases in the global MPA area are related to the protection of large areas around remote islands [17]. Besides being geopolitically biased [e.g. UK Overseas Territory, Pacific Remote Islands and Papahãnaumokuãkea (US), Motu Motria Hiva (Chile)], such initiatives involve limited displacement of stakeholders and take advantage of military facilities and long-standing restrictions to civil usage [18]. Therefore, the marine conservation challenge for most countries remains: the establishment of MPAs, including no-take reserves (NTRs), in densely populated regions and areas under dispute by domestic stakeholder groups [8,19]. Unfair or unequal impacts enhance local-level conflicts and hinder management, especially when resources for implementation are limited [20].

Indeed, MPAs in developing countries have limited prospects without local support, and such cooperation must be established during the planning process [3].

Marine Spatial Planning (MSP) is a conceptual and operational framework to help guide management decisions to be as efficient as possible at meeting stated goals. The success of interventions depends on effective implementation and compliance with the rules. The degree to which the rules are considered to be fair will influence whether those impacted by the rules abide to them (Ostrom, 1990). However social equity, in terms of social class, gender, ethnicity, generational, educational and occupation, is rarely explicitly assessed in the context of conservation planning. Conservation would benefit from a better use of exiting as well development of novel equity metrics for planning (e.g. input equity: degree of participation by stakeholder group) and evaluation of conservation interventions (e.g. outcome equity: resources' state, financial return to individuals or groups) [22].

Tradeoff analyses help managers determine how much of a given economic activity will be lost to achieve biodiversity conservation goals, which can be more important than reducing the global cost of MPAs [23,24,21,25,26]. Tradeoffs occur when the provision of an ecosystem service (e.g. resource's availability to fisheries) is reduced due to increased use of another (e.g. biodiversity conservation), allowing policy makers to understand the long-term effects of their choices [27]. When services overlap and are mutually exclusive (e.g. petroleum platforms vs. commercial fishing) losses can be extreme, but less severe tradeoffs are more frequent (e.g. fishing and recreational activities) and can be independently managed (e.g. fisheries in non-overlapping habitats) [28]. The simultaneous maximization of all interacting services is not achievable, and managers are required to make informed choices, improved by explicit consideration of tradeoffs [29].

In this study, we address the issue of equity in MPA planning by exploring the contentious conservation scenario of the Abrolhos Bank, Brazil [30]. The region is a biodiversity hotspot and encompasses South Atlantic's largest coral reefs and other relevant biodiversity attributes, besides producing the highest fisheries yields within Northeastern Brazil – largely from small scale fisheries [31–33]. Specifically, we addressed the tradeoffs between the area available for fishers and the protection of 30% of the region's biodiversity, and how distinct stakeholder groups are impacted by the conservation of different biodiversity targets. We also present and contrast different multiple zoning scenarios aiming to promote fisheries while simultaneously accomplishing biodiversity conservation goals. Our ultimate goal is to catalyze a second Abrolhos' MPA planning process, considering what has been learned from the previous attempt [34], which is briefly described and discussed.

2. MATERIALS AND METHODS

2.1 Study region

The Abrolhos Bank stretches across ~200 km of the Eastern Brazilian shelf between Bahia and Espírito Santo States (17-19.7°S), covering ~57,000 km^2 [30,35]. The region is a major breeding ground of Humpback Whales [36], has several reef fish spawning aggregation sites [32], and encompasses the largest coralline reefs and rhodolith beds of the South Atlantic [37,38]. Benthic habitats comprise a mosaic of soft sediments, shallow and mesophotic reefs, rhodolith beds, paleochannels and a complex of large sinkholes that trap organic matter and aggregate fish biomass in the mid and outer shelves [30,33,39]. Abrolhos is also the region with the highest fisheries yields in the entire Northeastern Brazil [40], encompassing nearshore fisheries over soft bottom and reef fisheries, both with limited regulations and enforcement [32,41,42]. Fisheries are carried out by small (<10m) and rudimentary fishing vessels, legally categorized as artisanal and largely operated under family ownership or partnerships among fishermen [43]. An artisanal-industrial transition has been taking place in last decade, with the establishment of small fleets with centralized command and ownership, and incorporation of new technologies that enhance captures (e.g. GPS, Echo Sounder). The region is also targeted by oil and gas exploitation [44] and mining [30], and is also affected by dredging of navigation channels for larger vessels that transport agricultural commodities [43]. So far, 1.7% of the region is covered by one NTR (Abrolhos National Marine, 880 km^2) and 3.7% are covered by two Marine Extractive Reserves (co-managed areas reserved for local fishers) (Corumbau, 895 km^2 and Cassurubá, 1,000 km^2). The largest multiple-use MPA is a 3,400 km^2 "paper-park" under Bahia State jurisdiction, which has not been implemented since its declaration in 1993.

2.2. MPA planning in Abrolhos

In the last decade, Brazil made little progress towards establishing a functional and representative MPA network, in spite of being CBD's first signatory. MPAs cover 1.5% of the country's Exclusive Economic Zone (EEZ), with <0.5% of NTRs [45]. Even regions with broadly recognized global relevance, such as the Abrolhos Bank [44,46,47], remain poorly protected and with major implementation gaps [30,33,48].

Since 2010, non-governmental organizations (NGOs) and the Ministry of Environment triggered an accelerated process of MPA creation in Abrolhos [45]. Catalysed by the UN Conference on Sustainable Development in 2012 (Rio+20), four new MPAs (15,736 km^2 as NTR and 95,826 km^2 as multiple use MPAs, Fig. 1) were put to public approval a few weeks before the conference. The proposed MPAs were based on outputs from a conservation planning software with limited stakeholder consultation [45]. The public consultation for this unprecedented *en masse* MPA declaration consisted of two meetings aiming to validate the proposal in a single discussion round. Most stakeholders, and even local MPA managers, were unaware of the process until a few days before the hearings, and the proposal was broadly rejected due to the overall lack of transparency, inequitable impacts over stakeholders and disregard of previously negotiated priorities. For instance, a long-standing fishers' demand for the creation of a third Extractive Reserve (Rio Doce) had not been integrated into the proposal [45]. As a result, resistance to MPAs increased, the process was halted and has not yet been resumed by the Ministry of Environment. This proposal will be hereafter referred to as the 2012 proposal.

2.3. Datasets

Biodiversity features: Given the lack of fine scale biodiversity data, we used broad scale benthic habitat maps and biophysical information to represent biodiversity features, including: unconsolidated bottom, estuaries, rhodolith beds, shallow reefs, mesophotic reefs, continental slope [30] and sinkholes [39] (Fig. 2a). We also used the areas with the highest whale concentrations [36], spawning aggregations sites [32], and the habitats of important fishing resources (Fig. 2b): *Rhomboplites aurorubens; Mycteroperca bonaci; M. venenosa; Lutjanus analis; L. jocu; L. synagris; Cephalopholis fulva; Dermatolepis inermis; Ocyurus chrysurus; Epinephelus morio*. We targeted the protection of 30% of all biodiversity features.

Fisheries resources: Groups of commercially important benthic and demersal species with a same common name (Fig. 3) were included as conservation targets. Catch data (kg.year^{-1}) was obtained from three projects funded by the Ministry of Fisheries in 2011 (since then, monitoring was halted countrywide; see Pinheiro et al. [49]). The first dataset (ES) was obtained by the Federal University of Espírito Santo and covers the main ports in Espírito Santo state [50]. The second dataset (BA) was obtained by NGO ECOMAR and covers the ports of Prado, Alcobaça, Caravelas, Nova Viçosa and Mucuri, in the southern coast of Bahia state (unpublished). The third dataset (ER) was obtained by NGO Conservation International and covers ports within the Extractive Reserves of Corumbau and Cassurubá, also in Southern Bahia (unpublished). The three datasets represent different Groups of Ports, in which different vessel types (gear/target species and boat size) operate.

Opportunity costs: Opportunity costs of fishers' displacement by NTRs was estimated with the FishCake algorithm (habitat-based approach to estimate opportunity cost for fishing) [51], which is based on fishermen accessibility (distance between Ports and PUs) and on the relative importance of each PU to each Group of Ports (REFER TO YOUR OTHER PAPER). Opportunity cost of oil/gas exploitation and mining were based on areas already licensed or under licensing [52]. Cost layers are illustrated on Fig. 2d.

2.4. Multiple zoning

We used software *Marxan with Zones* [53] to identify zoning arrangements that achieve conservation objectives simultaneously minimizing impacts on fisheries, at a minimum cost. This tool uses a simulated annealing algorithm to find near-optimal solutions in a flexible, efficient and replicable way [54], and can segregate multiple and potentially conflicting activities (e.g. conservation and socioeconomic), optimizing multiple zoning by considering differential contributions of zones to objectives and costs [53].

The planning region (Figure 1) was divided into a 1 km^2 grid, from the estuaries to the shelf edge (200 m isobath), resulting in 50,762 PUs that were further allocated into one of the following four zones: **No-Take Zone**, where no extractive activities are allowed (associated to opportunity cost for fisheries, oil and gas, and mining); **Fishing Zone**, where no mining is allowed (associated to opportunity costs for oil and gas, and mining); **Oil and Mining Zone**, exclusive to mining (associated to opportunity costs for fisheries). Additionally an **Available Zone** was included in order to improve the prioritization's performance. This zone does not contribute to any of the above objectives and is not associated to any cost. A target of 30% was used for each megahabitat and other biodiversity features, three times larger than those of CDB but similar to the targets used in the 2012 proposal.

2.5. Tradeoffs

We ran seven scenarios to assess tradeoffs between the conservation of biodiversity features and the use of natural resources. Similarly to Weeks et al. [26], we incrementally increased the fishery targets until it was not possible to simultaneously achieve all biodiversity, fisheries, oil and gas, and mining targets. The scenarios focused on different stakeholders groups. The first one, ***S1 (ES passive gears***), focused on evaluating tradeoffs involving Espírito Santo fishers who use passive techniques. The same strategy has been applied for scenarios ***S2 (BA passive gears)*** and ***S3 (ER passive gears)***, which involve fishers from Southern Bahia and Extractive Reserves, respectively. Scenarios ***S4 (ES trawling)*** and ***S5 (BA/ER trawling)*** focused on the tradeoffs involving shrimp trawling. Licensed area for oil exploration and the mining interest area were grouped in the scenario ***S6 – oil and mining***. In scenario ***S7 (all stakeholders)***, we considered all stakeholders simultaneously. A maximum exploitable area was defined as the portion of the resource's habitats or mining areas that will remain exploitable with the achievement of conservation targets.

The Feature Penalties Factor (FPF) was calibrated for each scenario following Ardron et al. [55], in order to keep shortfalls consistent and to make results comparable. Small FPF values (relative to the other parameters) generate the lowest cost solutions, but miss some targets due to penalties. Conversely, high FPF values tend to produce few higher-cost solutions. The FPF was equally calibrated and established for all targets and scenarios. Parameter Boundary Length Modifier (BLM), which controls the fragmentation of selected areas, influences the tradeoff curves and was set to 0 for tradeoff analyses. Marxan with Zones was set to run 100 solutions for each scenario. Datasets, including all GIS files, are supplied as Supplementary Materials.

The maximum exploitable percentages for S7 were included as goals for the Fishing Zone and Oil and Mining Zone to produce a "*best scenario*" that aims to promote resources availability to stakeholders given constraints related to equity and biodiversity objectives. In order to make the final scenario more applicable, parameters BLM and ZONEBOUNDCOST, which controls the zone boundary relationship) were calibrated following Ardron et al. [55] and Watts et al. [56].

3. RESULTS

3.1. Tradeoffs between biodiversity and resources' uses

In the Abrolhos Bank, the ambitious biodiversity targets of our exercise (30% of the area of each target) may be achieved even if 60-73% of the resources' area remain exploitable, as indicated by the overall small tradeoffs in S7 (Fig. 4). However, tradeoffs vary across stakeholder groups. Tradeoffs between biodiversity conservation and fishing were mainly driven by passive gear fishermen (S1, S2 and S3). Tradeoff between biodiversity conservation, trawling (S4 and S5), and oil and mining (S6) were minimum due to restricted spatial overlap with biodiversity features, nearshore (shrimp trawling habitat) and in the south region (where oil and mining areas are concentrated). In these cases, allocation of NTRs for achieving conservation targets may be flexible, since there is a huge offshore extension with no trawling and mining.

3.2. Conservation impacts on stakeholders

Soft bottom, rhodolith beds, mesophotic reefs and areas with higher whale concentrations were the conservation targets with higher impacts over fishermen using passive gears, from both ES and BA (Fig. 5a-b). In contrast, protection of soft bottoms and rhodolith beds impacted ER fishermen that use passive gears (Fig. 5c). Shrimp trawling, oil and mining had the lowest impact in the allocation of No-Take Zones (Fig. 5d-g).

3.3. Maximum exploitable area

When all stakeholders are simultaneously considered in MPA zoning (S7), 60-90% of the current resource use can still be undertaken while achieving all biodiversity conservation objectives (Fig. 6). Stingray, catfish, shark, weakfish, yellowtail snapper, lane snapper, and croaker fishing grounds were the most impacted by the accomplishment of the conservation objectives (Fig. 6). A solution that accomplishes the ambitious conservation targets (30% of each biodiversity feature) and minimizes impact over fisheries and oil and mining is presented in Fig. 7a, along with PUs selection frequency for each zone (Fig. 7b-d). This proposal can be used as a starting point to resume the Abrolhos' MPA planning initiative.

4. DISCUSSION

Equity is an emerging issue in conservation planning research, and has been assessed through metrics associated to the access level to natural resources and stakeholder participation in decision-making [21,57]. Because the division of fishing areas may relate linearly with conservation success (e.g. Territorial User Rights in Fisheries – TRUFs) [22], we have choosen to explore spatial access equity tradeoff analyses to evaluate MPA impacts on different stakeholder groups in the Abrolhos Bank, a region where small-scale artisanal fisheries are ubiquitous. Our results show that it is possible to achieve substantial protection goals without extensive impact on resource users. Tradeoffs between the protection of 30% of the targeted biodiversity features and the remaining exploitable areas is overall weak (Fig. 4), as indicated by the concave tradeoff curves [28,57]. On average, all biodiversity protection goals are accomplished when 44% of the areas exploitable by stakeholders are lost to NTR zones, possibly opportunity costs will decrease with less ambitious targets and can decrease further through the incorporation of stakeholders' inputs [57]. The achievement of conservation targets for unconsolidated bottom, rhodolith beds, mesophotic reefs and areas with higher whale concentration have the greatest impact on resources use.

Our study complements previous scientific literature showing that the explicit incorporation of targets and costs for different stakeholder groups improves the trade-off between the protection of biodiversity and the exploitation of natural resources. For example, Klein et al. [19] found a weak tradeoff while evaluating fishing economic losses (9%) to achieve the 30% biodiversity target in the context of California's Marine Life Protection Act. Also, Gurney et al. [57], in a study aiming to design a system of NTRs in Kubulau District, Fiji, found that it is possible to achieve low to mid-range biodiversity objectives with relatively small losses to fisheries. Brown and Mumby [58], in a modelling study, showed that trade-offs between the protection of functional communities and fisheries profits depend on the approach to management, whith mixed management (reducing fishing effort and MPAs) resulting in ~30% of reefs with functional communities.

We propose our "best scenario" as a a starting point for future MPA planning with representative stakeholder input and novel data that may become available, combining quantitative methods with idiosyncrasies of planners and stakeholders [62]. Indeed, the generic and ambitious targets that we used need to be discussed and adjusted. Large areas in the south of the Abrolhos Bank, which comprise soft bottom, mesophotic reefs and rhodolith beds, are promising for the expansion of NTRs. Mangrove areas and the Doce River Mouth (estuaries that are not part of the existing MPAs), as well as the offshore areas near the shelf break, also presented high selection frequency for NTR zoning.

Our model still has some caveats to be considered in forthcoming MSP. Benthic habitat maps are powerful surrogates to support the modeling of marine ecosystems [63], but habitat-based distribution models fail to represent the actual distributions of biomass and ecological processes [8,58]. For example, the lumping of mud (shrimp habitat) and sand in a single benthic megahabitat [30,35] contributed equally to the achievement of some targets, but it is expected that higher resolution sediment data will decrease the size and change the boundary of shrimp trawling grounds, impacting the tradeoff curves for this important fishery. In some cases, higher resolution habitat maps of unconsolidated bottom can be readily and reliably developed from stakeholder consultation [64]. Accordingly, the definition of fishing targets based on area proxies is also limited, these can be improved with population modeling pointing towards areas containing catches needed to keep fisheries profitable [19].

Targets based only on MPAs area have a limited ability to optimize marine biodiversity protection, giving governments, NGOs and the public a false sense of conservation achievement [11]. For instance, Edgar et al. [4] studied the conservation benefits of 87 MPAs across the globe considering five key features: no take, well enforced, old (> 10 years), large (> 100 km^2) and isolation (deep water or sand). While isolation depends on the geographic settlement of the planning region, the other key features are dependent on design (size and configuration) and management (NTR zoning, long term enforcement), and should be seriously considered in MPA design. In the South Atlantic, there are few remote oceanic islands that can host large MPAs, therefore, advances in the Brazilian spatial planning over marine and coastal areas are fundamental for the protection of the South Atlantic biodiversity.

The effectiveness of NTRs is well known to depend on fisheries management in the adjacent open and multiple-use zones [65], and these two dimensions need to be simultaneously addressed to regain stakeholders' attention and trust [66]. Spillover of biomass from NTRs does not guarantee inexhaustible sources of resources, and has limited spatial reach [67]. In addition, the effects of fishing effort redistribution after reservation is still poorly understood and may compromise the effectiveness of MPA networks [19]. The economic gains of Oil & Gas exploration and mining frequently alter spatial priorities and the opportunity cost of conservation, because the future of these politically powerful extractive industries that rely on non-renewable resources depends on new discoveries in increasingly larger marine areas [23]. The current dismantling of Brazilian fisheries management [49], including the extinction of the Fisheries Ministry, challenges MPA planning and implementation, and needs to be resumed under a collaborative basis among agencies, academia and stakeholders, instead of being centralized by a single ministry (Ministry of Environment) and a few environmental NGOs.

5. REFERENCES

[1] D.J. McCauley, M.L. Pinsky, S.R. Palumbi, J. a. Estes, F.H. Joyce, R.R. Warner, Marine defaunation: Animal loss in the global ocean, Science (80-.). 347 (2015) 1255641. doi:10.1126/science.1255641.

[2] A. Balmford, A. Bruner, P. Cooper, R. Costanza, S. Farber, R.E. Green, et al., Economic reasons for conserving wild nature., Science. 297 (2002) 950–3. doi:10.1126/science.1073947.

[3] M.P. Wells, T.O. McShane, Integrating protected area management with local needs and aspirations., Ambio. 33 (2004) 513–519. doi:10.1579/0044-7447-33.8.513.

[4] G.J. Edgar, R.D. Stuart-Smith, T.J. Willis, S. Kininmonth, S.C. Baker, S. Banks, et al., Global conservation outcomes depend on marine protected areas with five key features, Nature. 506 (2014) 216–220. doi:10.1038/nature13022.

[5] T.S. Agardy, Marine protected areas and ocean conservation, Academic Press, 1997.

[6] B. Worm, R. Hilborn, J.K. Baum, T. a Branch, J.S. Collie, C. Costello, et al., Rebuilding global fisheries., Science. 325 (2009) 578–85. doi:10.1126/science.1173146.

[7] CBD, Convention on Biological Diversity - Aichi Biodiversity Targets, (2010). http://www.cbd.int/sp/targets/ (accessed December 1, 2015).

[8] C.J. Klein, C.J. Brown, B.S. Halpern, D.B. Segan, J. McGowan, M. Beger, et al., Shortfalls in the global protected area network at representing marine biodiversity, Sci. Rep. 5 (2015) 17539. doi:10.1038/srep17539.

[9] A.N. Rife, B. Erisman, A. Sanchez, O. Aburto-Oropeza, When good intentions are not enough … Insights on networks of “paper park” marine protected areas, Conserv. Lett. 6 (2013) 200–212. doi:10.1111/j.1755-263X.2012.00303.x.

[10] A.C. Diegues, P.J. Nogara, O nosso lugar virou parque: estudo sócio-ambiental do Saco de Mamanguá-Parati-Rio de Janeiro, Sao Paulo (Brazil) Nucleo de Apoio a Pesquisa sobre Populacoes Humanas e Areas Umidas Brasileiras/CEMAR, Univ. de Sao Paulo, 1999.

[11] R. Devillers, R.L. Pressey, A. Grech, J.N. Kittinger, G.J. Edgar, T. Ward, et al., Reinventing residual reserves in the sea: Are we favouring ease of establishment over need for protection?, Aquat. Conserv. Mar. Freshw. Ecosyst. 25 (2014) 480–504. doi:10.1002/aqc.2445.

[12] N.C. Ban, M. Mills, J. Tam, C.C. Hicks, S. Klain, N. Stoeckl, et al., A social–ecological approach to conservation planning: embedding social considerations, Front. Ecol. Environ. 11 (2013) 194–202. doi:10.1890/110205.

[13] C.J. Klein, A. Chan, L. Kircher, A.J. Cundiff, N. Gardner, Y. Hrovat, et al., Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas., Conserv. Biol. 22 (2008) 691–700. doi:10.1111/j.1523-1739.2008.00896.x.

[14] E.A. Richardson, M.J. Kaiser, G. Edwards-Jones, H.P. Possingham, Sensitivity of marine-reserve design to the spatial resolution of socioeconomic data, Conserv. Biol. 20 (2006) 1191–1202. doi:10.1111/j.1523-1739.2006.00426.x.

[15] R.R. Stewart, H.P. Possingham, Efficiency, costs and trade-offs in marine reserve system design, Environ. Model. Assess. 10 (2005) 203–213. doi:10.1007/s10666-005-9001-y.

[16] B.S. Halpern, S.E. Lester, J.B. Kellner, Spillover from marine reserves and the replenishment of fished stocks, Environ. Conserv. 36 (2010) 268–276. doi:10.1017/S0376892910000032.

[17] P. Leenhardt, B. Cazalet, B. Salvat, J. Claudet, F. Feral, The rise of large-scale marine protected areas: Conservation or geopolitics?, Ocean Coast. Manag. 85 (2013) 112–118. doi:10.1016/j.ocecoaman.2013.08.013.

[18] E.M. De Santo, Missing marine protected area (MPA) targets: How the push for quantity over quality undermines sustainability and social justice, J. Environ. Manage. 124 (2013) 137–146. doi:10.1016/j.jenvman.2013.01.033.

[19] C.J. Klein, C. Steinback, M. Watts, A.J. Scholz, H.P. Possingham, Spatial marine zoning for fisheries and conservation, Front. Ecol. Environ. 8 (2010) 349–353. doi:10.1890/090047.

[20] G. Gurney, J. Cinner, N. Ban, Poverty and protected areas: An evaluation of a marine integrated

conservation and development project in Indonesia, Glob. Environ. 26 (2014) 98–107. http://www.sciencedirect.com/science/article/pii/S0959378014000697 (accessed June 18, 2014).

[21] B.S. Halpern, C.J. Klein, C.J. Brown, M. Beger, H.S. Grantham, S. Mangubhai, et al., Achieving the triple bottom line in the face of inherent trade-offs among social equity, economic return, and conservation., Proc. Natl. Acad. Sci. U. S. A. 110 (2013) 6229–34. doi:10.1073/pnas.1217689110.

[22] C. Klein, M.C. McKinnon, B.T. Wright, H.P. Possingham, B.S. Halpern, Social equity and the probability of success of biodiversity conservation, Glob. Environ. Chang. 35 (2015) 299–306. doi:10.1016/j.gloenvcha.2015.09.007.

[23] T. Mazor, H.P. Possingham, D. Edelist, E. Brokovich, S. Kark, The crowded sea: incorporating multiple marine activities in conservation plans can significantly alter spatial priorities., PLoS One. 9 (2014) e104489. doi:10.1371/journal.pone.0104489.

[24] H.S. Grantham, V.N. Agostini, J. Wilson, S. Mangubhai, N. Hidayat, A. Muljadi, et al., A comparison of zoning analyses to inform the planning of a marine protected area network in Raja Ampat, Indonesia, Mar. Policy. 38 (2013) 184–194. doi:10.1016/j.marpol.2012.05.035.

[25] P.D. Hirsch, W.M. Adams, J.P. Brosius, A. Zia, N. Bariola, J.L. Dammert, Acknowledging conservation trade-offs and embracing complexity., Conserv. Biol. 25 (2011) 259–64. doi:10.1111/j.1523-1739.2010.01608.x.

[26] R. Weeks, G.R. Russ, A. a. Bucol, A.C. Alcala, Incorporating local tenure in the systematic design of marine protected area networks, Conserv. Lett. 3 (2010) 445–453. doi:10.1111/j.1755-263X.2010.00131.x.

[27] J.P. Rodríguez, T.D. Beard, E.M. Bennett, G.S. Cumming, S.J. Cork, J. Agard, et al., Trade-offs across space, time, and ecosystem services, Ecol. Soc. 11 (2006). doi:10.2307/2390206.

[28] S.E. Lester, C. Costello, B.S. Halpern, S.D. Gaines, C. White, J.A. Barth, Evaluating tradeoffs among ecosystem services to inform marine spatial planning, Mar. Policy. 38 (2013) 80–89. doi:10.1016/j.marpol.2012.05.022.

[29] C. White, B.S. Halpern, C. V Kappel, Ecosystem service tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses, (2012). doi:10.1073/pnas.1114215109/-/DCSupplemental.www.pnas.org/cgi/doi/10.1073/pnas.1114215109.

[30] R.L. Moura, N.A. Secchin, G.M. Amado-Filho, R.B. Francini-Filho, M.O. Freitas, C.V. Minte-Vera, et al., Spatial patterns of benthic megahabitats and conservation planning in the Abrolhos Bank, Cont. Shelf Res. 70 (2013) 109–117. doi:10.1016/j.csr.2013.04.036.

[31] R. Moura, G. Dutra, R. Francini-Filho, Fisheries management in the Marine Extractive Reserve of Corumbau, Bahia, … as Fish. Manag. …. (2007) 175–187.

[32] M.O. Freitas, R.L. Moura, R.B. Francini-Filho, C.V. Minte-Vera, Spawning patterns of commercially important reef fish (Lutjanidae and Serranidae) in the tropical western South Atlantic, Sci. Mar. 75 (2011) 135–146. doi:10.3989/scimar.2011.75n1135.

[33] R.L. Moura, C.V. Minte-Vera, I.B. Curado, R.B. Francini-Filho, H.D.C.L. Rodrigues, G.F. Dutra, et al., Challenges and Prospects of Fisheries Co-Management under a Marine Extractive Reserve Framework in Northeastern Brazil, Coast. Manag. 37 (2009) 617–632. doi:10.1080/08920750903194165.

[34] H.S. Grantham, M. Bode, E. McDonald-Madden, E.T. Game, A.T. Knight, H.P. Possingham, Effective conservation planning requires learning and adaptation, Front. Ecol. Environ. 8 (2010) 431–437. doi:10.1890/080151.

[35] A.C. Bastos, V.S. Quaresma, M.B. Marangoni, D.P. D'Agostini, S.N. Bourguignon, P.H. Cetto, et al., Shelf morphology as an indicator of sedimentary regimes: A synthesis from a mixed siliciclastic–carbonate shelf on the eastern Brazilian margin, J. South Am. Earth Sci. 63 (2015) 125–136. doi:10.1016/j.jsames.2015.07.003.

[36] C.C.A. Martins, A. Andriolo, M.H. Engel, P.G. Kinas, C.H. Saito, Ocean & Coastal Management Identifying priority areas for humpback whale conservation at Eastern Brazilian Coast, Ocean Coast. Manag. 75 (2013) 63–71. doi:10.1016/j.ocecoaman.2013.02.006.

[37] J. Laborel, Madréporaires et hydrocoralliaires récifaux des côtes brésiliènnes, Masson, Paris, 1970.

[38] G.M. Amado-Filho, R.L. Moura, A.C. Bastos, L.T. Salgado, P.Y. Sumida, A.Z. Guth, et al., Rhodolith

beds are major CaCO3 bio-factories in the tropical South West Atlantic, PLoS One. 7 (2012) e35171. doi:10.1371/journal.pone.0035171.

[39] A.C. Bastos, R.L. Moura, G.M. Amado-Filho, D.P. D'Agostini, N. a. Secchin, R.B. Francini-Filho, et al., Buracas: Novel and unusual sinkhole-like features in the Abrolhos Bank, Cont. Shelf Res. 70 (2013) 118–125. doi:10.1016/j.csr.2013.04.035.

[40] P. Costa, G. Olavo, A. Martins, Áreas de pesca e rendimentos da frota de linheiros na região central da costa brasileira entre Salvador-BA e o Cabo de São Tomé-RJ, in: Pesca E Potenciais Explor. Recur. Vivos Na Região Cent. Da Zo. Econômica Exclus. Bras., 2005: pp. 57–70.

[41] M.O. Freitas, G.R.A. Rocha, P.D.T.D.C. Chaves, R.L. De Moura, Reproductive biology of the lane snapper, Lutjanus synagris, and recommendations for its management on the Abrolhos Shelf, Brazil, J. Mar. Biol. Assoc. United Kingdom. 94 (2014) 1711–1720. doi:10.1017/S0025315414001088.

[42] M. Previero, C. Minte-Vera, R. Moura, Fisheries monitoring in Babel: fish ethnotaxonomy in a hotspot of common names, Neotrop. Ichthyol. 11 (2013) 467–476.

[43] G.F. Dutra, G.R. Allen, T. Werner, S.A. McKenna, A rapid marine biodiversity assessment of the Abrolhos Bank, Bahia, Brazil, RAP Bull. Biol. Assess. 38 (2005) 155.

[44] G.B. Marchioro, M.A. Nunes, G.F. Dutra, R.L. Moura, P.G.. Pereira, Avaliação dos impactos da exploração o e produção o de hidrocarbonetos no Banco dos Abrolhos e adjacências, Megadiversidade. 1 (2005) 225–310.

[45] ICMBio, Proposição de Unidades de Conservação na Região dos Abrolhos, Brasília-DF, 2011.

[46] Z. Leão, R. Kikuchi, V. Testa, Corals and coral reefs of Brazil, Lat. Am. Coral Reefs. (2003) 9–52.

[47] Z.M.A.N. Leão, R.K.P. Kikuchi, A relic coral fauna threatened by global changes and human activities, Eastern Brazil., Mar. Pollut. Bull. 51 (2005) 599–611. doi:10.1016/j.marpolbul.2005.04.024.

[48] R.B. Francini-Filho, R.L. Moura, Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil, Aquat. Conserv. Mar. Freshw. Ecosyst. 18 (2008) 1166–1179. doi:10.1002/aqc.966.

[49] H.T. Pinheiro, F. Di Dario, L.C. Gerhardinger, M.R.S. de Melo, R.L. de Moura, R.E. Reis, et al., Brazilian aquatic biodiversity in peril., Science. 350 (2015) 1043–4. doi:10.1126/science.350.6264.1043-a.

[50] M.H. Silva, G.S.S. Soares, Boletim estatístico da pesca do Espírito Santo: ano 2011, Vitória, 2013. http://sdrv.ms/172N3pq.

[51] J.B. Teixeira, Novel habitat based approach to predict impacts to fishers when doing marine spatial planning, Unpubl. Results. (n.d.).

[52] DNPM, Sistema de informações geográficas da mineração. Departamento nacional de produção mineral., (2013). http://www.dnpm.gov.br (accessed January 1, 2013).

[53] M.E. Watts, I.R. Ball, R.S. Stewart, C.J. Klein, K. Wilson, C. Steinback, et al., Marxan with Zones: Software for optimal conservation based land- and sea-use zoning, Environ. Model. Softw. 24 (2009) 1513–1521. doi:10.1016/j.envsoft.2009.06.005.

[54] I.R. Ball, H.P. Possingham, M.E. Watts, Marxan and Relatives: Software for Spatial Conservation Prioritization, 2009.

[55] J.A. Ardron, H.P. Possingham, C.J. Klein, Marxan Good Practices Handbook, Version 2, Pacific Marine Analysis and Research Association, Victoria, 2010. ww.pacmara.org.

[56] M. Watts, C. Steinback, C. Klein, User guide: Applying Marxan with Zones. north central coast of California marine study, Univ. Queensland, Brisbane. (2008) 1–40. www.uq.edu.au/marxan.

[57] G.G. Gurney, R.L. Pressey, N.C. Ban, J.G. Álvarez-Romero, S. Jupiter, V.M. Adams, Efficient and equitable design of marine protected areas in Fiji through inclusion of stakeholder-specific objectives in conservation planning., Conserv. Biol. 00 (2015) 1–12. doi:10.1111/cobi.12514.

[58] C.J. Brown, P.J. Mumby, Trade-offs between fisheries and the conservation of ecosystem function are defined by management strategy, Front. Ecol. Environ. 12 (2014) 324–329. doi:10.1890/130296.

[59] I. Ball, H. Possingham, Marxan v1. 8.2: Marine reserve design using spatially explicit annealing, … .

Uq. Edu. Au/Marxan/Docs/Marxan_Manual_1_8_2. Pdf. (2000) 70.

[60] M. Watts, R. Stewart, D. Segan, Using the Zonae Cogito Decision Support System, … /Marxan/Zonae-Cogito- …. (2010) 1–35. www.uq.edu.au/marxan/docs/ZonaeCogitoManual_8March2011.pdf.

[61] L.R. Harris, M.E. Watts, R. Nel, D.S. Schoeman, H.P. Possingham, Using multivariate statistics to explore trade-offs among spatial planning scenarios, J. Appl. Ecol. 51 (2014) 1504–1514. doi:10.1111/1365-2664.12345.

[62] R.L. Pressey, Conservation Planning and Biodiversity: Assembling the Best Data for the Job, Conserv. Biol. 18 (2004) 1677–1681.

[63] C.B. Cogan, B.J. Todd, P. Lawton, T.T. Noji, The role of marine habitat mapping in ecosystem-based management, ICES J. Mar. Sci. 66 (2009) 2033–2042. doi:10.1093/icesjms/fsp214.

[64] J.B. Teixeira, A.S. Martins, H.T. Pinheiro, N.A. Secchin, R.L. Moura, A.C. Bastos, Traditional ecological knowledge and the mapping of benthic marine habitats, J. Environ. Manage. 115 (2013) 241–250. doi:10.1016/j.jenvman.2012.11.020.

[65] A.C. Alcala, G.R. Russ, No-take marine reserves and reef fisheries management in the Philippines: a new people power revolution., Ambio. 35 (2006) 245–254. doi:10.1579/05-A-054R1.1.

[66] J. Matera, Livelihood diversification and institutional (dis-)trust: Artisanal fishing communities under resource management programs in Providencia and Santa Catalina, Colombia, Mar. Policy. 67 (2016) 22–29. doi:10.1016/j.marpol.2016.01.021.

[67] R.B. Francini-Filho, R.L. Moura, Evidence for spillover of reef fishes from a no-take marine reserve: An evaluation using the before-after control-impact (BACI) approach, Fish. Res. 93 (2008) 346–356. doi:10.1016/j.fishres.2008.06.011.

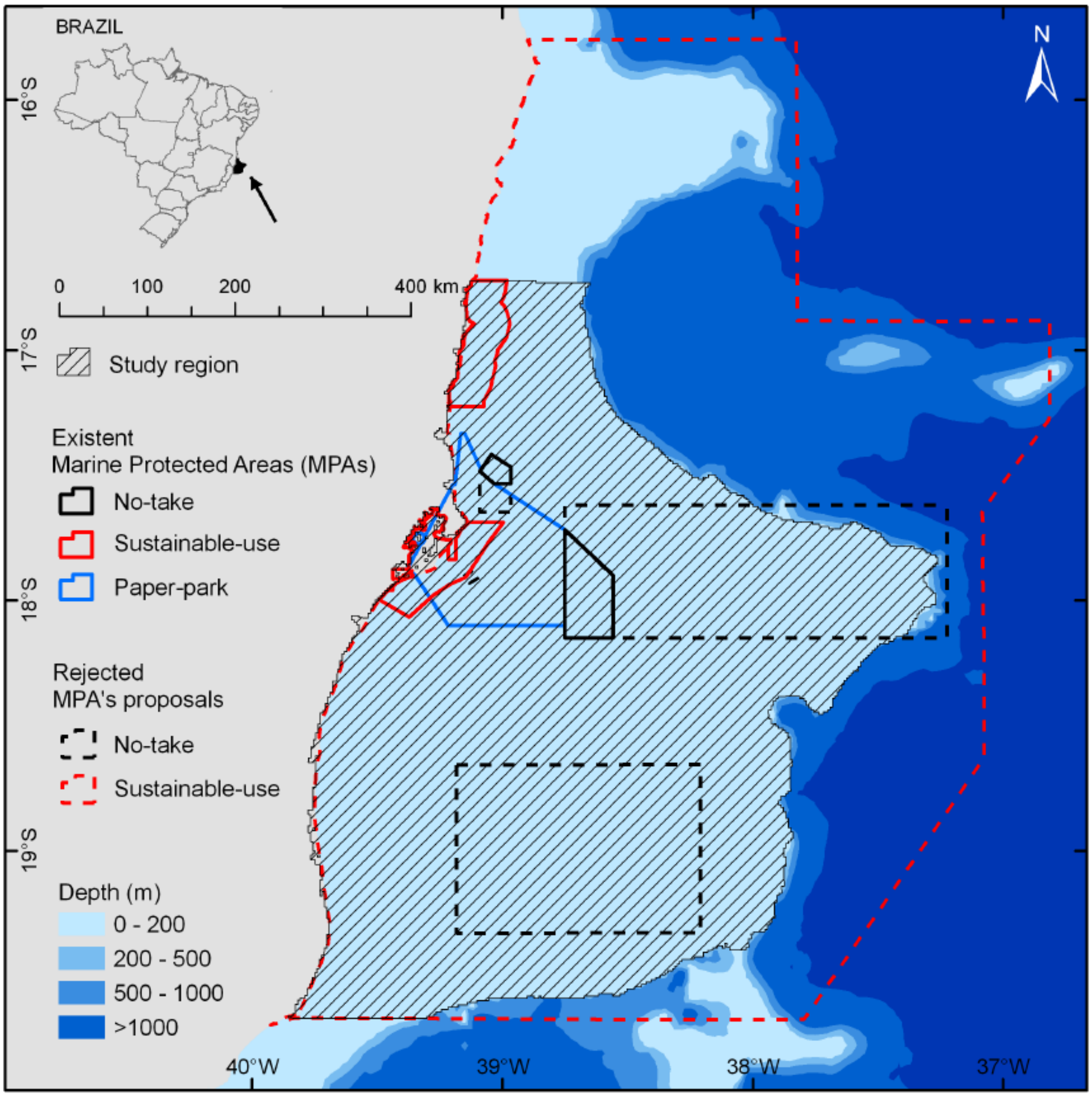


Fig. 1. The Abrolhos Bank shelf, Brazil (study region). Marine Protected Areas coverage and the rejected proposals.

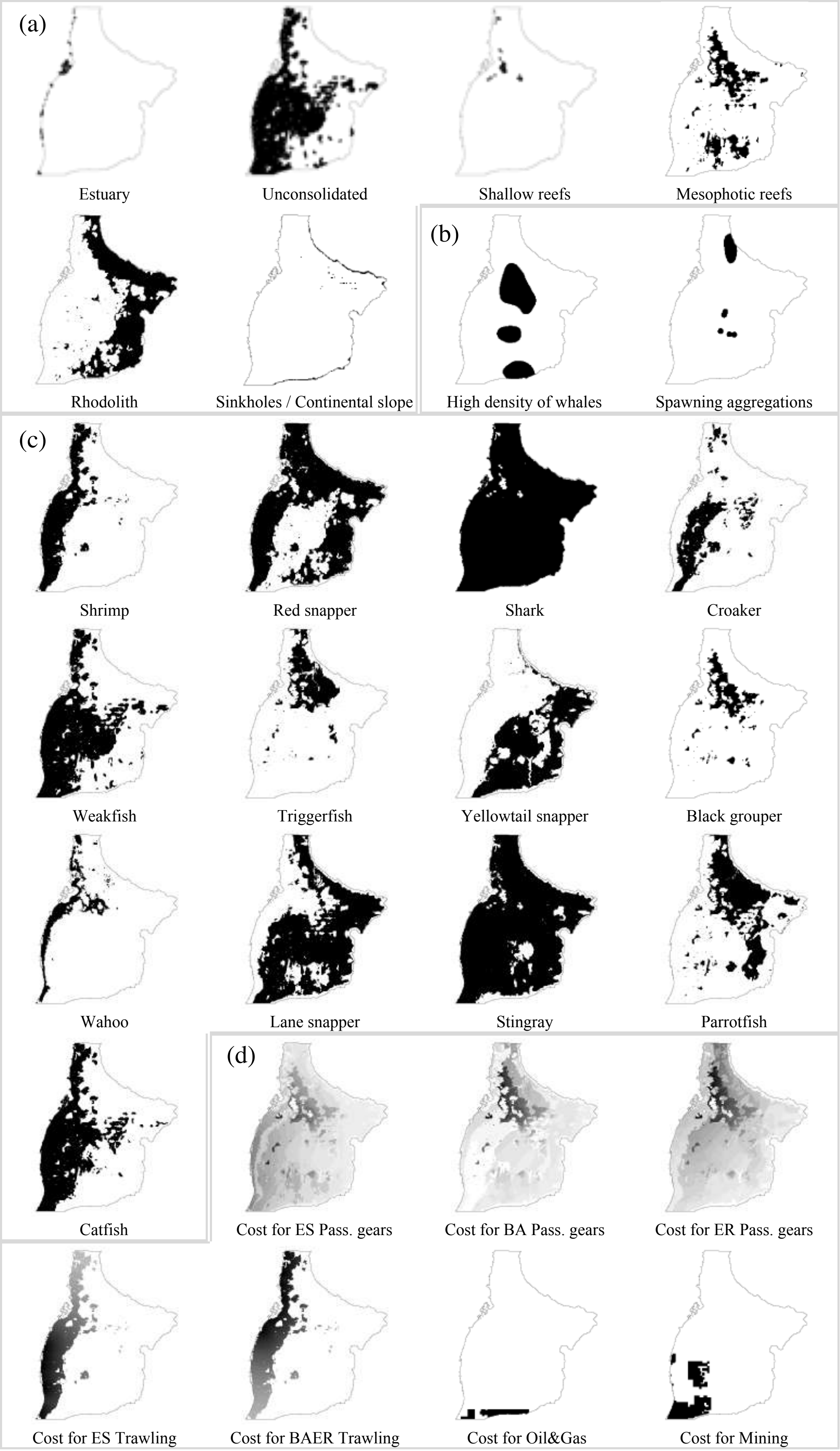


Fig. 2. Megahabitats (a), biodiversity features (b), habitats of fishing resources (c) and opportunity costs of conservation (d) in the Abrolhos Bank. Cost representation: normalized from 0 to 1; light gray = minimun cost; black = maximum cost.

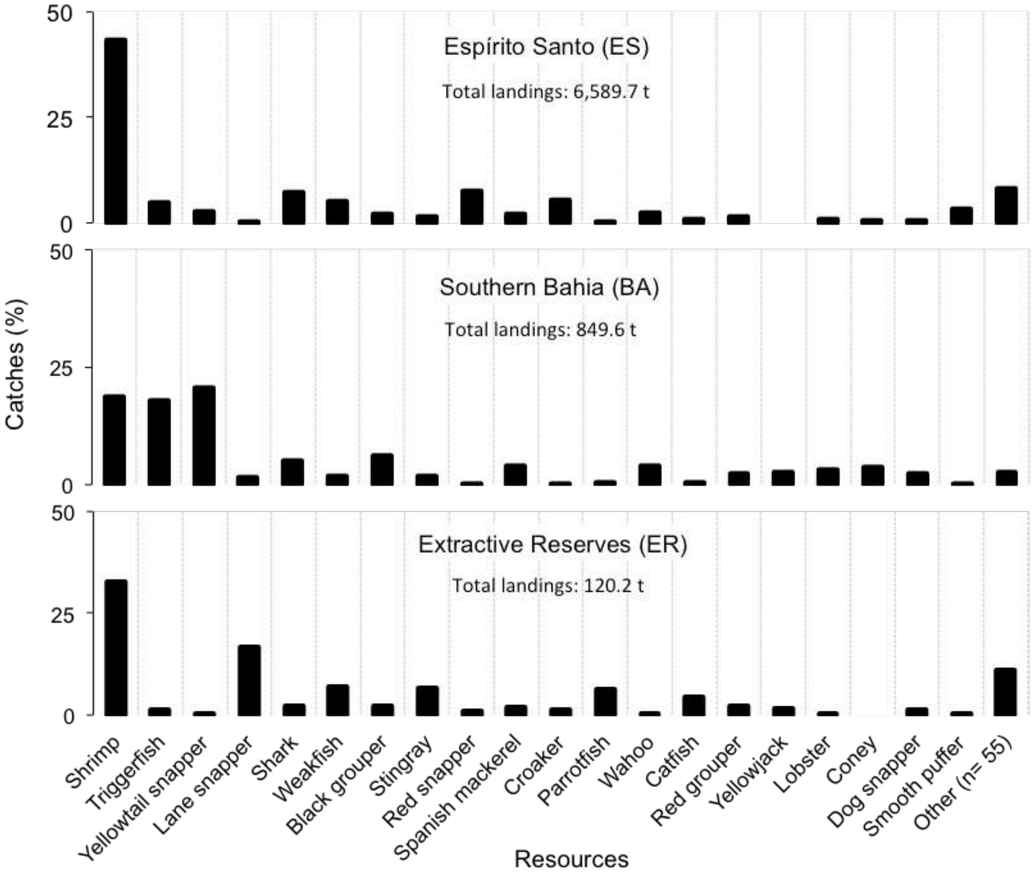


Fig. 3. Three groups of ports with the respective landings in 2011 of the main resources with mapped habitats in the Abrolhos Bank.

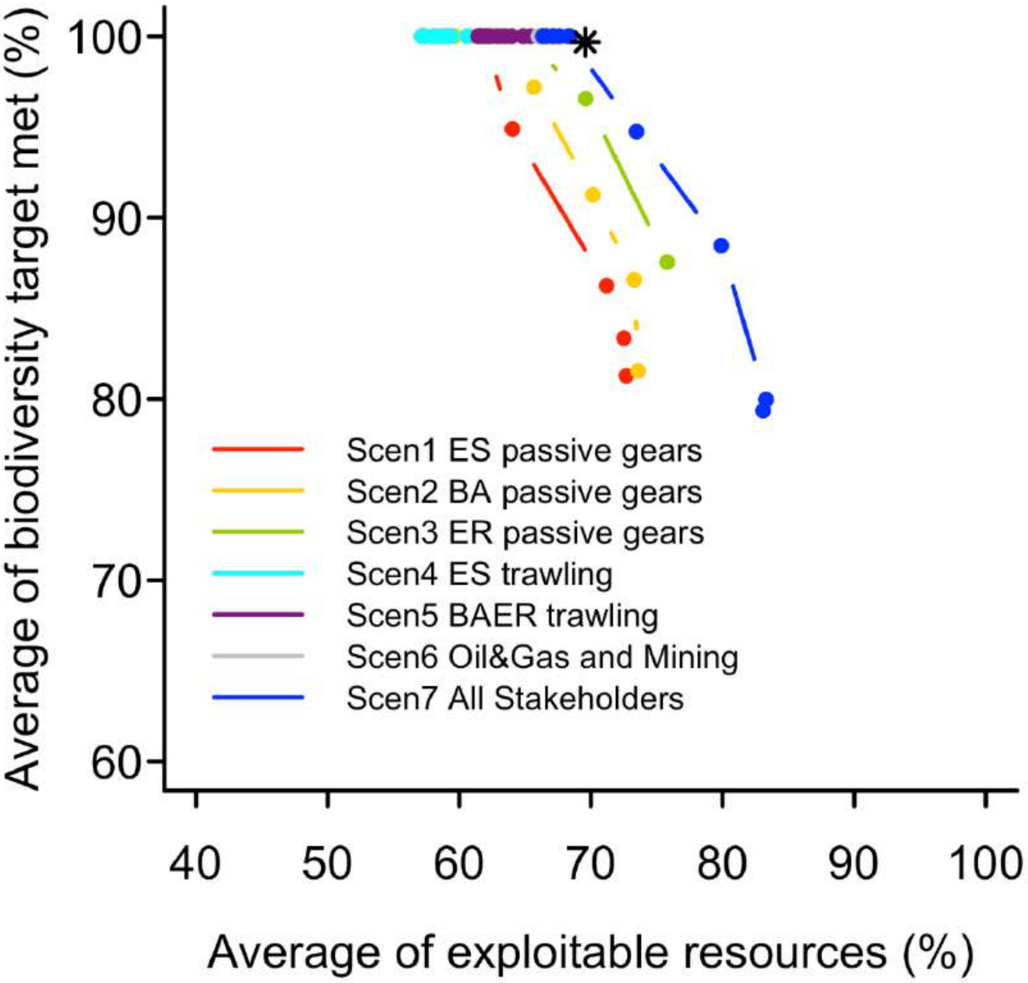


Fig. 4. Trade off curve between the average of percentage of biodiversity target met in the no-take zone and the average of percentage of exploitable resource areas in the stakeholder's zones (Fishing, Oil and Gas, and Mining zones), accounting for different scenarios with specific resources' target.

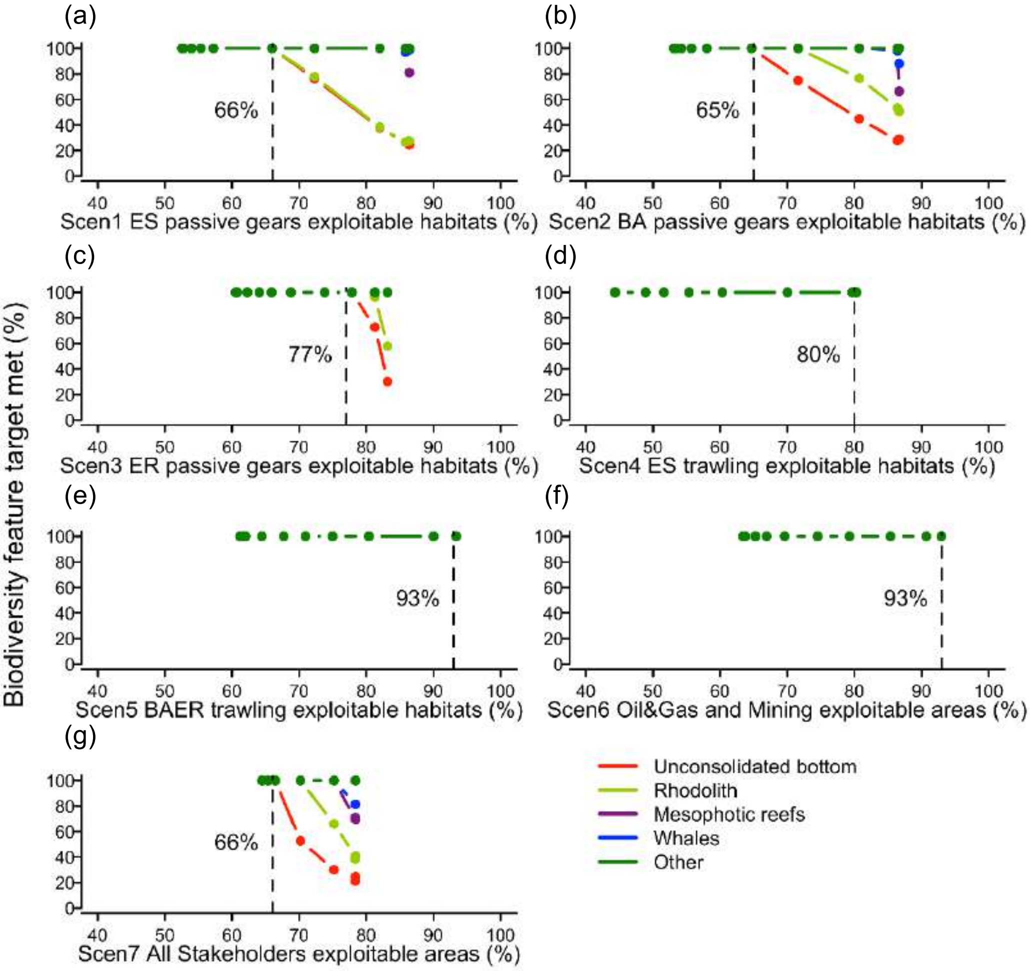


Fig. 5. Tradeoff between the accomplishment of the 30% biodiversity target goal and the average percentage of each stakeholder exploitable area (a-f) Scenarios with specific targets and costs for each of the six stakeholders groups (g) Scenario including every biodiversity target.

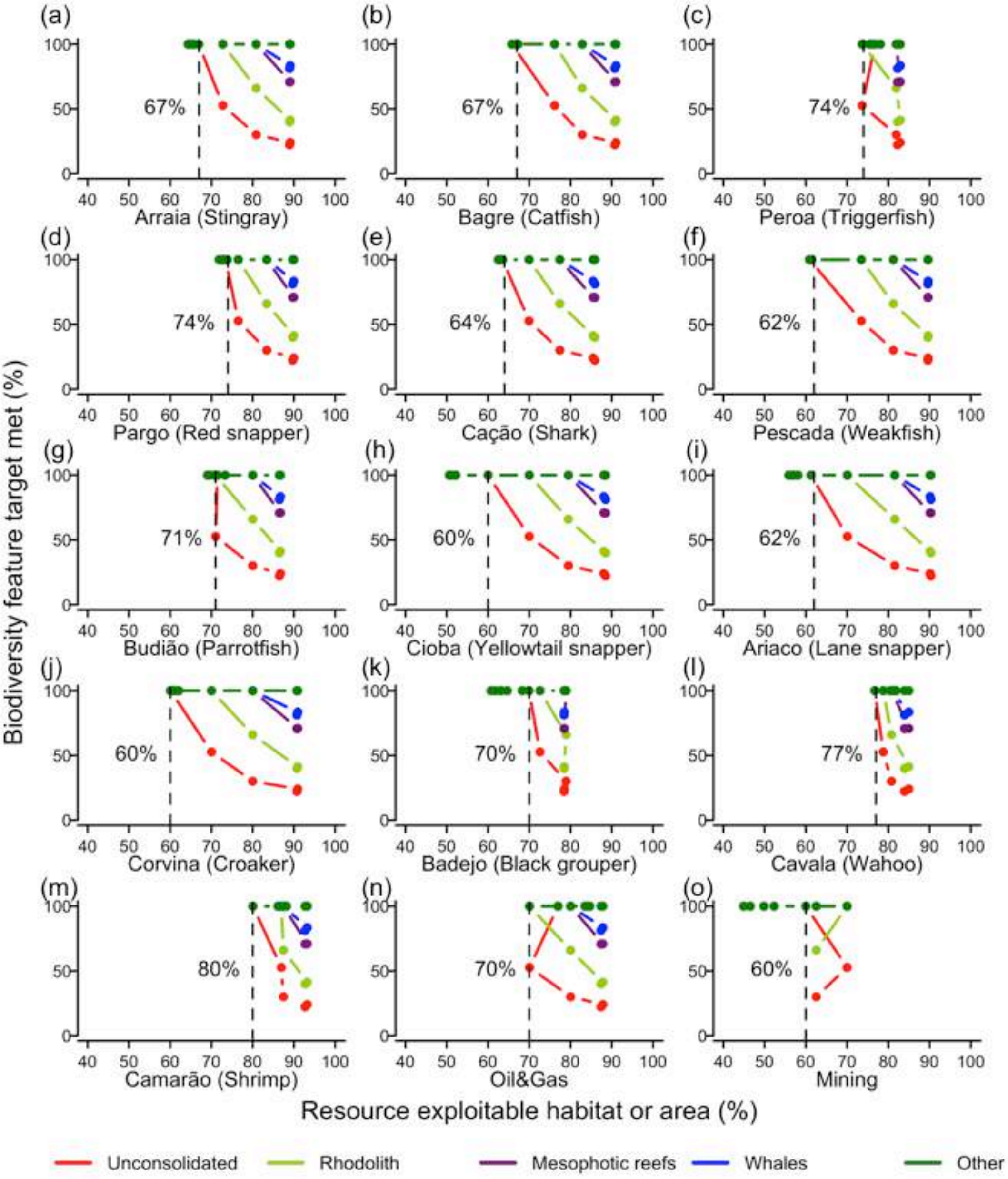


Fig. 6. Tradeoff between the accomplishment of the 30% biodiversity target goal and the exploitable percentage of each resource considering the scenario with every stakeholder group (a-m) Maximum percentage of exploitable habitat in the fishing zone (n-o) Maximum percentage of exploitable areas in the Oil and Gas and Mining zone.

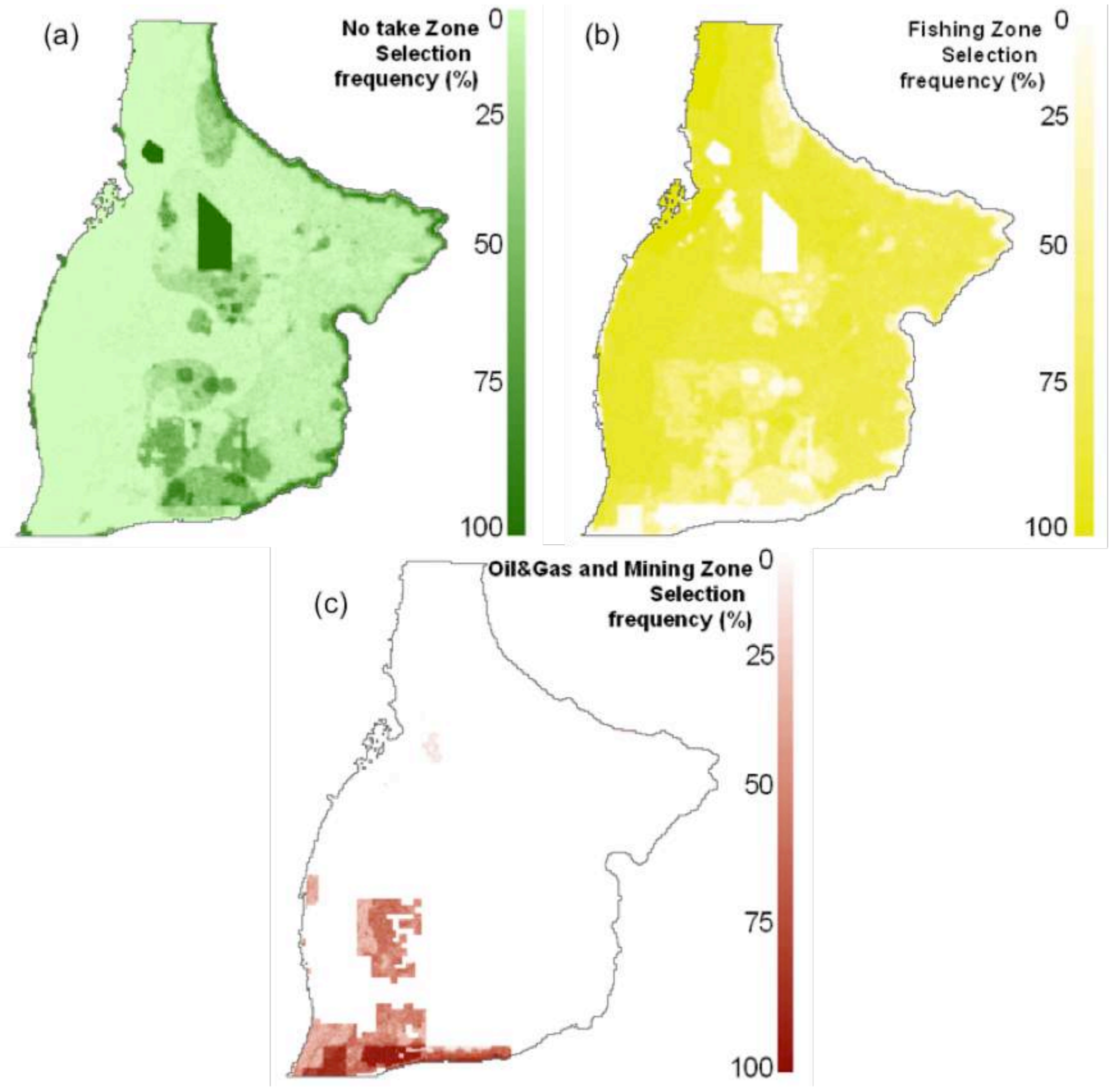


Fig. 7. Irreplaceability map that considered the maximum exploitable area as input targets for fishing and oil and mining zone. (a) Selection frequency of planning units for the No-Take Zone. (b) Selection frequency for the fishing zone. (c) Selection frequency for Oil & Gas and Mining zone.

Table 1. Scenario settings of target, cost and locked areas.

		Biodiversity targets	Fishing targets				Oil&Gas and Mining targets		Opportunity costs considered							Locked areas	
			ES passive gears	BA passive gears	ER passive gears	ES, BA and ER trawling											
		Unconsolidated; Estuary; Rhodolith; Shallow reefs; Mesophotic reefs; Sinkholes; Slope; Whales; Spawning aggregation	Pargo (Red snapper); Cação (Shark); Corvina (Croaker); Pescada (Weakfish); Peroa (Triggerfish)	Ariaco (Lane snapper); Arraia (Stingray); Budião (Parrotfish); Bagre (Catfish); Pescada (Weakfish)	Cioba (Yellowtail snapper); Badejo (Black grouper); Cavala (Wahoo); Peroa (Triggerfish); Cação (Shark)	Camarão (Shrimp)	Oil & Gas	Mining interest	ES passive gears	BA passive gears	ER passive gears	ES trawling	BA/ER trawling	Oil&Gas	Mining	Existent extractive reserves	Marine National Park
S1 Espírito Santo Passive Gears	Z1																
	Z2		0~100%						No								
	Z3	30%															X
	Z4													No	No		
S2 Southern Bahia Passive Gears	Z1																
	Z2			0~100%						No							
	Z3	30%															X
	Z4													No	No		
S3 Extractive Reserves Passive Gears	Z1																
	Z2				0~100%						No					X	
	Z3	30%															X
	Z4													No	No		
S4 Espírito Santo Trawling	Z1																
	Z2					0~100%						No					
	Z3	30%															X
	Z4													No	No		
S5 Bahia/Extract. Reserves Trawling	Z1																
	Z2					0~100%							No			X	
	Z3	30%															X
	Z4													No	No		
S6 Oil&Gas and Mining	Z1																
	Z2								No	No	No	No	No				
	Z3	30%															X
	Z4						0~100%	0~100%						No	No		
S7 All stakeholders	Z1																
	Z2		0~100%	0~100%	0~100%	0~100%			No	No	No	No	No			X	
	Z3	30%															X
	Z4						0~100%	0~100%						No	No		

CONCLUSÕES GERAIS

A revisão da literatura sobre custos de conservação para a pesca evidenciou que a dependência de dados representativos e abrangentes para múltiplas pescarias e múltiplos recursos é um problema recorrente que compromete as iniciativas de planejamento espacial marinho, especialmente a criação de Áreas Marinhas Protegidas (AMPs). A deficiência de dados representativos para os diferentes grupos de pescadores é típica dos países em desenvolvimento, e representa uma lacuna importante para o (re)estabelecimento das iniciativas de planejamento espacial na região do Banco dos Abrolhos, onde a pesca artesanal de pequena escala representa uma importante atividade. Esse problema foi endereçado através do desenvolvimento de uma nova abordagem para estimar camadas heterogêneas de custos de oportunidade, baseada na distribuição dos habitats dos recursos pesqueiros.

Para avaliar as permutas (tradeoffs) entre a conservação da biodiversidade e a exploração de recursos naturais, além dos setores minerário e de óleo e gás, foram evidenciados cinco grupos de pescadores que necessitam de representação específica: pescadores com artes passivas do Espírito Santo; pescadores com artes passivas do Sul da Bahia; pescadores com artes passivas das reservas extrativistas; pescadores com rede de arrasto do Espírito Santo; e pescadores com rede de arrasto do Sul da Bahia e das Reservas Extrativistas. A combinação entre os custos destes grupos gerou uma camada de custo representativa para o setor pesqueiro como um todo. Nesse contexto, a análise de permutas revelou que metas ambiciosas de proteção de 30% dos alvos de biodiversidade, incluindo todos os megahabitats bênticos, implicou em redução média de 44% da área disponível para exploração dos principais recursos. Essa perda pode ser reduzida a partir do refinamento das metas de conservação e da inclusão de zonas de uso múltiplo que forneçam contribuição parcial para seu atingimento.

O modelo disponibilizado permite a elaboração de cenários custo-efetivos de uso múltiplo para o Banco dos Abrolhos, atendendo a metas globais de conservação. Além disso, permite avaliar as permutas (tradeoffs) entre a conservação da biodiversidade e a exploração de recursos naturais sob diferentes configurações, podendo subsidiar a retomada das discussões com os atores envolvidos com a criação de AMPs.