**UNIVERSIDADE FEDERAL DE ALAGOAS**
**INSTITUTO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE**
**Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos**

**CACILDA MICHELE CARDOSO ROCHA CELA**

# PEIXES DE RECIFES DE CORAL, PESCARIAS E CONSERVAÇÃO NO ANTROPOCENO

**MACEIÓ - ALAGOAS**
**Fevereiro/2023**

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

**Orientador: Prof. Dr. Cláudio Luis Santos Sampaio**

**Co-Orientadora: Profa. Dra. Taciana Pinto Kramer**

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**Cacilda Michele Cardoso Rocha Cela**

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Tese aprovada em 28 de fevereiro de 2023.

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**Maceió-Alagoas**
**Fevereiro/2023**

*Dedico esta tese à minha família, e àquelas de baixa renda que não medem esforços para educar seus filhos com honestidade, superação e garra; e aos Povos e Comunidades Tradicionais que utilizam a biodiversidade do ambiente costeiro e marinho como meios de sobrevivência; fonte de inspiração deste trabalho.*

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*“Eu gostaria que você usasse todos os meios à sua disposição– filmes, expedições, a web, novos submarinos, campanhas – para inflamar o apoio público a uma rede global de áreas marinhas protegidas, Hope Spots grandes o suficiente para salvar e restaurar o Oceano, o coração azul do planeta. – Dra. Sylvia Earle”*

## RESUMO

Recifes de coral contribuem para a regulação do clima planetário em diferentes escalas espaciais, e participam da promoção da resiliência de zonas costeiras e marinhas. O conjunto da biodiversidade recifal, promove a manutenção de bens e Serviços Ecossistêmicos (SEs) imateriais e materiais, que são preponderantes para a garantia da segurança alimentar, promoção do bem-estar individual e coletivo, senso de pertencimento, e socioeconômico de milhões de pessoas. Entretanto, as mudanças climáticas, tendências de sobrepesca, ausência de planejamento espacial costeiro e marinho, além das atividades turísticas não manejadas, contribuem para a poluição, e aceleram a degradação desses ambientes. Sinergisticamente esses estressores contribuem para a alteração dos ecossistemas, pela modificação da estrutura populacional, biomassa, e diversidade de grupos tróficos de peixes nas comunidades recifais. Os efeitos dessas mudanças desencadeiam diminuições de áreas de cobertura de corais pétreos, e um aumento gradativo e substituição por macroalgas, resultando em mudanças de fase. Na teia trófica recifal, grupos de peixes recifais piscívoros, carnívoros e herbívoros equilibram o balanço entre a produtividade primária e o consumo, mas, a sobrepesca enfraquece as interações induzindo cascatas tróficas acelerando as mudanças. O objetivo geral desta tese foi investigar como o conhecimento científico sobre peixes recifais herbívoros avançou no Brasil, incluindo a percepção humana para a conservação da biodiversidade marinha e processos ecossistêmicos desempenhados pelos peixes recifais. No primeiro capítulo, uma análise cienciométrica evidenciou que em mais de cinquenta anos, o conhecimento científico multidisciplinar avançou no Atlântico Sudoeste (AS), incluindo as metodologias de amostragem dos ambientes e táxon, componentes e processos ecossistêmicos mais estudados. As lacunas evidenciadas apontaram para a necessidade de identificar os estressores antrópicos que degradam os recifes de coral, a ocorrência das mudanças de fase no AS, e a importância de utilizar o Conhecimento Ecológico Local (CEL) de pescadores em pesquisas para identificar os SEs relacionados aos peixes, pescarias e a proposição de soluções práticas para a conservação e o manejo local. No segundo capítulo, utilizamos o CEL de pescadores para preencher as lacunas identificadas no primeiro capítulo, e testamos a hipótese da ocorrência da Síndrome de Deslocamento de Referencial (SDR) nas capturas de grupos tróficos de peixes carnívoros, piscívoros, e herbívoros, entre diferentes categorias de pescadores por tempo de experiência em uma ilha tropical. Presumimos que tendências da diminuição de estoques de diferentes grupos tróficos, e a co-ocorrência de estressores disparam mudanças de fase. Desde 1952 até 2022, os peixes e pescarias são SEs que promovem alimentos, trabalho e renda para as pessoas. Entretanto, o aumento da quantidade e a multiplicidade de artes de pesca sendo incrementadas ao longo do tempo, os relatos sobre a diminuição das capturas de maiores indivíduos piscívoros e herbívoros na zona rasa, o declínio na biomassa reportados destes grupos, indica um aumento gradativo no esforço pesqueiro sugerindo que está havendo depleção do estoque. Detectamos um desvio de percepção pelas gerações, que foi evidenciado a partir da observação do aumento do estoque e mudança de alvos da categoria experiente; alinhada à percepção de declínio no estoque, aceitação da raridade, e desconhecimento de grandes espécies carnívoras e herbívoras pela intermediária; enquanto que a iniciante considerou como um padrão comum espécies de budiões e vermelhos não crescerem muito. A sobrepesca, a degradação de habitats, e o turismo não manejado foram identificados como os principais estressores antrópicos. As soluções apontadas foram a diminuição de artes de baixa seletividade nos recifes de coral como as redes de emalhar, manejo (ex.: seletividade na captura), alinhado a efetiva fiscalização das pescarias, conjuntamente com o monitoramento das atividades turísticas. Uma proposta que inclua o manejo das pescarias baseado no ecossistema, e o planejamento espacial costeiro e marinho associada à adoção de uma governança multinível em redes de colaboração pode minimizar os estressores, e consistem em alternativas que podem promover o enfrentamento, além da mitigação das mudanças de fase.

**Palavras-chave:** Conhecimento Ecológico Local, Co-ocorrência de estressores antrópicos, Mudanças de fase, Serviços Ecossistêmicos, Síndrome de Deslocamento de Referencial.

**ABSTRACT**

Coral reefs contribute to climate regulation on planet at different spatial scales and participate in promoting the resilience of coastal and marine areas. The set of reef biodiversity promotes the maintenance of immaterial and material goods and Ecosystem Services (SEs), which are preponderant for guaranteeing food security, promoting individual and collective well-being, sense of place, and socioeconomic benefits of millions of people. However, climate change, overfishing trends, lack of marine spatial planning, unmanaged tourism activities, contribute to pollution, and accelerate the degradation of these environments. Synergistically, these stressors contribute to the alteration of ecosystems, by modifying the population structure, biomass, and diversity of trophic groups of fish in reef communities. The effects of these changes trigger a decrease in stony coral cover areas, and a gradual increase and replacement by macroalgae, resulting in phase shifts. In the reef food web, groups of carnivorous, piscivorous and herbivorous reef fish promotes the balance between primary productivity and consumption, but overfishing weakens interactions inducing trophic cascades accelerating changes. The general objective of this thesis was to investigate how scientific knowledge about herbivorous reef fish has advanced in Brazil, including the human perception for the conservation of marine biodiversity and ecosystem processes performed by reef fish. In the first chapter, a scientometric analysis showed that in more than fifty years, multidisciplinary scientific knowledge has advanced in the Southwest Atlantic (SWA), including the most studied environments and taxon sampling methodologies, components, and ecosystem processes. The evidenced gaps pointed to the need to identify the anthropic stressors that degrade coral reefs, the occurrence of phase shifts in the SWA, and the importance of using the Local Ecological Knowledge (LEK) of fishers in research to identify the SEs related to the fish, fisheries and proposing practical solutions for conservation and local management. In the second chapter, we use the LEK of fishers to fill in the gaps identified in the first chapter, and we test the hypothesis of the occurrence of the Shifting Baseline Syndrome (SBS) in the catches of trophic groups of carnivorous, piscivorous, and herbivorous fish, among different generations of fishermen on a tropical island. We presume that decreasing trends in stocks of different trophic groups and the co-occurrence of stressors trigger phase shifts. From 1952 to 2022, fish and fisheries are SEs that promote food, jobs, and income for people. However, the increase in the quantity and the multiplicity of fishing gear being increased over time, the reports on the decrease in catches of larger species of all trophic groups in the shallow zone, the decline in biomass reported by fishermen, indicates a gradual increase in the fishing effort suggesting that there is a depletion of the stock. We detected a shift in perception across generations, which was evidenced by observing the increase in stock and changing targets in the experienced category; aligned with the perception of decline in stock, acceptance of rarity, and lack of knowledge of large carnivorous and herbivorous species by the beginners; while the beginner considered parrotfish and snappers species not to grow much as a common pattern. Overfishing, habitat degradation, and unmanaged tourism were identified as the main anthropogenic stressors. The solutions pointed out were the reduction of low selectivity gear in coral reefs such as gill nets, management (e.g.: selectivity in capture), aligned with the effective inspection of fisheries, together with the monitoring of tourism activities. A proposal that includes ecosystem-based fisheries management, and coastal and marine spatial planning associated with the adoption of multilevel governance in collaborative networks can minimize stressors, and consist of alternatives that can promote coping, in addition to mitigating phase shifts.

**Keywords:** Local Ecological Knowledge, Co-occurrence of human stressors, Phase Shifts, Ecosystem Services, Shifting Baseline Syndrome.

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## Capítulo I: A review of the knowledge of reef fish in the Southwest Atlantic

*bahianus*; *Haemulon aurolineatum*; *Acanthurus chirurgus*; *Lutjanus jocu*; *Acanthurus coeruleus*; *Chaetodon striatus*; *Diplectrum radiale*; *Lutjanus synagris*; *Halichoeres poeyi*; *Haemulon parra*; *Haemulon plumierii*; *Lutjanus analis*; *Cephalopholis fulva*; *Anisotremus virginicus*; *Haemulon steindachneri* and *Epinephelus marginatus.*

**Figura 11** The number of the most cited reef fish families studied from 1967 to 2020 in Southwestern Atlantic.

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**Figura 14** Ecosystem processes studied every five years from 1967 to 2020 in Southwestern Atlantic. BioCoMa: Biodiversity Conservation and Management; Biogeo: Biogeographic; SociBeh: Social behaviour; SpBiology: Species biology.

**Capítulo II: Coral reef fish, fisheries, and people in a tropical island in the Anthropocene**

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## SUMÁRIO

# 1 INTRODUÇÃO GERAL

O antropoceno é uma época na história da Terra, em que as interações humanas pervasivas pela extração e usos dos recursos naturais, estão alterando enormemente a dinâmica dos seus processos geológicos e ecológicos (Lewis and Maslin, 2015). Uma clara visão sistêmica das interações humanas topo-base é observada pela co-ocorrência de múltiplos estressores, como a degradação de habitats, poluição, contaminação, e a sobrepesca (Steffen et al., 2015). A humanidade é a principal responsável pela alteração em cerca de 75% dos padrões naturais de funcionamento dos ecossistemas terrestres e do Oceano (Hughes et al., 2013), cujo metabolismo social e econômico demanda crescentes extrações de recursos, levando-os à escassez, e extinções de espécies (Young et al.; 2016; Malhi, 2017).

Estressores antrópicos criam mecanismos que perturbam a estabilidade e a capacidade de ecossistemas naturais de absorver mudanças, movendo-os de um estado a outro, que oscila entre os limiares de equilíbrio, instabilidade, neutro, e transições aleatórias criando flutuações no comportamento de suas variáveis abióticas e bióticas (Holling, 1973; Rocha, 2022). A persistência dos ecossistemas no estado natural para um alterado, e as mudanças na estrutura e nos padrões de funcionamento são disparadas, podendo levá-los a perda da resiliência (Holling, 1973; Rocha, 2022).

Em recifes de coral, eventos estocásticos (ex.: desastres naturais, cataclismas), e determinísticos (ex.: co-ocorrência de múltiplos estressores antrópicos) provocam *outbreaks*, surtos de doenças nos corais, além das espécies invasoras, e da sobrepesca conduzindo o ecossistema entre um estado estável alternativo para um novo estado perturbado (Scheffer et al., 2001; Scheffer and Carpenter, 2003). A mudança de fase ecossistêmica, é então observada, pelas transições catastróficas no aumento do número de espécies oportunistas, de reprodução rápida, as chamadas *r*-estrategistas como a predominância de macroalgas foliosas, filamentosas, turfs algais, invertebrados bentônicos e planctônicos (Bellwood et al., 2004; Norström et al., 2009; Nyström et al., 2012). Quando o ecossistema apresenta um estado de *hysteresis* no qual as transições para o estado original foram modificadas persistentemente, a recuperação da resiliência se torna difícil (Scheffer and van Nes, 2004).

A co-ocorrência de múltiplos estressores nos recifes de coral (Norström et al., 2016; Setter; Franklin; Mora, 2022; Soares et al., 2022), muitas vezes associados a uma gestão e governança inefetivas, podem causar alterações profundas na biodiversidade, e no conjunto de bens e Serviços Ecossistêmicos (SEs) fornecidos para as pessoas, bem como nos valores estéticos das paisagens recifais que são difíceis ou impossíveis de reverter (Hughes et al., 2013).

A sobrepesca é um estressor severo que altera múltiplos processos ecológicos como as interações competitivas interespecíficas e multiespecíficas (Scheffer and van Nes, 2004), enfraquecendo a conectividade das interações topo-base e base-topo da teia trófica (Bascompte et al., 2005; Pauly. et al., 1998; Scheffer et al., 2005). A sobrepesca leva a diminuição dos padrões de abundância, densidade, diversidade funcional e taxonômica, disparando o fenômeno das cascatas tróficas, e promovendo transições críticas levando às mudanças de fase (Jackson et al., 2001; Pandolfi et al., 2003; Pershing et al., 2015).

Diferentes grupos tróficos de peixes recifais, como os carnívoros, piscívoros, e herbívoros participam da transferência de energia e matéria que equilibram o balanço entre os processos de produtividade primária e o consumo nos recifes (Ladd and Shantz, 2020). Os peixes piscívoros e carnívoros participam do equilíbrio trofodinâmico controlando a abundância, densidade e a biomassa de outros níveis tróficos de vertebrados e invertebrados nos recifes (Estes et al., 2011), inclusive eliminando animais doentes e espécies invasoras (Hammerschlag et al., 2019; Holmlund and Hammer, 1999). Os grupos funcionais de peixes herbívoros, promovem a manutenção da biodiversidade, resiliência e a saúde dos corais, atuando como raspadores, podadores, e bioerodidores participam da produção e transporte de sedimentos (Longo et al., 2014; Tebbett et al., 2020). Essas interações bióticas e abióticas dos herbívoros, são responsáveis pela manutenção do controle da produtividade de macroalgas e turfs liberando espaços no substrato recifal para o assentamento de pólipos de corais, recrutamento e o estabelecimento de novas colônias (Bennett et al., 2015; Lefcheck et al., 2019).

Recifes de coral regulam e mantêm processos biológicos que são preponderantes para o equilíbrio do clima global sequestrando dióxido de carbono, liberando oxigênio para a atmosfera, promovendo a resiliência, e saúde do Oceano (IPCC, 2022). Os SEs materiais e imateriais dos recifes são responsáveis por promoverem alimentos, renda e labor para milhões de pessoas através da pesca e do turismo (Cinner et al., 2020; FAO, 2018; Spalding et al., 2017).

No antropoceno, para alcançar os objetivos propostos para o desenvolvimento sustentável do Oceano, a manutenção dos SEs, e continuar a promover indefinidamente o crescimento econômico, a sociedade precisará reduzir os efeitos dos múltiplos estressores nos ecossistemas marinhos (Knowlton, 2021) e as vulnerabilidades sociais associadas (Hicks, 2011; McClanahan et al., 2008). Entretanto, os cenários são diversos, tanto para amenização ou aumento das taxas de pobreza, quanto pela escassez através da redução e produção pesqueira, falta de saneamento (eutrofização, lixo, poluição e contaminantes), e declínios massivos da biodiversidade (Eddy et al., 2021; Harborne et al., 2017). Não podemos ignorar que o planeta está vivenciando rápidas mudanças ambientais, sociais e a busca pelo desenvolvimento econômico é crescente e sem precedentes, onde o comportamento humano é o principal impulsionador destas transformações (Hughes et al., 2013; Norström et al., 2016).

Sabendo que a resiliência ecossistêmica opera em diferentes escalas espaciais, nas áreas marinhas protegidas, para compatibilizar a manutenção da resiliência recifal e o provimento dos SEs, o reconhecimento de ameaças potenciais é estratégico para a efetiva conservação e manejo, objetivando os múltiplos usos de forma sustentável (Hughes et al., 2003). Nesse contexto, é necessário o entendimento das mudanças pretéritas que os ecossistemas sofreram, e identificar se está ocorrendo Síndrome de Deslocamento de Referencial (SDR) geracional para a proposição de programas de pesquisa visando a conservação da biodiversidade (Papworth et al., 2009; Pauly, 1995). A SMR descreve a tendência gradual que novas gerações têm de desconsiderar mudanças pretéritas na biomassa e riqueza nas pescarias, aceitando a cada nova geração um padrão mais baixo como uma norma (Pauly, 1995).

Detectar a ocorrência precoce da SMR pode subsidiar o desenvolvimento de programas de pesquisas de longa duração, e o estabelecimento de cooperações para a transferência de conhecimentos que podem nortear planos de conservação (Soga and Gaston, 2018), manejo e governança da biodiversidade localmente (Knowlton and Jackson, 2008a). Nesta perspectiva, uma combinação entre o Conhecimento Ecológico Local (CEL) e o científico surge como um novo paradigma na busca por soluções democráticas e participativas (Hughes et al., 2005) para garantir a resiliência ambiental e social (Folke, 2006). Frente aos múltiplos estressores, a efetividade da gestão e governança dos recifes de coral é estratégica para a manutenção dos seus SEs, as quais dependem da adoção de perspectivas multiníveis através da criação de arranjos cooperativos entre diferentes setores da sociedade para o estabelecimento de diálogos e busca por soluções coletivas (Díaz et al., 2018; Hughes et al., 2005; CB, 2020).

O CEL de pescadores é utilizado e recomendado como uma ferramenta democrática (Fisher et al., 2015) para entender as mudanças pretéritas nos ecossistemas, e detectar desvios de percepção, ameaças atuais e as soluções coletivas para a conservação e o manejo local dos recursos marinhos (Berkström et al., 2019; Knowlton and Jackson, 2008b). A necessidade de melhorar a gestão dos recifes de coral nas diferentes escalas em todo o mundo é imensa e urgente (Campbell et al., 2016; Hughes et al., 2013), sendo assim, entender quais são os impulsionadores dessas mudanças pode ajudar a sociedade a transformar a governança local através de ações práticas e engajamento social para a sua conservação e o manejo (Bender et al., 2022; Folke et al., 2011).

As pesquisas desta tese objetivaram contribuir para o entendimento dos mecanismos relacionados às mudanças de fase nos recifes de coral relacionada aos processos ecológicos dos peixes, e identificar como o CEL pode contribuir para avançar em práticas conservacionistas e para gestão sustentável desses ecossistemas em escala local.

No primeiro capítulo através de revisão sistemática procurou-se identificar como o conhecimento científico sobre os peixes recifais avançou no Atlântico Sudoeste. No segundo capítulo através de entrevistas, o CEL foi utilizado em escala local para: testar a hipótese da ocorrência da Síndrome de Deslocamento de Referencial (SDR) entre diferentes gerações de pescadores; para identificar como grupos tróficos de peixes recifais e pescarias promovem SEs para as pessoas; bem como identificar a co-ocorrência de estressores antrópicos, as mudanças de fase; e soluções alternativas para a mitigação dos impactos.

# REFERÊNCIAS


Bascompte, J., Melian, C.J., Sala, E., 2005. Interaction strength combinations and the overfishing of a marine food web. Proceedings of the National Academy of Sciences 102, 5443–5447. https://doi.org/10.1073/pnas.0501562102

Bellwood, D.R., Hughes, T.P., Folke, C., Nyström, M., 2004. Confronting the coral reef crisis. Nature 429, 827–833. https://doi.org/10.1038/nature02691

Bender, M., Bustamante, R., Leonard, K., 2022. Living in relationship with the Ocean to transform governance in the UN Ocean Decade. PLoS Biol 20, e3001828. https://doi.org/10.1371/journal.pbio.3001828

Bennett, S., Wernberg, T., Harvey, E.S., Santana-Garcon, J., Saunders, B.J., 2015. Tropical herbivores provide resilience to a climate-mediated phase shift on temperate reefs. Ecol Lett 18, 714–723. https://doi.org/10.1111/ele.12450

Berkström, C., Papadopoulos, M., Jiddawi, N.S., Nordlund, L.M., 2019. Fishers' Local Ecological Knowledge (LEK) on Connectivity and Seascape Management. Front Mar Sci 6, 1–10. https://doi.org/10.3389/fmars.2019.00130

Campbell, L.M., Gray, N.J., Fairbanks, L., Silver, J.J., Gruby, R.L., Dubik, B.A., Basurto, X., 2016. Global Oceans Governance: New and Emerging Issues. Annu Rev Environ Resour 41, 517–543. https://doi.org/10.1146/annurev-environ-102014-021121

Cinner, J.E., Zamborain-Mason, J., Gurney, G.G., Graham, N.A.J., MacNeil, M.A., Hoey, A.S., Mora, C., Villéger, S., Maire, E., McClanahan, T.R., Maina, J.M., Kittinger, J.N., Hicks, C.C., D'agata, S., Huchery, C., Barnes, M.L., Feary, D.A., Williams, I.D., Kulbicki, M., Vigliola, L., Wantiez, L., Edgar, G.J., Stuart-Smith, R.D., Sandin, S.A., Green, A.L., Beger, M., Friedlander, A.M., Wilson, S.K., Brokovich, E., Brooks, A.J., Cruz-Motta, J.J., Booth, D.J., Chabanet, P., Tupper, M., Ferse, S.C.A., Sumaila, U.R., Hardt, M.J., Mouillot, D., 2020. Meeting fisheries, ecosystem function, and biodiversity goals in a human-dominated world. Science (1979) 368, 307–311. https://doi.org/10.1126/science.aax9412

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., van Oudenhoven, A.P.E., van der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C.A., Hewitt, C.L., Keune, H., Lindley, S., Shirayama, Y., 2018. Assessing nature's contributions to people. Science (1979) 359, 270–272. https://doi.org/10.1126/science.aap8826

Eddy, T.D., Lam, V.W.Y., Reygondeau, G., Cisneros-Montemayor, A.M., Greer, K., Palomares, M.L.D., Bruno, J.F., Ota, Y., Cheung, W.W.L., 2021. Global decline in capacity of coral reefs to provide ecosystem services. One Earth 4, 1278–1285. https://doi.org/10.1016/j.oneear.2021.08.016

Estes, J.A., Terborgh, J., Brashares, J.S., Power, M.E., Berger, J., Bond, W.J., Carpenter, S.R., Essington, T.E., Holt, R.D., Jackson, J.B.C., Marquis, R.J., Oksanen, L., Oksanen, T., Paine, R.T., Pikitch, E.K., Ripple, W.J., Sandin, S.A., Scheffer, M., Schoener, T.W., Shurin, J.B., Sinclair, A.R.E., Soulé, M.E., Virtanen, R., Wardle, D.A., 2011. Trophic Downgrading of Planet Earth. Science: 333, 301–306. https://doi.org/10.1126/science.1205106

FAO, 2018. Review of the state of world marine fishery resources, Organization.

Fisher, J., Jorgensen, J., Josupeit, H., Kalikoski, D., Lucas, C.M., 2015. Fishers' knowledge and the ecosystem approach to fisheries. Applications, experiences and lessons in Latin America, FAO technical paper.

Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change 16, 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S.R., Stuart Chapin, F., Crépin, A.S., Daily, G., Danell, K., Ebbesson, J., Elmqvist, T., Galaz, V., Moberg, F., Nilsson, M., Österblom, H., Ostrom, E., Persson, Å., Peterson, G., Polasky, S., Steffen, W., Walker, B., Westley, F., 2011. Reconnecting to the biosphere, in: Ambio. pp. 719–738. https://doi.org/10.1007/s13280-011-0184-y

Hammerschlag, N., Schmitz, O.J., Flecker, A.S., Lafferty, K.D., Sih, A., Atwood, T.B., Gallagher, A.J., Irschick, D.J., Skubel, R., Cooke, S.J., 2019. Ecosystem Function and Services of Aquatic Predators in the Anthropocene. Trends Ecol Evol 34, 369–383. https://doi.org/10.1016/j.tree.2019.01.005

Harborne, A.R., Rogers, A., Bozec, Y.M., Mumby, P.J., 2017. Multiple Stressors and the Functioning of Coral Reefs. Ann Rev Mar Sci. https://doi.org/10.1146/annurev-marine-010816-060551

Hicks, C.C., 2011. How Do We Value Our Reefs? Risks and Tradeoffs Across Scales in "Biomass-Based" Economies. Coastal Management 39, 358–376. https://doi.org/10.1080/08920753.2011.589219

Holling C. S, 1973. Resilience and stability of ecological systems. Annu. Rev. Ecol. Syst. 41, 1–24.

Holmlund, C.M., Hammer, M., 1999. Ecosystem services generated by fish populations. Ecological Economics 29, 253–268.

Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R., Folke, C., Grosberg, R., Jackson, J.B.C., Kleypas, J., Lough, J.M., Marshall, P., Nystro, M., 2003. Climate Change , Human Impacts , and the Resilience of Coral Reefs. Science: Review 301, 929–934.

Hughes, T.P., Bellwood, D.R., Folke, C., Steneck, R.S., Wilson, J., 2005. New paradigms for supporting the resilience of marine ecosystems. Trends Ecol Evol 20, 380–386. https://doi.org/10.1016/j.tree.2005.03.022

Hughes, T.P., Carpenter, S., Rockström, J., Scheffer, M., Walker, B., 2013. Multiscale regime shifts and planetary boundaries. Trends Ecol Evol 28, 389–395. https://doi.org/10.1016/j.tree.2013.05.019

IPCC, 2022. Changing Ocean, Marine Ecosystems, and Dependent Communities, in: The Ocean and Cryosphere in a Changing Climate. Cambridge University Press, pp. 447–588. https://doi.org/10.1017/9781009157964.007

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. Science: 293, 629–637. https://doi.org/10.1126/science.1059199

Knowlton, N., 2021. Ocean Optimism: Moving Beyond the Obituaries in Marine Conservation. Ann Rev Mar Sci 13, 479–499. https://doi.org/10.1146/annurev-marine-040220-101608

Knowlton, N., Jackson, J.B.C., 2008. Shifting baselines, local impacts, and global change on coral reefs. PLoS Biol 6, 0215–0220. https://doi.org/10.1371/journal.pbio.0060054

Ladd, M.C., Shantz, A.A., 2020. Trophic interactions in coral reef restoration: A review. Food Webs 24, e00149. https://doi.org/10.1016/j.fooweb.2020.e00149

Lefcheck, J.S., Innes-Gold, A.A., Brandl, S.J., Steneck, R.S., Torres, R.E., Rasher, D.B., 2019. Tropical fish diversity enhances coral reef functioning across multiple scales. Sci Adv 5, eaav6420. https://doi.org/10.1126/sciadv.aav6420

Lewis, S.L., Maslin, M.A., 2015. Defining the Anthropocene. Nature 519, 171–180. https://doi.org/10.1038/nature14258

Longo, G.O., Ferreira, C.E.L., Floeter, S.R., 2014. Herbivory drives large-scale spatial variation in reef fish trophic interactions. Ecol Evol 4, 4553–4566. https://doi.org/10.1002/ece3.1310

Malhi, Y., 2017. The Concept of the Anthropocene. Annu Rev Environ Resour 42, 77–104. https://doi.org/10.1146/annurev-environ-102016-060854

McClanahan, T.R., Hicks, C.C., Darling, E.S., 2008. Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. Ecological Applications 18, 1516–1529. https://doi.org/10.1890/07-0876.1

Norström, A., Nyström, M., Lokrantz, J., Folke, C., 2009. Alternative states on coral reefs: beyond coral–macroalgal phase shifts. Mar Ecol Prog Ser 376, 295–306. https://doi.org/10.3354/meps07815

Norström, A. v, Nyström, M., Jouffray, J.-B., Folke, C., Graham, N.A., Moberg, F., Olsson, P., Williams, G.J., 2016. Guiding coral reef futures in the Anthropocene. Front Ecol Environ 14, 490–498. https://doi.org/10.1002/fee.1427

Nyström, M., Norström, A. v., Blenckner, T., de la Torre-Castro, M., Eklöf, J.S., Folke, C., Österblom, H., Steneck, R.S., Thyresson, M., Troell, M., 2012. Confronting Feedbacks of Degraded Marine Ecosystems. Ecosystems 15, 695–710. https://doi.org/10.1007/s10021-012-9530-6

Convention on Biological Diversity, 2020. Global Biodiversity Outlook 5: Summary for Policymakers, Secretariat of the Convention on Biological Diversity.

Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, R.R., Jackson, J.B.C., 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science: 301, 955–958. https://doi.org/10.1126/science.1085706

Papworth, S.K., Rist, J., Coad, L., Milner-Gulland, E.J., 2009. Evidence for shifting baseline syndrome in conservation. Conserv Lett 2, 93–100. https://doi.org/10.1111/j.1755-263X.2009.00049.x

Pauly, D., 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends Ecol Evol 10, 430.

Pauly., D., Christensen, V., Dalsgaard, J., Froese, R., Torres Jr.F., 1998. Fishing down food webs. Science (1979) 279, 5.

Pershing, A.J., Mills, K.E., Record, N.R., Stamieszkin, K., Wurtzell, K. v., Byron, C.J., Fitzpatrick, D., Golet, W.J., Koob, E., 2015. Evaluating trophic cascades as drivers of regime shifts in different ocean ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences 370, 20130265. https://doi.org/10.1098/rstb.2013.0265

Rocha, J.C., 2022. Ecosystems are showing symptoms of resilience loss. Environmental Research Letters 17. https://doi.org/10.1088/1748-9326/ac73a8

Scheffer, M., Carpenter, C., Young, B. de, 2005. Cascading effects of overfishing marine systems. Trends Ecol Evol 20, 579–581. https://doi.org/10.1016/j.tree.2005.08.007

Scheffer, M., Carpenter, S., Foley, J.A., Folke, C., Walkerk, B., 2001. Catastrophic shifts in ecosystems. National Academies Press 413, 591–596. https://doi.org/10.1130/0-8137-2366-3.167

Scheffer, M., Carpenter, S.R., 2003. Catastrophic regime shifts in ecosystems: linking theory to observation 18, 648–656. https://doi.org/10.1016/j.tree.2003.09.002

Scheffer, M., van Nes, E.H., 2004. Mechanisms for marine regime shifts: Can we use lakes as microcosms for oceans? Prog Oceanogr. https://doi.org/10.1016/j.pocean.2004.02.008

Setter, R.O., Franklin, E.C., Mora, C., 2022. Co-occurring anthropogenic stressors reduce the timeframe of environmental viability for the world's coral reefs. PLoS Biol 20, 1–12. https://doi.org/10.1371/journal.pbio.3001821

Soares, M.O., Kitahara, M.V., Santos, M.E.A., Bejarano, S., Rabelo, E.F., Cruz, I.C.S., 2022. The flourishing and vulnerabilities of zoantharians on Southwestern Atlantic reefs. Mar Environ Res 173, 105535. https://doi.org/10.1016/j.marenvres.2021.105535

Soga, M., Gaston, K.J., 2018. Shifting baseline syndrome: causes, consequences, and implications. Front Ecol Environ 16, 222–230. https://doi.org/10.1002/fee.1794

Spalding, M., Burke, L., Wood, S.A., Ashpole, J., Hutchison, J., Zu Ermgassen, P., 2017. Mapping the global value and distribution of coral reef tourism. Mar Policy 82, 104–113. https://doi.org/10.1016/j.marpol.2017.05.014

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science (1979) 347. https://doi.org/10.1126/science.1259855

Tebbett, S.B., Hoey, A.S., Depczynski, M., Wismer, S., Bellwood, D.R., 2020. Macroalgae removal on coral reefs: realised ecosystem functions transcend biogeographic locations. Coral Reefs 39, 203–214. https://doi.org/10.1007/s00338-019-01874-w

Young, H. S., McCauley, D. J., Galetti, M., & Dirzo, R. (2016). Patterns, Causes, and Consequences of Anthropocene Defaunation. Annual Review of Ecology, Evolution, and Systematics, 47(1), 333–358. https://doi.org/10.1146/annurev-ecolsys-112414-054142

# 2 APRESENTAÇÃO

Nesta tese, foi investigado a partir de uma revisão sistemática, como o conhecimento científico multidisciplinar sobre os peixes recifais herbívoros avançaram em mais de cinquenta anos no Atlântico Sudoeste (AS), e a partir do Conhecimento Ecológico Local (CEL) foi identificado como os peixes recifais influenciam processos e funções ecológicas para promover bens e Serviços Ecossistêmicos (SEs), como estressores antrópicos afetam esses processos, e como estão associados às mudanças de fase em Área de Proteção Ambiental sem plano de manejo. Para traçar um panorama e ampliar as perspectivas para atingir o objetivo geral proposto, uma revisão sistemática entre 1967 e 2020 foi conduzida, onde procurou-se entender de que maneira o conhecimento sobre os peixes recifais avançou no Atlântico Sudoeste. Primeiramente foi mapeada as redes de colaboração entre pesquisadores, instituições e países, quantificando o número de revistas de alto fator de impacto, artigos, e autores mais citados. Na revisão, foi quantificado e identificado as disciplinas, ecossistemas, metodologias de amostragem das áreas geográficas, espécies, famílias e as categorias tróficas mais citadas, componentes (ex.: táxon, ecossistema), e os processos ecossistêmicos mais estudados. Na segunda etapa da revisão, foram identificadas as perspectivas para avançar no entendimento sobre as mudanças de fase nos recifes, os SEs dos peixes e pescarias, as lacunas na utilização do Conhecimento Ecológico Local (CEL) para trazer soluções alternativas (ex.: manejo das artes e espécies), e as perspectivas para pesquisas científicas futuras sobre os peixes recifais.

No segundo capítulo, o CEL foi utilizado para testar a hipótese da ocorrência da SMR geracional entre pescadores com diferentes tempos de experiências nas atividades pesqueiras em uma ilha tropical nas capturas de espécies dos grupos tróficos dos peixes carnívoros, piscívoros e herbívoros. Assumiu-se como premissas, que a co-ocorrência de múltiplos estressores antropogênicos, como a sobrepesca, criam bacias de atração nos recifes que promovem mudanças entre um estado natural para um estado alterado desencadeando as mudanças de fase*.* Então, investigou-se: (i) os benefícios imateriais e materiais dos peixes e pescarias paras as pessoas; (ii) a ocorrência de Síndrome de Deslocamento de Referencial (SDR) entre diferentes gerações de pescadores em relação a diminuição ou o aumento das capturas, anos das melhores pescarias e capturas, os maiores indivíduos já capturados, as pescarias dos grupos tróficos em diferentes zonas dos recifes; (iii) múltiplas bacias de atração para as mudanças de fase; e as principais (iv) soluções alternativas e participativas para a conservação e manejo de acordo com a percepção dos pescadores.

Aqui, identificou-se que os peixes e as pescarias são fundamentais para a alimentação, geração de trabalho, renda, recreação, cultura e espiritualidade para as diferentes gerações de pescadores. Foi detectada a SMR entre as gerações de pescadores que apresentaram desvios de percepção sobre a produtividade pesqueira e capturas dos maiores indivíduos dos grupos tróficos carnívoros, piscívoros e herbívoros ao longo do tempo, desde os recifes costeiros até aqueles afastados da costa. Na sequência, as premissas de que a co-ocorrência de múltiplos estressores antrópicos relacionados às mudanças de fase nos recifes foram aceitas, e os pescadores indicaram soluções alternativas para a conservação, manejo, gestão, e governança dos recifes de coral e das pescarias.

## 3 CAPÍTULO I: A REVIEW OF THE KNOWLEDGE OF REEF FISH IN THE SOUTHWEST ATLANTIC

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### ABSTRACT

Reef environments are rapidly transforming worldwide due to climate change, habitat damage and overfishing, and these changes are causing major impacts to the reef ecosystem. Scientific knowledge is strategic for marine conservation and management in these scenarios. Aiming to contribute to this subject, a systematic review from 1967 to 2020 was conducted, in order to identify gaps in studies regarding reef fish species, ecosystem components and processes. Multidisciplinary sciences concerning reef fish have been rising, mainly in the fields of basic biology and ecology. Besides that, phase shifts and ecosystem services were absent terms in the analyzes of co-occurrence of terms and keywords in articles analysed. Research in the ethnosciences needs to be increased, and will improve access to local ecological knowledge, which can be used as a tool to address issues in reef environments. Socio-ecological systems are components

of this landscape that have had few publications, and their participation in the elaboration of public policies can be a new avenue to foster the biodiversity of reef environments.

**Keywords:** Bibliometrics**,** Coastal zone, Coral reefs, Phase shifts, Ecosystem

## 3.1 INTRODUCTION

Reef environments support immense biodiversity (Connell, 1978; Stoddart, 1969). These environments also provide highly complex hotspots for habitat specialization, encouraging the evolution of corals and reef fishes in the ocean (Bellwood et al., 2017; Cowman and Bellwood, 2013; Pinheiro et al., 2018). The complex habitats and heterogeneity provided by reef environments are suitable for refuge, which promote trophic interactions between fishes in marine food webs (Graham and Nash, 2013; Kovalenko et al., 2012).

Reefs environments maintain a myriad of ecosystem services (ESs) that help to sustaining ecological processes and are fundamental for humanities well-being (Costanza et al., 2014; MEA, 2005; Moberg and Folke, 1999). The contributions of coral reef biodiversity to people are expressed by the myriad of material and immaterial ESs that promote the regulation and maintenance of biological processes, food production, materials, and labor, and supporting identities (e.g., recreational, cultural and spiritual) (Díaz et al., 2018; Holmlund and Hammer, 1999; MEA, 2005; Moberg and Folke, 1999). Millions of people rely on fishing as a source of livelihood, and it is one of the most significant tourism industries globally (Cinner, 2014; Food and Agriculture Organization of the United Nations, 2017; Spalding et al., 2017).

Despite the ecological, socioeconomic, and cultural importance, reef environments have been declining worldwide as a result of global and local threats (Bellwood et al., 2019a). At a local scale, habitat destruction, and more importantly overfishing (Newton et al., 2007), have been contributing severely to the general depletion of reef fish worldwide.

This has lead to extinctions and genetic erosion of key species (Jackson et al., 2001; Myers and Worm, 2003b; Pandolfi et al., 2003; Pauly. et al., 1998).

Overfishing can lead to a decrease in the abundance of reef fish and is the primary cause of the reduction of fish biomass and trophic categories (Myers and Worm, 2003b; Trindade-Santos et al., 2020). Overfishing trigger trophic cascades, causing depletion of piscivorous and large herbivorous species inducing community phase shifts which is led to decreasing of the ESs provided by reef fish (Conversi et al., 2015a; Daskalov et al., 2007; Rocha et al., 2015).

Extensive cascading effects caused by the removal of apex predators is the main driver of transitions in community structure in freshwater and marine ecosystems (Estes et al., 2011; Mumby et al., 2006; Pershing et al., 2015). In reef environments, community phase shifts are mainly represented by changes in structure from coral-dominated ecosystems to environments dominated by fast growth organisms, such as macroalgae, soft corals, sponges, and sea urchins (Bellwood et al., 2004a; Done, 1992; Graham, 2015; Norström et al., 2009). Shedding light on the knowledge of phase shifts in reef environments (Cruz et al., 2015; Graham, 2015; Rocha et al., 2017), is a necessary step to achieve the objectives of the UN decade of ocean science for sustainable development (ONU, 2015; UNESCO, 2020).

Understanding the main issues of concern related to changes and degradation of a reefs communities' structure are important in order to support marine management strategies that assure the conservation and maintenance of reef ecosystem functions (Conversi et al., 2015b; Scheffer et al., 2001).

It is strategic for marine conservation and sustainable management in phase shifts scenarios in Southwest Atlantic (SA) to understand how much the scientific knowledge has progressed about reef fish. In order to maximize research time efforts, bibliometrics analysis is a research tool to map areas and subareas of scientific knowledge (Verbeek et al., 2002), that are relevant to reorient interdisciplinary marine projects and international agendas (Markus et al., 2018; Visbeck, 2018).

Bibliometrics networks deal with the statistical analysis of information to map co-occurrences (terms, keywords) in scientific documents (Havemann and Scharnhorst, 2012; Waltman et al., 2010). In the main bibliometric studies, tracking the citations has been used to elements of similar keywords, thereby increasing the productivity in research projects (Behrouzi et al., 2020).

Aiming to contribute to this subject, a systematic review through bibliometric analysis was used to quantify how much scientific progress on reef environments and associated fishes has been made in the SA. We also worked to map the actual knowledge, identifying gaps, and addressing perspectives of the future.

## 3.2 MATERIAL AND METHODS

### 3.2.1 Data Search

The data collection was carried between October 2020 and September 2021 through searches in the Scopus, Web of Science (WoS) and SciELO Brazil databases. We limited our searches to articles published in English, Portuguese, and German, during the timespan between 1967 to 2020. We performed a comprehensive literature search for studies published using these keywords in the search fields: (north brazil shelf, tropical southwestern atlantic, south atlantic ocean, tropical atlantic, brazil OR brazil* ocean) AND (coral reef ecosystem*, shallow reef*, OR rocky reef*, reef ecosystem*, mesophotic reef*, rariphotic reef*, deep reef*) AND (fish*, herbivore fish*, scarus*, acanthuridae, surgeonfish*, parrotfish*, fish assemblage*, reef fish community* OR reef community*). The search results were manually filtered, and the titles, keywords, and entire body of the articles were reviewed. We organized all the articles according to the PRISMA diagram (Preferred Reporting Items for Systematic Reviews).

### 3.2.2 Data organization and categorization

The selected articles were organized according to year, most used journals, impact factor (IF), H-index of SCImago Journal & Country Rank (SCImago, 2020), most cited article, co-occurrence terms, and researched areas. Each article was categorized to the study sites of marine realms, province, and ecoregions (Spalding et al., 2007). A map to visualize the number of articles sampled according to marine ecoregions of the world (Marine Institute, 2021), was made from the uploaded website Data Basin (Conservation Biology Institute, 2021). We used Inkscape v.1.0.2-2 software (Rasband, 2005) to improve the quality of the map.

The study also registered and categorized the type of reef environments (according to Araújo et al., 2020 and ReBentos, 2015), depth range, sampling methodologies, fish species and trophic categories, ecosystem components and processes studied (see categorization in the supplementary material).

The trophic categories assigned were based on diet and feeding modes according to Ferreira et al. (2004) and Froese and Pauly (2022), these being: (1) Roving herbivores (ROVH): which include in their diet plants, turf algae, macroalgae and detritus; (2) Mobile invertebrate feeders (MIFs): which feed on all benthic mobile invertebrates like crustaceans and mollusks; (3) Sessile invertebrate feeders (SIF): feeding on a variety of sessile benthic invertebrates such as cnidarians, ascidians and sponges; (4) Omnivores (OMN): feeding on plants and animals; (4) Planktivores (PLK): feeding on basically macro- and microplankton, and (5) Piscivores (PIS): which feed on only live fishes.

### 3.2.3 Analysis

To facilitate the visualization of the graphic data, the results obtained were recorded in periods of five years whenever possible (1967-1977; 1996-2000; 2001-2005; 2006-2010; 2011-2015; 2016-2020). We used VOSviewer v 1.6.18 to create the network analyses of (1) term co-occurrence in titles and abstracts through time (van Eck and Waltman, 2010).

Linear regression ($p < 0.05$) analysis was used to test the relationship between number of articles published and their number of citations (citation count sums), in order to determine how much scientific production about reef fish in the SA has been made over time. Two-way ANOVA was applied to verify significant differences in citations per article during the study period, using countries and numbers of co-author's countries as predictive factors.

All the statistical analysis were made using Microsoft Excel, and the graphs were edited using the R Software version 1.4.1106 (RStudio, 2021).

## 3.3 RESULTS

From the 3,984 articles records generated by our search on the WoS, Scopus and SciELO Brazil, 557 were considered valid for our analysis (Fig.1).

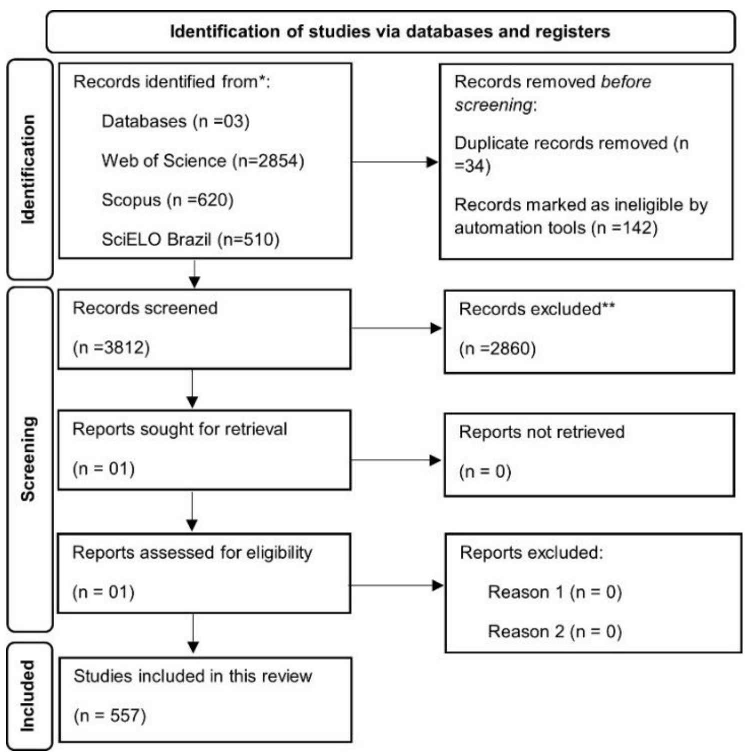

**Figure 1:** PRISMA 2020 flowchart describing the process of selecting articles included/excluded in the process of this systematic review. Legend: *Web of Science-WoS, Scopus, SciELO.

The number of scientific articles about reef fish in the SA has progressed over time ($R^2$= 0.55; $p < 0.001$). The articles were published in 134 journals, and 10 most used were selected (Table 1). The Journal of Fish Biology (n= 56; 10%, 1.495; 108) and Neotropical Ichthyology (n= 41; 5.36%; 0.589; 37) were the two with the highest number of articles published. We identified only nine journals (n= 20; 1.5%) that are exclusively for studies published in marine conservation, and the most used were the Perspective in Ecology and Conservation (n=3; 0.58%; 3.563; 31) and the Biological Conservation (n=2; 0.38%; 4.69; 199).

**Table 1** The top 10 most used journals about reef fish during 1967 to 2020 (TP= total publications and percentage in total publications (n=557; %), IF= impact factor from the Journal Citation Report (JCR) published in 2019, H-index= journal rank in the category).

| **Journal name** | **TP** | **TP (%)** | **IF** | **H-index** |
|---|---|---|---|---|
| Journal of Fish Biology | 56 | 10 | 1.495 | 108 |
| Neotropical Ichthyology | 41 | 7.4 | 0.589 | 37 |
| Environmental Biology of Fishes | 29 | 5.2 | 0.617 | 82 |
| Journal of the Marine Biological Association of the United Kingdom | 21 | 3.8 | 0.606 | 66 |
| Brazilian Journal of Oceanography | 21 | 3.8 | 0.451 | 23 |
| PLoS One | 16 | 2.87 | 2.74 | 300 |
| Marine Biology | 15 | 2.11 | 1.019 | 114 |
| Biota Neotropica | 15 | 2.7 | 1.33 | 32 |
| Ocean and Coastal Management | 14 | 2.68 | 0.984 | 77 |
| Marine Environmental Research | 13 | 2.49 | 1.081 | 89 |

The ANOVA significantly indicated variations in citations per article related to the country of origin ($p < 0.0001$; F = 4.65) and number of co-author countries ($p < 0.0001$; F= 2.2) for the studied period (Fig.2). Brazil is at the top of scientific productivity in SA and international scientists included 10 countries in co-authorship. The United States of America-USA (n=66) and Australia (n=59) stands out in the number of articles. The main countries that are part of these co-authorship production are from the European community, these being Portugal (n=25), France (n=21) and Germany (n=18). In South America, aside from Brazil, we also registered Argentina (n=07). The number of articles published between 1967 and 2020 showed a rising trend after 2004, as well as the number of citations that increased dramatically from this period (Fig.2).

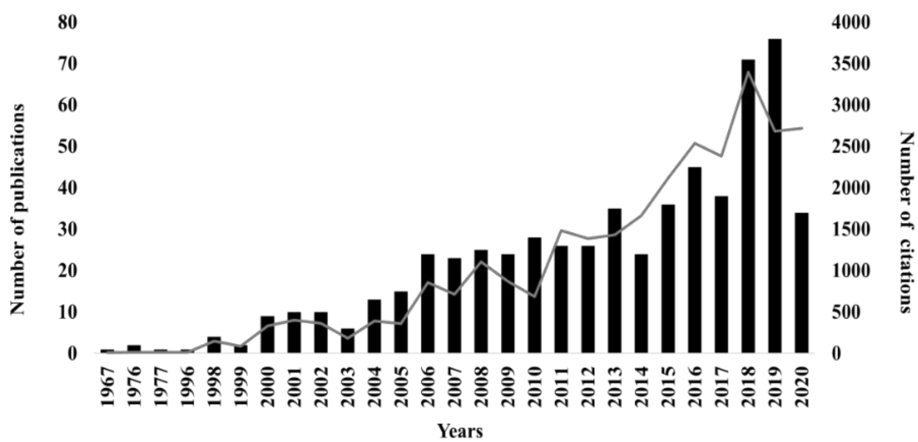


**Figure 2:** Number of publications and citations counts (line) by years about reef fish during 1967 to 2020.

Between 1967 and 1977 the number of articles is exceptionally low (n=04) compared to the period between 1996 and 2000 (n=17). We counted 102 more publications between 2006 and 2010. This trend continues until 2016-2020, which was the period with the largest number of articles published (n= 236).

Most of the top 10 cited articles since 2008 (Table 2), in the main themes were related to functional ecology, community structure, fisheries, and other different subjects related to ecology and species distribution.

**Table 2** The top 10 most cited articles about reef fish in WoS, Scopus, and SciELO Brazil from 1967 to 2020.

| Rank | First Author | Number of citations | Title |
|---|---|---|---|
| 1 | Floeter et al., (2008) | 764 | Atlantic reef fish biogeography and evolution |
| 2 | Floeter et al., (2007) | 494 | Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover |
| 3 | Sadovy de Mitcheson et al., (2013) | 473 | Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion-dollar fishery |
| 4 | Ferreira et al., (2004) | 424 | Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison |
| 5 | Ferreira and Gonçalves, (2001) | 326 | Community structure of fishes and habitat complexity on a tropical rocky shore |
| 6 | Floeter et al., (2005) | 322 | Geographical gradients of marine herbivorous fishes: patterns and processes |
| 7 | Kulbicki et al., (2013) | 263 | Global Biogeography of Reef Fishes: A Hierarchical Quantitative Delineation of Regions |
| 8 | Floeter et al., (2001) | 257 | Geographic variation in reef-fish assemblages along the Brazilian coast |
| 9 | Luiz et al., (2012) | 253 | Ecological traits influencing range expansion across large oceanic dispersal barriers: insights from tropical Atlantic reef fishes |
| 10 | Galetti et al., (2000) | 236 | An overview of marine fish cytogenetics |

Term co-occurrence total analysis separated the most relevant research terms from WoS in four clusters (Fig.3). The network analyses of terms display division between target fishes in fisheries and reproductive biology; reef environment variables and communities; family and species distribution; key species and marine conservation.

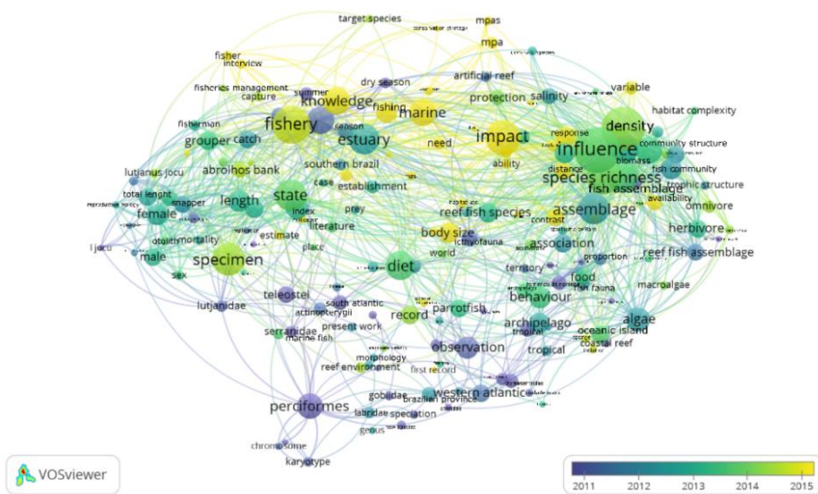


**Figure 3** Network map of most relevant research terms about reef fish during 1967 to 2020 in WoS from 1967 to 2020. The size of nodes reflects the number of articles, whereas the density of connecting lines indicates the number of co-occurrences.

From Scopus and SciELO Brazil, the co-occurrence analyses also separated the most relevant terms in four clusters (Fig.4). The network exposed a clear division between biology, reproduction, feed behavior; and research directly linked to community structure, and species distribution. Research related to basic biology was frequent in both networks.

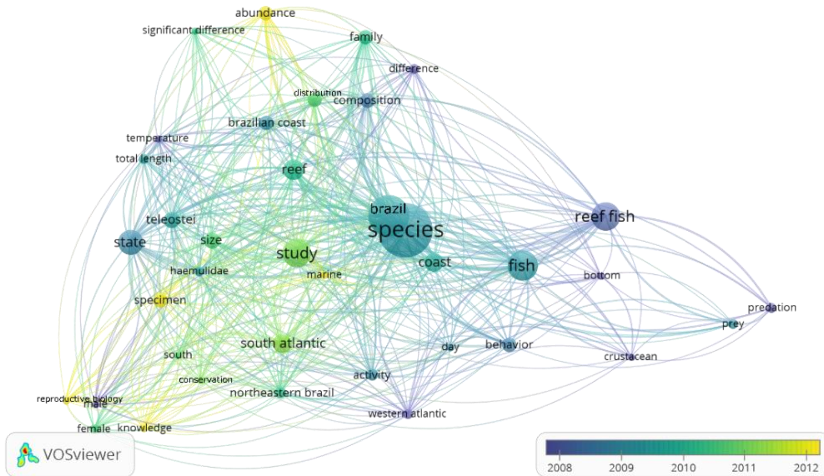


**Figure 4** Network map of most relevant research terms about reef fish during 1967 to 2020 in Scopus and SciELO Brazil. The size of nodes reflects the number of articles, whereas the density of connecting lines indicates the number of co-occurrences.

The most frequent keywords in the co-occurrence network analysis in WoS, Scopus and SciELO Brazil were reef fish species (18.24 %; 44 %). While herbivore (17.6 %), parrotfish (16.5 %) and Western Atlantic (17.6 %) were more frequent in WoS. The term coral reefs (17.5 %) was frequent in Scopus and SciELO. The total volume of articles analyzed, studies contributing to a broader understanding of herbivorous fishes accounted for 46 articles (n= 557; 8.2%). Nonetheless, co-occurrences of terms related to phase shifts ES of reef fish were absent.

The main scientific research disciplines in the field of the themes were ecology (n=265), species biology (n=93), and applied ecology and conservation (n=79) since 1967 (Fig.5) (see categorization on supplemental material). Studies focusing on biogeography, macroecology, and phylogeography (n=54) have been in development since 2006 in the SA. Some subjects such as food webs and biodiversity (n=22); ethnobiology, and ethnoecology (n=10) presented a smaller number of publications.

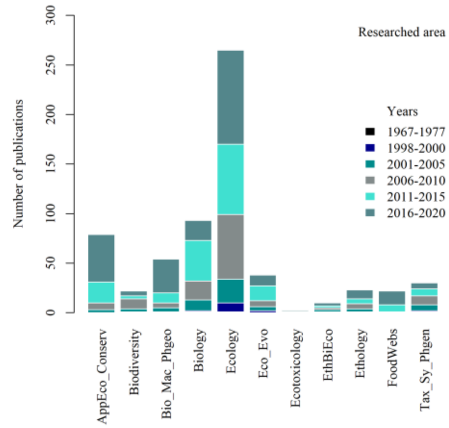


**Figure 5:** Researched areas studied by publications (n=557), every five years from 1967 to 2020.

The Tropical Atlantic (TA) realm was observed as having the largest number of studies (n=550) and the Tropical Southwestern Atlantic (TSA) (n=249) the most researched province (Fig.6). Meanwhile, in North Brazil Shelf (NBS) (n=130) province, Amazonia (AM) ecoregion has been increasing the number of articles (n=85) published since 2011. The contribution of the reef fish studies in the Warm Temperate Southwestern Atlantic (WTSA; n=249) province was from South Brazil (SBr; n=206) ecoregion. In the total volume of articles published in the period of studies, Northeastern Brazil (NO; n=215) and Eastern Brazil (EA; n=197) ecoregions accumulated the largest amount. Fernando de Noronha archipelago (FN) and the Rocas Atoll (FNAR; n=111) were the most studied oceanic ecoregions presenting more studies than Trindade and Martin Vaz islands (TrMVz; n=84).

A total of 343 (n=557; 62%) articles were carried out in Marine Protected Area (MPA), including in 17 different ecosystems, such as estuaries, coastal, shallow and mesophotic reefs, and oceanic seamounts (Fig.7). We observed that the surveys were carried out during the period 1960-1977 (n=4), as well as most of the articles analyzed (n=200), did not report the sampled depth of sampled area. Between the years of 1996 to

2000, most research focused on sampling up to 15 m (n=26); although more than 42% of the sampled depths were above 50 m (n=257). The first studies that sampled depths greater than 115 m in reef environments took place over the years 2001-2005 (n=30), and since the period 2011-2015 (n=124) research studies have been increasing annually – 46% occurring in depths up to 50 m.

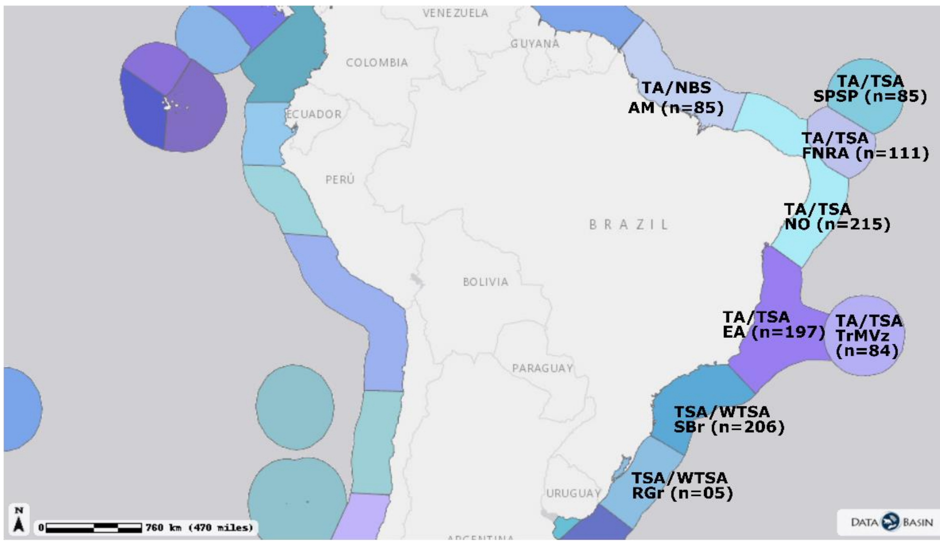


**Figure 6:** Researched Marine Ecoregions of the Southwestern Atlantic studied from 1967 to 2020. Marine Realms: TA and TSA; Provinces: NBS, TSA, and WTSA. Ecoregions: AM, SPSP, FNRA, NO, EA, TrMVz, SBr and RGr.

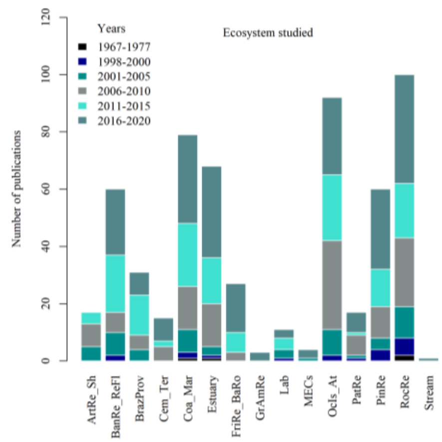


**Figure 7:** Ecosystems studied from 1967 to 2020 in Southwestern Atlantic. ArtRe_Sh: Artificial reef/Shipwreck; BanRe_ReFl: Bank Reefs and Flat Reefs; BrazProv: Brazilian Province; Cem_Ter: Cemented Terraces; Co_Mar: Coastal and Marine; FriRe_BaRo: Fringing reefs and Beach-rockys; GrAmRe: Great Amazon Reef System; Lab: Laboratory; MECs: Mesophotic Ecosystems; Ocls_At: Ocean Islands and Atoll; PatRef: Patch Reefs; PinRe: Pinnacle reefs; RocRe: Rocky shore, Rocky reefs, and Rocky pools.

Between 1967 and 1977, the most applied sampling methodologies were the use of chemical substances (anesthetics) and interviews for the ethnoecological research approach (n=4) (Fig.8). However, from 1996 to 2020, fishing (n=205) was the most used methodology. SCUBA diving (Self Contained Underwater Breathing Apparatus) has been increasingly used for the study of marine ecosystems (n=201), followed by free diving and direct observation (n=102). The use of modern equipment's such as video and photo cameras, bait with remote underwater video (BRUV), remotely operated underwater vehicle (ROV) and diver-operated stereo-video (DOV) have gained prominence mainly since 2010 (n=28).

The application of standardized methodologies (e.g.: Point Intercept Transect, Belt Transect) for sampling reef fish has been the most used by researchers since 1996 (n=138) (Fig.9). The researchers fished for sample fauna through a myriad of miscellaneous gear (n=120), including hooks and lines (n=38), gillnets (n=34), trawls (n=28), and traps (n=20). The application of methodologies used in ethnobiology through interviews, surveys, reviews, and questionnaires (n=64) has been used since 1967, especially between 2016 and 2020 – increasing the total of indexed publications by more than 52%.

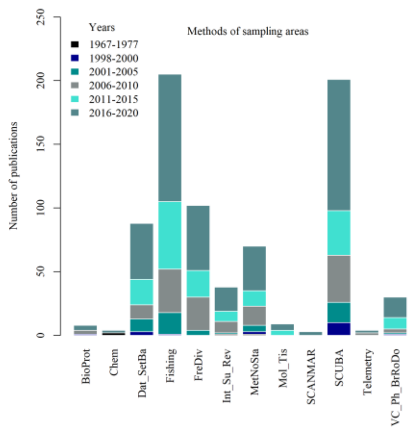


**Figure 8:** Methods of sampling areas every five years from 1967 to 2020 in Southwestern Atlantic. BioProt: Biological Protocols; Chem: Chemicals; Dat_SetBa: Dataset or Database; FreDiv: Freediving; Int_Su_Rev: Interview, Survey or Review; MeNoSta: Method Not Stated; Mol_Tis: Molecular or Tissue; VC_Ph_BrRoDo: Video camera, Photo, BRUV, ROV or DOV.

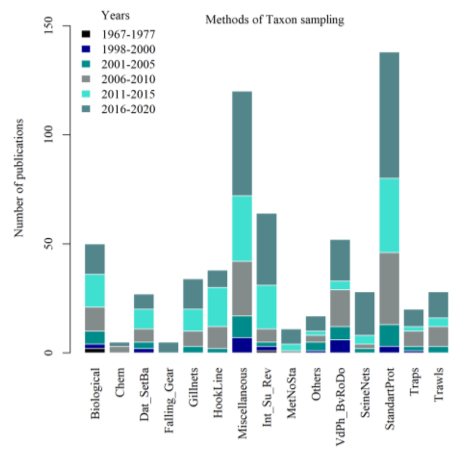


**Figure 09:** Methods of taxon sampling every five years from 1967 to 2020 in Southwestern Atlantic. Biological: biological protocols; Chem: Chemicals; Dat_SetBa: Database, Dataset or Checklist; HookLine: hooks and lines; Miscellaneous gear; Int_Su_Rev: interview, survey, review, or questionnaire; MetNoSta: Method Not Stated; VdPh_BvRoDo: Video camera, photo, BRUV, DOV; StandartProt: Standard protocols.

A total of 412 reef fish species belonging to 84 families of Osteichthyes and 10 of Chondrichthyes were recorded. The most cited species include the pomacentrids *Abudefduf saxatilis* and *Stegastes fuscus,* with similar number of studies for each over recent years (n=48) (Fig.10). Since 2001-2005, the *Acanthurus bahianus*, *Acanthurus chirurgus* and *Acanthurus coeruleus* (n=38; 28; 22) have been frequently investigated by marine researchers.

The most investigated family were Pomacentridae (n=162), followed by Scaridae (n=155), Haemulidae (n=113), and Lutjanidae (n=104) (Fig.11).

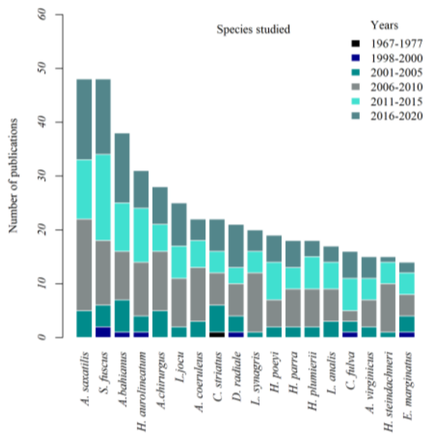


**Figure 10.** The number of the most cited reef fish species studied from 1967 to 2020 in Southwestern Atlantic. Legend: *Abudefduf saxatilis*; *Stegastes fuscus*; *Acanthurus bahianus*; *Haemulon aurolineatum*; *Acanthurus chirurgus*; *Lutjanus jocu*; *Acanthurus coeruleus*; *Chaetodon striatus*; *Diplectrum radiale*; *Lutjanus synagris*; *Halichoeres poeyi*; *Haemulon parra*; *Haemulon plumierii*; *Lutjanus analis*; *Cephalopholis fulva*; *Anisotremus virginicus*; *Haemulon steindachneri* and *Epinephelus marginatus.*

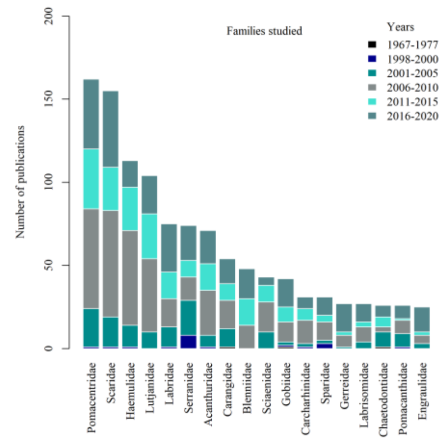


**Figure 11.** The number of the most cited reef fish families studied from 1967 to 2020 in Southwestern Atlantic.

Trophic categories of guilds that had the highest accumulated volume of articles analyzed was SIF (n=598) (Fig. 12). In this category, the butterflyfish *Chaetodon striatus* (n= 16) was the most studied specie of the Chaetodontidae family.

Since 2004, in Southwestern Atlantic, the ROVH species (n= 354) show a clear increase in the number of studies, it includes parrotfishes and surgeonfishes. One of the most cited family of ROVH species was Scaridae (n=155). In this trophic category two of the mostly mentioned species were the *Sparisoma axillare* (n=38) and the large *Scarus trispinosus* (n=22).

Between 2001 and 2006 the number of articles investigating the trophic group of PIS (n=377) increased. PIS species include the large groupers such as *Epinephelus marginatus* (n=14) and *Mycteroperca bonaci* (n=05) of Serranidae family (n=74). Chondrichthyes species include the most cited higher trophic level tiger shark *Galeocerdo cuvier* (n=04) of Carcharhinidae family (n=31).

In our systematic review, the most studied component was the taxon (class; order; family; genera; species) (n=290), especially since 2016, followed by community (n=207), population (n=68) and biogeography (n=44) (Fig.13) (See categorization on supplementary material). We observed that since 2011, the ecosystem (n=30) has had a significant increase in publications in relation to previous years. Studies focusing on food webs and Social-Ecological Systems-SES had the same number of studies (n=2).

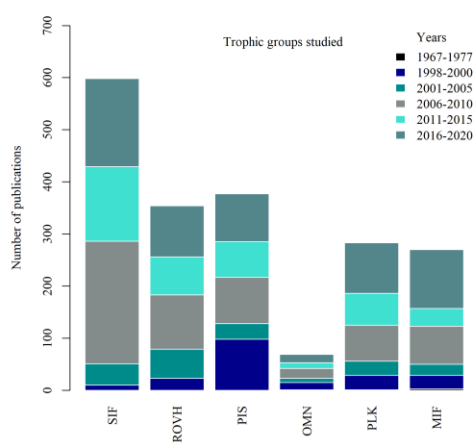

**Figure 12.** The number of the most cited trophic categories studied from 1967 to 2020 in Southwestern Atlantic. Sessile invertebrate feeders (SIF); Roving herbivores (ROVH); Piscivores (PIS); Omnivores (OMN); Planktivores (PLK); Mobile invertebrate feeders (MIFs).

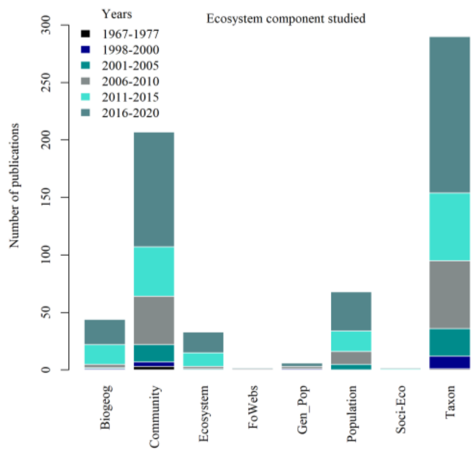


**Figure 13:** Ecosystem component studied every five years from 1967 to 2020 in Southwestern Atlantic. FoWebs: Food Webs; SociEco: Social-Ecological Systems.

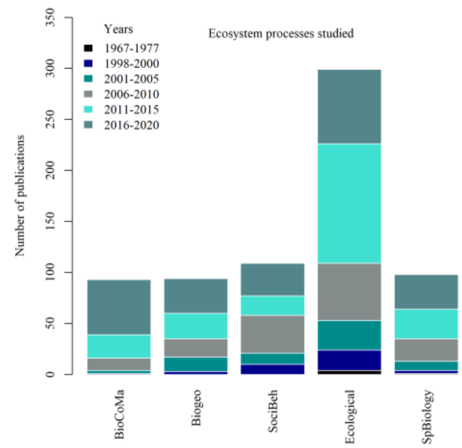


**Figure 14:** Ecosystem processes studied every five years from 1967 to 2020 in Southwestern Atlantic. BioCoMa: Biodiversity Conservation and Management; Biogeo: Biogeographic; SociBeh: Social behaviour; SpBiology: Species biology.

The most studied ecosystem process category was the ecological (n=299) since 1967 (Fig.14) (see categorization on supplementary material). Social behavior (n=109), species biology (n=98) and biogeography (n=94) had a similar number of publications. Processes related to biodiversity, conservation, and management (n=93) presented 24%

of publications indexed in the WoS, Scopus and SciELO between 2016 and 2020. In this category (see categorization on supplementary material), we observed that human behavior, the design of MPA's, governance were the processes with the least publications.

**3.4 DISCUSSION**

Multidisciplinary scientific studies about reef environments, reef fish species, families and trophic categories has been rising since 1967 in Southwestern Atlantic. However, the main issues related to the changes and degradation of reef community structures needs further study in order to support marine management strategies in SA (Rocha et al., 2015, 2017).

Several studies have reported phase shifts prior to the 1980's, when reefs transitioned from coral to algal dominance (Done, 1992). Shifts between stable states in reef communities from hard corals followed catastrophic events or man-made disturbances (Knowlton, 1992; Nyström et al., 2012).

Phase shifts have multiple drivers, drastically affecting the ESs of biodiversity (supporting), fisheries (provisioning), as well as cultural or aesthetic aspects (Rocha et al., 2015). However, there is no common understanding on what the main drivers of phase shifts or triggering mechanisms are, and the theoretical framework for addressing the main impacts for the management are still in development (Conversi et al., 2015a; Möllmann et al., 2015).

Scientific production has progressed over time, showing an increased volume of publications with a high IF impact factor, and H-index journals rank in the category of the Journal Citation Report (SCImago, 2020). There is a considerable amount of journals devoted to publishing studies about coastal and marine environments, which cover many topics. The wide audience received by the international Journal of Fish Biology and the more regional journal Neotropical Ichthyology, is explained by the acceptance of publications in all aspects of fish diversity and fisheries (freshwater, estuarine, and marine ecosystems)

The use of broad scope journals offer advantages to expand the dissemination of multidisciplinary knowledge between scientists, government and citizens aimed at proposing solutions for the multiple human impacts on reef environments. The cross-disciplinary marine sciences are key to the pursuit of directing and engaging society in research programs, conservation practices and initiatives proposed for the Decade of Ocean Science (Markus et al., 2018; Visbeck, 2018).

Brazil is at the top of scientific productivity among countries in SA, with most cited articles focusing mainly on ecology, conservation, and fisheries research. This is due to the investments in long-term research projects. Despite Brazil accounting for a significant proportion of the global production in these fields of research, studies point to the need for the internationalization of co-author countries networks (Oliveira Júnior et al., 2016; Partelow et al., 2020). The high representation of the USA, Australia and Europe may be due to the strong economic investments in immaterial science (teaching, partnership networks), material infrastructure (e.g.: BRUVs, DOVs, Submersibles, diving equipment´s), laboratories, and the English-language-based ocean-related knowledge production (Oliveira Júnior et al., 2016; Partelow et al., 2020).

The most frequent terms and keywords used for indexing the articles were coral reefs, reef fish species and Western Atlantic, to highlight the development of Brazilian science. Bibliometrics analyses were an effective tool linking keywords and citations for the prospection, compilation, and progress measuring of the diversified scientific knowledge (Behrouzi et al., 2020; Mantelatto et al., 2018; Verbeek et al., 2002). Moreover, the study assumed that the progress in these fields of knowledge is related to the long-term ecological research programs that have been elaborated in recent years in SA, in the oceanic islands, in the Rocas Atoll, the archipelagos and in several coastal areas (Miranda et al., 2020).

We highlighted the term local ecological knowledge (LEK) which was rarely used as terms in indexing publications. This fact may be related to the mostly instrumental nature of the research carried out in reef environments. Despite this, the use of the LEK has been encouraged in research studies and is recognized in the ethnosciences as useful in the management of target fishes in fisheries (Begossi, 2015). The use of the LEK has been accepted by government agencies as essential to improve research, in order to achieve the sustainable use of biodiversity, for mitigation of environmental conflicts and for adaptation to climate change (Brondízio et al., 2021; ONU and UNEP, 2019).

We observed that the ethnosciences have generally received little attention by researchers and was the first research approach on fish biology and ecology since 1967. We recommend the use of LEK as a potential tool to bring people closer to environmental issues by making use of this knowledge of the ecosystem and its components.

The use of LEK is recurrent to complement investigations for the design of small-scale fisheries, public policy, food security, and for the adjustment of a target species that are overfished in reef fisheries (Begossi, 2015; Bender et al., 2014; Gerhardinger et al., 2009; Zapelini et al., 2019). The use of LEK in ethnoecological research has also been used to access the ecological baselines of some depleted PIS species in order to propose management and conservation measures (Barbosa-Filho et al., 2020; Giglio et al., 2015), and as a source of data-poor fisheries where there is a lack of information related to endangered species management (Lopes et al., 2019; Sáenz-Arroyo and Revollo-Fernández, 2016).

Ecotoxicology was a less researched area in the analyzed studies. The need to apply integrative and innovative methods to monitor the health of ecosystems requires systematic investments in material and qualified human resources. In the last five years, the great environmental disasters that occurred in SA severely impacted hydrographic basins and the NO, EA, and SBr marine ecoregions of SA with heavy metals and oil spills (Andrades et al., 2020; Lourenço et al., 2020). The scarcity of this type of study, and the absence of biomonitoring programes in the reef environments of SA raise an important alert in government agencies.

The high connectivity, biodiversity and ESs promoted by these ecosystems, which support human livelihoods (Moberg and Folke, 1999), indicate a need to carry out precise spatial planning of the marine biome (Magris and Giarrizzo, 2020) and encourage investments in biomonitoring programs for effective conservation and management (Magalhães et al., 2020).

Marine ecoregions of SA are important corridors, centers of endemism, speciation and dispersion, and are hotspots for reef fish worldwide (Floeter et al., 2008; Mouillot et al., 2014; Pinheiro et al., 2018). The TSA and WTSA provinces harbor hundreds of the most frequent reef fish species, families and trophic categories distributed along different gradients of depths and latitudes (Ferreira et al., 2004a; Magris, 2021; Reis et al., 2016). However, rare and endemic parrotfishes with low abundance and functional redundancy, and some snappers and groupers are at risk of extinction due to the high pressure exerted by reef fisheries (Anderson et al., 2014; Araújo et al., 2020b; Bender et al., 2013b; Roos et al., 2020).

Most of the samplings in SA were carried out in the MPAs, which are natural laboratories for long-term studies, and refuges to marine life. In recent years, new discoveries, and advances in the sampling of reef fish in these MPAs, along tide pools, shallow, coastal environments, islands, rhodolith beds, coralline hills, and depth reefs, have been applied (Francini-Filho et al., 2018; Guabiroba et al., 2022; Pinheiro et al., 2020; Quimbayo et al., 2019).

Frontiers in ecology and new development discoveries impose technological and operational challenges to the advancement of knowledge that supports marine biodiversity in deep reefs. The expansion of knowledge about mesophotic reefs, provides opportunities for conservation efforts and the establishment of technical and scientific cooperation networks in SA (Kitahara et al., 2020; Moura et al., 2016; Pinheiro et al., 2021; Simon et al., 2022).

Fishing using different types of gear was the methodology most employed by scientists for the study of reef fish. The sampling of fish fauna through fishing is considered one of the least selective methods to capture specific target species. Some studies warned against this methodology of sampling through fisheries because it contributes to overfishing of some endangered trophic categories, such as groupers (Epinephelidae), snappers (Lutjanidae), wrasses and parrotfishes (Labridae) (Jennings and Kaiser, 1998;

Johnson, 2010). Miscellaneous gear such as nets and traps decrease the comparability of quantitative data in reef ecosystems, because they underestimate samples by size classes, abundance, broader trophic levels, as well as cryptic species (Caldwell et al., 2016).

The most cited reef fish species were both from the Pomacentridae family, the omnivore *Abudefduf saxatilis* and the herbivore *Stegastes fuscus.* Both species are abundant and widely distributed in fringing, patch, bank and pinnacle reefs along the entire coast and oceanic islands in the NO, EA and SBr ecoregions of SA (Araújo et al., 2020b).

In addition, this high number of citations may also be related to the number of studies developed in the NO, EA and SBr ecoregions, where the more extensive reef formations in SA are located (Mantelatto et al., 2018). The scientific literature observes that *A. saxatilis* has a certain plastic diet and commonly feeds on benthos (Ferreira et al., 2004b; Floeter et al., 2004). Dozens of reef environments located at different latitudes of the ecoregions (FR, NO, EA, SBr) of SA are dominated by either algal turfs or frondose macroalgae, suggesting the occurrence of a phase shifts in benthic communities (Aued et al., 2018) favoring the establishment of populations of opportunist species like *A. saxatilis.*

A similar situation was observed for *S. fuscu*s, which is a strongly territorial herbivore. The adult diet of this damselfish generally consists of both algal turfs and includes a low percentage of detritus (Ferreira et al., 2004b), while juveniles prefer feeding on the fire-coral *Millepora alcicornis* polyps, a common hydrocoral in SA (Leal et al., 2015).

The most representative species of the Acanthuridae family were *Acanthurus bahianus* and *Acanthurus chirurgus*, indicating their wide occurrence in SA. Studies suggest that herbivorous reef fish are common in the Tropical Atlantic Ocean, where the most intense grazing processes performed by the ROVH group are largely restricted to tropical reef environments that have a greater abundance and richness of these species (Ferreira et al., 2004b; Floeter et al., 2004; Longo et al., 2018).

The high representativeness of reef fish families Acanthuridae, Chaetodontidae, Pomacentridae and Scaridae is probably explained by the processes of dispersion and speciation of lineage diversification from the tropics (Siqueira et al., 2016). These evolutionary mechanisms, together with habitat use and diet, offer some explanations reinforcing why Pomacentridae is one of the richest families with many endemic species in SA (Pinheiro et al., 2018).

The most cited type of SIF category was *Chaetodon striatus*, having a wide-ranging and long-term success colonization, responsible for higher abundance in rocky shore and reef environments in the NO, EA and SBr ecoregions in SA (Ferreira et al., 2004b; Joyeux et al., 2001).

The sessile invertebrate feeder was the most studied trophic category because it is a feed strategy related to benthonic communities (Ferreira et al., 2004b) in different latitudinal gradients in SA, where algal turfs and macroalgae are present in high coverage (Aued et al., 2018; Longo et al., 2014). Despite this dominance of turfs and high coverage of frondose macroalgae (e.g.: *Caulerpa verticillata*), the formation of this benthic substrate is favorable to the development of complex habitats for many small invertebrates, which probably serve as food for SIF species (Kovalenko et al., 2012; Aued et al. 2018).

As mentioned before, ROVH species of surgeonfishes and parrotfishes occur widely in SA ecoregions. In addition to the patterns observed in the dispersal and speciation processes of these families in the lineage diversification in tropical regions (Siqueira et al., 2016), the food plasticity indicated a more efficient use of low-quality food resources (e.g.: algal turfs, cyanobacteria, filamentous algae, and detritus) by this trophic category (Clements et al., 2016; Ferreira et al., 2004b). The functions played by some ROVH species in the process of grazing, scraping, excavating, and transporting of sediments are some of the most important ESs provided by this group for the maintenance, resilience and health of corals in reef environments (Bellwood et al., 2019b; Woodhead et al., 2019).

Piscivores (e.g.: sharks, groupers, snappers) play important functions in structuring the abundance, biomass and productivity of communities or other trophic levels in freshwater and marine environments (Myers et al., 2007; Pace et al., 1999). Notwithstanding, the overfishing of PIS species is considered a driver of phase shifts and is becoming a serious problem worldwide because it leads to weakening the functions of reef food webs (Estes et al., 2011; Rocha et al., 2015).

Commercial and recreational fisheries cause local extinctions of PIS species, such as sharks and big groupers and snappers, in oceanic islands and in many coastal reefs (Giglio et al., 2017; Luiz and Edwards, 2011; Pinheiro et al. 2018). The main reason for this overexploitation is related to some biological attributes, such as slow growth, late maturity and low reproductive yield (Bender et al., 2013; Jennings and Kaiser, 1998; Sadovy et al., 2013).

However, the establishment of marine reserves through effective management are solutions which contribute to the accumulation of biomass, body size and lifespans of groupers, lutjanids, surgeonfishes and parrotfishes (Anderson et al., 2018; Begossi and Silvano, 2008; McClanahan et al., 2022).

In the past, the conservation of biodiversity had a practical interest in protecting a specific component of the ecosystem, such as a key species, iconic, or threatened by extinction (Bellwood et al., 2019a; Bennett et al., 2009). New research needs to broadly understand the ecological functions of reef fish in marine food webs, which support the maintenance of resilience, diversity, and ESs for the future (Bellwood et al., 2019b; Moberg and Folke, 1999; Spalding et al., 2017).

A globalized crisis that is affecting the structure and functioning of marine ecosystems and the imminent phase shifts (Bellwood et al., 2004b; Conversi et al., 2015a), make it necessary to think of strategies to recover ecological processes at the ecosystem level, species diversity, and the functional redundancy of different trophic levels of food webs (Duarte et al., 2020; Harvey et al., 2017).

The SES was the least studied ecosystem component in the analyzed publications and this fact deserves to be heeded as a warning to humanity. Humans are using marine resources to the point of exhaustion to satisfy their growing economies. The continuity and maintenance of the ESs from these environments will depend on a complete restructuring of the SES and their dynamics (Norström et al., 2016). The SES are directly benefited by the ESs arising from the use, occupation, and exploitation of natural ecosystems, for multiple economic purposes, particularly for boosting tourism industries and the livelihoods of millions of people worldwide (Cinner, 2014; Spalding et al., 2017). A complete and fundamental economic and technological reorganization of SES is required for the sustainable use of the ESs of reef environments, and local communities have a central role in managing the sustainable use of biodiversity (Díaz et al., 2019).

Human behavior received little attention in the publications of ecosystem processes studied (see categorization on supplementary material). People and society depend on nature and its ESs to live and survive. Currently there has been a greater emphasis on the global environmental movement towards a new escalation of conservational change, a paradigm shifts away from humanity's pervasive interactions with nature, in the direction of more sustainable developmental processes (Díaz et al., 2019; Folke et al., 2011).

The spatial planning of the coastal and marine landscapes is a major management challenge that must be guided by inclusive and sustainable actions, that establish scenarios for dialogue and for sharing knowledge amongst the SES, academia, and public agencies (Hughes et al., 2017; Knowlton and Jackson, 2008).

## 3.5 CONCLUSIONS

In summary, our study evidenced that the scientific knowledge about reef fish species, families and trophic categories has progressed significantly over the last few decades. Despite this progress, there are gaps that need further investigation on the main drivers and mechanisms of phase shifts in reef environments and on the impacts of such changes on ecosystem services provided by reef fish in the SA.

The repercussion of phase shifts is well known worldwide, they can be drastic to the human livelihoods that depend on reefs, particularly in Brazilian Ecoregions: FNRA, NO, EA, TrMVz, and SBr.

Brazil accounts for a significant proportion of global scientific production of reef fish and fisheries in SA, and the internationalization of co-author countries' networks represents an opportunity to expand on these issues in the Decade of Ocean Science.

The Ethnosciences are promising areas for investment in research and human resources, and will serve as tools to engage fishers, users and SES in the search and proposition of solutions to reef related problems.

Hundreds of studies about reef fish are being carried out in the MPA, indicating a need to expand sampling efforts in reef formations located in urban areas.

Integration between local ecological knowledge, academia and government in the elaboration and proposition of public policies, can be a new avenue to foster and guarantee the biodiversity of reef environments for generations to come.

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## REFERENCES


Anderson, A.B., Bonaldo, R.M., Barneche, D.R., Hackradt, C.W., Félix-Hackradt, F.C., García-Charton, J.A., Floeter, S.R., 2014. Recovery of grouper assemblages indicates effectiveness of a marine protected area in Southern Brazil. Mar Ecol Prog Ser 514, 207–215. https://doi.org/10.3354/meps11032

Andrades, R., Guabiroba, H.C., Hora, M.S.C., Martins, R.F., Rodrigues, V.L.A., Vilar, C.C., Giarrizzo, T., Joyeux, J.-C., 2020. Early evidences of niche shifts in estuarine fishes following one of the world's largest mining dam disasters. Mar Pollut Bull 154, 111073. https://doi.org/10.1016/j.marpolbul.2020.111073

Araújo, M.E. de, Mattos, F.M.G. de, Melo, F.P.L. de, Chaves, L. de C.T., Feitosa, C.V., Lippi, D.L., Félix Hackradt, F.C., Hackradt, C.W., Nunes, J.L.S., Leão, Z.M. de A.N., Kikuchi, R.K.P. de, Ferreira Junior, A.V., Pereira, P.H.C., Macedo, C.H.R., Sampaio, C.L.S., Feitosa, J.L.L., 2020a. Diversity patterns of reef fish along the Brazilian tropical coast. Mar Environ Res 160. https://doi.org/10.1016/j.marenvres.2020.105038

Araújo, M.E. de, Mattos, F.M.G. de, Melo, F.P.L. de, Chaves, L. de C.T., Feitosa, C.V., Lippi, D.L., Félix Hackradt, F.C., Hackradt, C.W., Nunes, J.L.S., Leão, Z.M. de A.N., Kikuchi, R.K.P. de, Ferreira Junior, A.V., Pereira, P.H.C., Macedo, C.H.R., Sampaio, C.L.S., Feitosa, J.L.L., 2020b. Diversity patterns of reef fish along the Brazilian tropical coast. Mar Environ Res 160. https://doi.org/10.1016/j.marenvres.2020.105038

Aued, A.W., Smith, F., Quimbayo, J.P., Cândido, D. v., Longo, G.O., Ferreira, C.E.L., Witman, J.D., Floeter, S.R., Segal, B., 2018. Large-scale patterns of benthic marine communities in the Brazilian Province. PLoS One 13, e0198452. https://doi.org/10.1371/journal.pone.0198452

Barbosa-Filho, M.L.V., de Souza, G.B.G., Lopes, S. de F., Siciliano, S., Hauser Davis, R.A., Mourão, J. da S., 2020. Evidence of shifting baseline and Fisher judgment on lane snapper (Lutjanus synagris) management in a Brazilian marine protected area: Shifting L. synagris baseline and management. Ocean Coast Manag 183. https://doi.org/10.1016/j.ocecoaman.2019.105025

Begossi, A., 2015. Local ecological knowledge (LEK): understanding and managing fisheries, in: Fischer, J., Jorgensen, J., Josupeit, H., Kalikoski, D., Lucas, C.M. (Eds.), Fishers' Knowledge and the Ecosystem Approach to Fisheries: Applications, Experiences and  Lessons in Latin America. FAO Fisheries and Aquaculture , Rome, pp. 7–18.

Begossi, A., Silvano, R.A.M., 2008. Ecology and ethnoecology of dusky grouper [garoupa, Epinephelus marginatus (Lowe, 1834)] along the coast of Brazil. J Ethnobiol Ethnomed 4, 1–14. https://doi.org/10.1186/1746-4269-4-20

Behrouzi, S., Shafaeipour Sarmoor, Z., Hajsadeghi, K., Kavousi, K., 2020. Predicting scientific research trends based on link prediction in keyword networks. J Informetr 14, 101079. https://doi.org/10.1016/j.joi.2020.101079

Bellwood, D.R., Goatley, C.H.R., Bellwood, O., 2017. The evolution of fishes and corals on reefs: form, function and interdependence. Biological Reviews 92, 878–901. https://doi.org/10.1111/brv.12259

Bellwood, D.R., Hughes, T.P., Folke, C., Nyström, M., 2004a. Confronting the coral reef crisis. Nature 429, 827–833. https://doi.org/10.1038/nature02691

Bellwood, D.R., Pratchett, M.S., Morrison, T.H., Gurney, G.G., Hughes, T.P., Álvarez-Romero, J.G., Day, J.C., Grantham, R., Grech, A., Hoey, A.S., Jones, G.P., Pandolfi, J.M., Tebbett, S.B., Techera, E., Weeks, R., Cumming, G.S., 2019a. Coral reef conservation in the Anthropocene: Confronting spatial mismatches and prioritizing functions. Biol Conserv 236, 604–615. https://doi.org/10.1016/j.biocon.2019.05.056

Bellwood, D.R., Streit, R.P., Brandl, S.J., Tebbett, S.B., 2019b. The meaning of the term ‘function’ in ecology: A coral reef perspective. Funct Ecol 33, 948–961. https://doi.org/10.1111/1365-2435.13265

Bender, M.G., Floeter, S.R., Mayer, F.P., Vila-Nova, D.A., Longo, G.O., Hanazaki, N., Carvalho-Filho, A., Ferreira, C.E.L., 2013. Biological attributes and major threats as predictors of the vulnerability of species: a case study with Brazilian reef fishes. Oryx 47, 259–265. https://doi.org/10.1017/S003060531100144X

Bender, M.G., Machado, G.R., de Azevedo Silva, P.J., Floeter, S.R., Monteiro-Netto, C., Luiz, O.J., Ferreira, C.E.L., 2014. Local ecological knowledge and scientific data reveal overexploitation by multigear artisanal fisheries in the Southwestern Atlantic. PLoS One 9. https://doi.org/10.1371/journal.pone.0110332

Bender, M.G., Pie, M.R., Rezende, E.L., Mouillot, D., Floeter, S.R., 2013. Biogeographic, historical and environmental influences on the taxonomic and functional structure of Atlantic reef fish assemblages. Global Ecology and Biogeography 22, 1173–1182. https://doi.org/10.1111/geb.12099

Bennett, A.F., Haslem, A., Cheal, D.C., Clarke, M.F., Jones, R.N., Koehn, J.D., Lake, P.S., Lumsden, L.F., Lunt, I.D., Mackey, B.G., Nally, R. mac, Menkhorst, P.W., New, T.R., Newell, G.R., O-Hara, T., Quinn, G.P., Radford, J.Q., Robinson, D., Watson, J.E.M., Yen, A.L., 2009. Ecological processes: A key element in strategies for nature conservation. Ecological Management & Restoration 10, 192–199. https://doi.org/10.1111/j.1442-8903.2009.00489.x

Brondízio, E.S., Aumeeruddy-Thomas, Y., Bates, P., Carino, J., Fernández-Llamazares, Á., Ferrari, M.F., Galvin, K., Reyes-García, V., Mcelwee, P., Molnár, Z., Samakov, A., Shrestha, U.B., 2021. Annual Review of Environment and Resources Locally Based, Regionally Manifested, and Globally Relevant: Indigenous and Local Knowledge, Values, and Practices for Nature. https://doi.org/10.1146/annurev-environ-012220

Caldwell, Z.R., Zgliczynski, B.J., Williams, G.J., Sandin, S.A., 2016. Reef Fish Survey Techniques: Assessing the Potential for Standardizing Methodologies. PLoS One 11, e0153066. https://doi.org/10.1371/journal.pone.0153066

Cinner, J., 2014. Coral reef livelihoods. Curr Opin Environ Sustain 7, 65–71. https://doi.org/10.1016/j.cosust.2013.11.025

Clements, K.D., German, D.P., Piché, J., Tribollet, A., Choat, J.H., 2016. Integrating ecological roles and trophic diversification on coral reefs: multiple lines of evidence identify parrotfishes as microphages. Biological Journal of the Linnean Society 120, 729–751. https://doi.org/10.1111/bij.12914

Connell, J.H., 1978. Diversity in Tropical Rain Forests and Coral Reefs. Science (1979) 199, 1302–1310.

Conservation Biology Institute, 2021. Data Basin [WWW Document]. Data Basin. URL https://databasin.org (accessed 4.9.21).

Conversi, A., Dakos, V., Gårdmark, A., Ling, S., Folke, C., Mumby, P.J., Greene, C., Edwards, M., Blenckner, T., Casini, M., Pershing, A., Möllmann, C., 2015a. A Holistic view of Marine Regime shifts. Philosophical Transactions of the Royal Society B: Biological Sciences 370, 1–8. https://doi.org/10.1098/rstb.2013.0279

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., Turner, R.K., 2014. Changes in the global value of ecosystem services. Global Environmental Change 26, 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002

Cowman, P.F., Bellwood, D.R., 2013. The historical biogeography of coral reef fishes: global patterns of origination and dispersal. J Biogeogr 40, 209–224. https://doi.org/10.1111/jbi.12003

Creative Commons Attribution License, 2020. PRISMA: Transparent Reporting of Systematic Reviews and Meta-Analyses [WWW Document]. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only. URL https://prisma-statement.org/ (accessed 10.10.22).

Cruz, I.C.S., Loiola, M., Albuquerque, T., Reis, R., Nunes, J. de A.C.C., Reimer, J.D., Mizuyama, M., Kikuchi, R.K.P., Creed, J.C., 2015. Effect of Phase Shift from Corals to Zoantharia on Reef Fish Assemblages. PLoS One. https://doi.org/10.1371/journal.pone.0116944

Daskalov, G.M., Grishin, A.N., Rodionov, S., Mihneva, V., 2007. Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. Proceedings of the National Academy of Sciences 104, 10518–10523. https://doi.org/10.1073/pnas.0701100104

Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., Garibaldi, L.A., Ichii, K., Liu, J., Subramanian, S.M., Midgley, G.F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Chowdhury, R.R., Shin, Y.J., Visseren-Hamakers, I., Willis, K.J., Zayas, C.N., 2019. Pervasive human-driven decline of life on Earth points to the need for transformative change. Science (1979) 366, eaax3100. https://doi.org/10.1126/science.aax3100

Done, T.J., 1992. Phase shifts in coral reef communities and their ecological significance. Hydrobiologia 247, 121–132. https://doi.org/10.1007/BF00008211

Duarte, C.M., Agusti, S., Barbier, E., Britten, G.L., Castilla, J.C., Gattuso, J.-P., Fulweiler, R.W., Hughes, T.P., Knowlton, N., Lovelock, C.E., Lotze, H.K., Predragovic, M., Poloczanska, E., Roberts, C., Worm, B., 2020. Rebuilding marine life. Nature 580, 39–51. https://doi.org/10.1038/s41586-020-2146-7

Estes, J.A., Terborgh, J., Brashares, J.S., Power, M.E., Berger, J., Bond, W.J., Carpenter, S.R., Essington, T.E., Holt, R.D., Jackson, J.B.C., Marquis, R.J., Oksanen, L., Oksanen, T., Paine, R.T., Pikitch, E.K., Ripple, W.J., Sandin, S.A., Scheffer, M., Schoener, T.W., Shurin, J.B., Sinclair, A.R.E., Soulé, M.E., Virtanen, R., Wardle, D.A., 2011. Trophic Downgrading of Planet Earth. Science (1979) 333, 301–306. https://doi.org/10.1126/science.1205106

Ferreira, C.E.L., Floeter, S.R., Gasparini, J.L., Ferreira, B.P., Joyeux, J.C., 2004a. Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. J Biogeogr 31, 1093–1106. https://doi.org/10.1111/j.1365-2699.2004.01044.x

Ferreira, C.E.L., Gonçalves, J.E.A., 2001. Community structure and diet of roving herbivorous reef fishes in the Abrolhos Archipelago, south-western Atlantic. J Fish Biol 69, 1533–1551. https://doi.org/10.1111/j.1095-8649.2006.01220.x

Floeter, S.R., Behrens, M.D., Ferreira, C.E.L., Paddack, M.J., Horn, M.H., 2005. Geographical gradients of marine herbivorous fishes: patterns and processes. Mar Biol 147, 1435–1447. https://doi.org/10.1007/s00227-005-0027-0

Floeter, S.R., Guimarães, R.Z.P., Rocha, L.A., Ferreira, C.E.L., Rangel, C.A., Gasparini, J.L., 2001. Geographic variation in reef-fish assemblages along the Brazilian coast. Global Ecology and Biogeography 10, 423–431. https://doi.org/10.1046/j.1466-822X.2001.00245.x

Floeter, S.R., Ferreira, C.E.L., Dominici-Arosemena, A., Zalmon, I.R., 2004. Latitudinal gradients in Atlantic reef fish communities: trophic structure and spatial use patterns. J Fish Biol 64, 1680–1699. https://doi.org/10.1111/j.0022-1112.2004.00428.x

Floeter, S.R., Krohling, W., Gasparini, J.L., Ferreira, C.E.L., Zalmon, I.R., 2007. Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover. Environ Biol Fishes 78, 147–160. https://doi.org/10.1007/s10641-006-9084-6

Floeter, S.R., Rocha, L.A., Robertson, D.R., Joyeux, J.C., Smith-Vaniz, W.F., Wirtz, P., Edwards, A.J., Barreiros, J.P., Ferreira, C.E.L., Gasparini, J.L., Brito, A., Falcón, J.M., Bowen, B.W., Bernardi, G., 2008. Atlantic reef fish biogeography and evolution. J Biogeogr 35, 22–47. https://doi.org/10.1111/j.1365-2699.2007.01790.x

Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S.R., Stuart Chapin, F., Crépin, A.S., Daily, G., Danell, K., Ebbesson, J., Elmqvist, T., Galaz, V., Moberg, F., Nilsson, M., Österblom, H., Ostrom, E., Persson, Å., Peterson, G., Polasky, S., Steffen, W., Walker, B., Westley, F., 2011. Reconnecting to the biosphere, in: Ambio. pp. 719–738. https://doi.org/10.1007/s13280-011-0184-y

Food and Agriculture Organisation of the United Nations, 2017. Fao Working for Sdg 14 1–35.

Francini-Filho, R.B., Asp, N.E., Siegle, E., Hocevar, J., Lowyck, K., D'Avila, N., Vasconcelos, A.A., Baitelo, R., Rezende, C.E., Omachi, C.Y., Thompson, C.C., Thompson, F.L., 2018. Perspectives on the Great Amazon Reef: Extension, Biodiversity, and Threats. Front Mar Sci 5, 1–5. https://doi.org/10.3389/fmars.2018.00142

Froese, R., Pauly, D., 2022. FishBase [WWW Document]. Editors. URL www.fishbase.org (accessed 3.12.22).

Galetti, P., Molina, W., Accioly, I., 2000. An overview of marine fish cytogenetics. Hydrobiologia 420, 55–62.

Gerhardinger, L.C., Godoy, E.A.S., Jones, P.J.S., 2009. Local ecological knowledge and the management of marine protected areas in Brazil. Ocean Coast Manag 52, 154–165. https://doi.org/10.1016/j.ocecoaman.2008.12.007

Giglio, V.J., Bender, M.G., Zapelini, C., Ferreira, C.E.L., 2017. The end of the line? Rapid depletion of a large-sized grouper through spearfishing in a subtropical marginal reef. Perspect Ecol Conserv 15, 115–118. https://doi.org/10.1016/j.pecon.2017.03.006

Giglio, V.J., Luiz, O.J., Gerhardinger, L.C., 2015. Depletion of marine megafauna and shifting baselines among artisanal fishers in eastern Brazil. Anim Conserv 18, 348–358. https://doi.org/10.1111/acv.12178

Graham, N.A.J., 2015. Phase shifts and coral reef fishes. Ecology of Fishes on Coral Reefs 191–198. https://doi.org/10.1017/CBO9781316105412.021

Graham, N.A.J., Nash, K.L., 2013. The importance of structural complexity in coral reef ecosystems. Coral Reefs 32, 315–326. https://doi.org/10.1007/s00338-012-0984-y

Guabiroba, H.C., Rocha, L.A., Joyeux, J.-C., Pimentel, C.R., Teixeira, J.B., Macieira, R.M., Gasparini, J.L., Francini-Filho, R.B., Andrades, R., Mazzei, E., Simon, T., Sissini, M., Costa, T.J.F., Pinheiro, H.T., 2022. Coralline Hills: high complexity reef habitats on seamount summits of the Vitória-Trindade Chain. Coral Reefs 41, 1075–1086. https://doi.org/10.1007/s00338-022-02269-0

Harvey, E., Gounand, I., Ward, C.L., Altermatt, F., 2017. Bridging ecology and conservation: from ecological networks to ecosystem function. Journal of Applied Ecology. https://doi.org/10.1111/1365-2664.12769

Havemann, F., Scharnhorst, A., 2012. Bibliometric Networks.

Hughes, T.P., Barnes, M.L., Bellwood, D.R., Cinner, J.E., Cumming, G.S., Jackson, J.B.C., Kleypas, J., Lough, I.A. van de L.J.M., Morrison, T.H., Palumbi, S.R., Nes, E.H. van, Scheffer, M., 2017. Coral reefs in the anthropocene. Nature 546, 82–90. https://doi.org/10.1007/978-94-017-7249-5

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. Science (1979) 293, 629–637. https://doi.org/10.1126/science.1059199

Jennings, S., Kaiser, M.J., 1998. The Effects of Fishing on Marine Ecosystems, in: Advances in Marine Biology. pp. 201–352. https://doi.org/10.1016/S0065-2881(08)60212-6

Johnson, A., 2010. Reducing bycatch in coral reef trap fisheries: escape gaps as a step towards sustainability. Mar Ecol Prog Ser 415, 201–209. https://doi.org/10.3354/meps08762

Joyeux, J.C., Floeter, S.R., Ferreira, C.E.L., Gasparini, J.L., 2001. Biogeography of tropical reef fishes: The south Atlantic puzzle. J Biogeogr 28, 831–841. https://doi.org/10.1046/j.1365-2699.2001.00602.x

Kitahara, M.V., Cordeiro, R.T.S., Barbosa, R.V., Pires, D. de O., Sumida, P.Y.G., 2020. Brazilian Deep-Sea Corals, in: Brazilian Marine Biodiversity. pp. 73–107. https://doi.org/10.1007/978-3-030-53222-2_4

Knowlton, N., 1992. Thresholds and multiple stable states in coral reef community dynamics. Integr Comp Biol 32, 674–682. https://doi.org/10.1093/icb/32.6.674

Knowlton, N., Jackson, J.B.C., 2008. Shifting baselines, local impacts, and global change on coral reefs. PLoS Biol 6, 0215–0220. https://doi.org/10.1371/journal.pbio.0060054

Kovalenko, K.E., Thomaz, S.M., Warfe, D.M., 2012. Habitat complexity: approaches and future directions. Hydrobiologia 685, 1–17. https://doi.org/10.1007/s10750-011-0974-z

Kulbicki, M., Parravicini, V., Bellwood, D.R., Arias-Gonzàlez, E., Chabanet, P., Floeter, S.R., Friedlander, A., McPherson, J., Myers, R.E., Vigliola, L., Mouillot, D., 2013. Global biogeography of reef fishes: A hierarchical quantitative delineation of regions. PLoS One 8. https://doi.org/10.1371/journal.pone.0081847

Leal, I.C.S., de Araújo, M.E., da Cunha, S.R., Pereira, P.H.C., 2015. The influence of fire-coral colony size and agonistic behaviour of territorial damselfish on associated coral reef fish communities. Mar Environ Res 108, 45–54. https://doi.org/10.1016/j.marenvres.2015.04.009

Longo, G.O., Ferreira, C.E.L., Floeter, S.R., 2014. Herbivory drives large-scale spatial variation in reef fish trophic interactions. Ecol Evol 4, 4553–4566. https://doi.org/10.1002/ece3.1310

Longo, G.O., Hay, M.E., Ferreira, C.E.L., Floeter, S.R., 2018. Trophic interactions across 61 degrees of latitude in the Western Atlantic. Global Ecology and Biogeography 28, 107–117. https://doi.org/10.1111/geb.12806

Lopes, P.F.M., Verba, J.T., Begossi, A., Pennino, M.G., 2019. Predicting species distribution from fishers' local ecological knowledge: a new alternative for data-poor management. Canadian Journal of Fisheries and Aquatic Sciences 76, 1423–1431. https://doi.org/10.1139/cjfas-2018-0148

Lourenço, R.A., Combi, T., Alexandre, M. da R., Sasaki, S.T., Zanardi-Lamardo, E., Yogui, G.T., 2020. Mysterious oil spill along Brazil's northeast and southeast seaboard (2019–2020): Trying to find answers and filling data gaps. Mar Pollut Bull 156, 111219. https://doi.org/10.1016/j.marpolbul.2020.111219

Luiz, O.J., Edwards, A.J., 2011. Extinction of a shark population in the Archipelago of Saint Paul's Rocks (equatorial Atlantic) inferred from the historical record. Biol Conserv 144, 2873–2881. https://doi.org/10.1016/j.biocon.2011.08.004

Luiz, O.J., Madin, J.S., Robertson, D.R., Rocha, L.A., Wirtz, P., Floeter, S.R., 2012. Ecological traits influencing range expansion across large oceanic dispersal barriers: insights from tropical Atlantic reef fishes. Proceedings of the Royal Society B: Biological Sciences 279, 1033–1040. https://doi.org/10.1098/rspb.2011.1525

Magalhães, K.M., Barros, K.V. de S., Lima, M.C.S. de, Rocha-Barreira, C. de A., Rosa Filho, J.S., Soares, M. de O., 2020. Oil spill + COVID-19: A disastrous year for Brazilian seagrass conservation. Science of The Total Environment x, 7. https://doi.org/10.1016/j.scitotenv.2020.142872

Magris, R., Giarrizzo, T., 2020. Mysterious oil spill in the Atlantic Ocean threatens marine biodiversity and local people in Brazil. Mar Pollut Bull 153, 3. https://doi.org/10.1016/j.marpolbul.2020.110961

Magris, R.A., 2021. Effectiveness of Large-Scale Marine Protected Areas in the Atlantic Ocean for Reducing Fishing Activities. Front Mar Sci 8, 1–7. https://doi.org/10.3389/fmars.2021.711011

Mantelatto, M.C., Cruz, I.C.S., Creed, J.C., 2018. A review of the knowledge of shallow subtidal benthic communities in Brazil. Mar Environ Res 140, 69–77. https://doi.org/10.1016/j.marenvres.2018.05.022

Marine Institute, F., 2021. Marine Regions [WWW Document]. URL https://www.marineregions.org/sources.php (accessed 4.9.21).

Markus, T., Hillebrand, H., Hornidge, A.-K., Krause, G., Schlüter, A., 2018. Disciplinary diversity in marine sciences: the urgent case for an integration of research. ICES Journal of Marine Science 75, 502–509. https://doi.org/10.1093/icesjms/fsx201

McClanahan, T.R., Friedlander, A.M., Wantiez, L., Graham, N.A.J., Bruggemann, J.H., Chabanet, P., Oddenyo, R.M., 2022. Best-practice fisheries management associated with reduced stocks and changes in life histories. Fish and Fisheries 23, 422–444. https://doi.org/10.1111/faf.12625

MEA, 2005. The Millennium Ecosystem Assessment Series Ecosystems, Ecosystems and Human Well-being: Current State and Trends. Island Press, Washington D.C, Covelo, London.

Miranda, R.J., Malhado, A.C.M., Fabré, N.N., Batista, V. da S., Santos, R., Campos-Silva, J.V., Correia, R., Santos, A.P. de O., Cardoso, A., Pinheiro, B.R., Oliveira, B.S.S.P. de, Sampaio, C.L.S., Moura, F. de B.P., Normande, I.C., Ramires, L., Araujo, L.M. de, Efe, M.A., Belluci, M. da S.P., Landell, M.F., Carvalho, N.A. de, Cavalcante, R.J. de M., Pinto, T.K. de O., Mott, T., Ladle, R.J., 2020. Integrating Long Term Ecological Research (LTER) and Marine Protected Area management: challenges and solutions. Oecologia Australis 24, 279–300. https://doi.org/10.4257/oeco.2020.2402.05

Moberg, F., Folke, C., 1999. Ecological goods and services of coral reef ecosystems. Ecological Economics 29, 215–233. https://doi.org/10.1016/S0921-8009(99)00009-9

Möllmann, C., Folke, C., Edwards, M., Conversi, A., 2015. Marine regime shifts around the globe: theory, drivers and impacts. Philosophical Transactions of the Royal Society B: Biological Sciences 370, 20130260. https://doi.org/10.1098/rstb.2013.0260

Mouillot, D., Villéger, S., Parravicini, V., Kulbicki, M., Arias-González, J.E., Bender, M., Chabanet, P., Floeter, S.R., Friedlander, A., Vigliola, L., Bellwood, D.R., 2014. Functional over-redundancy and high functional vulnerability in global fish faunas on tropical reefs. Proc Natl Acad Sci U S A 111, 13757–13762. https://doi.org/10.1073/pnas.1317625111

Moura, R.L., Amado-Filho, G.M., Moraes, F.C., Brasileiro, P.S., Salomon, P.S., Mahiques, M.M., Bastos, A.C., Almeida, M.G., Silva, J.M., Araujo, B.F., Brito, F.P., Rangel, T.P., Oliveira, B.C.V., Bahia, R.G., Paranhos, R.P., Dias, R.J.S., Siegle, E., Figueiredo, A.G., Pereira, R.C., Leal, C. v., Hajdu, E., Asp, N.E., Gregoracci, G.B., Neumann-Leitão, S., Yager, P.L., Francini-Filho, R.B., Fróes, A., Campeão, M., Silva, B.S., Moreira, A.P.B., Oliveira, L., Soares, A.C., Araujo, L., Oliveira, N.L., Teixeira, J.B., Valle, R.A.B., Thompson, C.C., Rezende, C.E., Thompson, F.L., 2016. An extensive reef system at the Amazon River mouth. Sci Adv 2. https://doi.org/10.1126/sciadv.1501252

Mumby, P.J., Dahlgren, C.P., Harborne, A.R., Kappel, C. v., Micheli, F., Brumbaugh, D.R., Holmes, K.E., Mendes, J.M., Broad, K., Sanchirico, J.N., Buch, K., Box, S., Stoffle, R.W., Gill, A.B., 2006. Fishing, trophic cascades, and the process of grazing on coral reefs. Science (1979) 311, 98–101. https://doi.org/10.1126/science.1121129

Myers, R.A., Baum, J.K., Shepherd, T.D., Powers, S.P., Peterson, C.H., 2007. Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. Science (1979) 315, 1846–1850. https://doi.org/10.1126/science.1138657

Myers, R.A., Worm, B., 2003a. Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283. https://doi.org/10.1038/nature01610

Myers, R.A., Worm, B., 2003b. Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283. https://doi.org/10.1038/nature01610

Newton, K., Côté, I.M., Pilling, G.M., Jennings, S., Dulvy, N.K., 2007. Current and Future Sustainability of Island Coral Reef Fisheries. Current Biology 17, 655–658. https://doi.org/10.1016/j.cub.2007.02.054

Norström, A. v, Nyström, M., Jouffray, J.-B., Folke, C., Graham, N.A., Moberg, F., Olsson, P., Williams, G.J., 2016. Guiding coral reef futures in the Anthropocene. Front Ecol Environ 14, 490–498. https://doi.org/10.1002/fee.1427

Norström, A. v., Nyström, M., Lokrantz, J., Folke, C., 2009. Alternative states on coral reefs: Beyond coral-macroalgal phase shifts. Mar Ecol Prog Ser 376, 293–306. https://doi.org/10.3354/meps07815

Nyström, M., Norström, A. v., Blenckner, T., de la Torre-Castro, M., Eklöf, J.S., Folke, C., Österblom, H., Steneck, R.S., Thyresson, M., Troell, M., 2012. Confronting Feedbacks of Degraded Marine Ecosystems. Ecosystems 15, 695–710. https://doi.org/10.1007/s10021-012-9530-6

Oliveira Júnior, J.G.C., Silva, L.P.S., Malhado, A.C.M., Batista, V.S., Fabré, N.N., Ladle, R.J., 2016. Artisanal Fisheries Research: A Need for Globalization? PLoS One 11, e0150689. https://doi.org/10.1371/journal.pone.0150689

ONU, 2015. 70/1. Transforming our world: the 2030 Agenda for Sustainable Development.

ONU, UNEP, 2019. Report of the Conference of the parties to the Convention on Biological Diversity on its Fourteenth Meeting, Antimicrobial agents and chemotherapy.

Pace, M.L., Cole, J.J., Carpenter, S.R., Kitchell, J.F., 1999. Trophic cascades revealed in diverse ecosystems. TREE 14, 483–488.

Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, R.R., Jackson, J.B.C., 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science (1979) 301, 955–958. https://doi.org/10.1126/science.1085706

Partelow, S., Hornidge, A.K., Senff, P., Stäbler, M., Schlüter, A., 2020. Tropical marine sciences: Knowledge production in a web of path dependencies. PLoS One 15. https://doi.org/10.1371/journal.pone.0228613

Pauly., D., Christensen, V., Dalsgaard, J., Froese, R., Torres Jr.F., 1998. Fishing down food webs. Science (1979) 279, 5.

Pershing, A.J., Mills, K.E., Record, N.R., Stamieszkin, K., Wurtzell, K. v., Byron, C.J., Fitzpatrick, D., Golet, W.J., Koob, E., 2015. Evaluating trophic cascades as drivers of regime shifts in different ocean ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences 370, 20130265. https://doi.org/10.1098/rstb.2013.0265

Pinheiro, H.T., Macena, B.C.L., Francini-Filho, R.B., Ferreira, C.E.L., Albuquerque, F. v., Bezerra, N.P.A., Carvalho-Filho, A., Ferreira, R.C.P., Luiz, O.J., Mello, T.J., Mendonça, S.A., Nunes, D.M., Pimentel, C.R., Pires, A.M.A., Soares-Gomes, A., Viana, D.L., Hazin, F.H. v., Rocha, L.A., 2020. Fish biodiversity of Saint Peter and Saint Paul's Archipelago Mid-Atlantic Ridge, Brazil: new records and a species database. J Fish Biol 97, 1143–1153. https://doi.org/10.1111/jfb.14484

Pinheiro, H.T., Rocha, L.A., Macieira, R.M., Carvalho-Filho, A., Anderson, A.B., Bender, M.G., di Dario, F., Ferreira, C.E.L., Figueiredo-Filho, J., Francini-Filho, R., Gasparini, J.L., Joyeux, J.-C., Luiz, O.J., Mincarone, M.M., Moura, R.L., Nunes, J. de A.C.C., Quimbayo, J.P., Rosa, R.S., Sampaio, C.L.S., Sazima, I., Simon, T., Vila-Nova, D.A., Floeter, S.R., 2018. South-western Atlantic reef fishes: Zoogeographical patterns and ecological drivers reveal a secondary biodiversity centre in the Atlantic Ocean. Divers Distrib 24, 951–965. https://doi.org/10.1111/ddi.12729

Pinheiro, H.T., Shepherd, B., Teixeira, J.B., Pimentel, C.R., Pereira, P.H.C., Stein, C.E., Reis-Filho, J.A., Garla, R.C., Macieira, R.M., Delfino, S.D.T., Giarrizzo, T., Joyeux, J.-C., Gasparini, J.L., Rocha, L.A., 2021. Fish aggregations and reproductive behaviour on mesophotic coral ecosystems of a southwestern Atlantic Oceanic archipelago. J Nat Hist 55, 2017–2025. https://doi.org/10.1080/00222933.2021.1985645

Quimbayo, J.P., Dias, M.S., Kulbicki, M., Mendes, T.C., Lamb, R.W., Johnson, A.F., Aburto-Oropeza, O., Alvarado, J.J., Bocos, A.A., Ferreira, C.E.L., Garcia, E., Luiz, O.J., Mascareñas-Osorio, I., Pinheiro, H.T., Rodriguez-Zaragoza, F., Salas, E., Zapata, F.A., Floeter, S.R., 2019. Determinants of reef fish assemblages in tropical Oceanic islands. Ecography 42, 77–87. https://doi.org/10.1111/ecog.03506

Rasband, W., 2005. Inkscape-1.0.2-2- Open Source Scalable Vector Graphics Editor Draw Freely.

Reis, R.E., Albert, J.S., di Dario, F., Mincarone, M.M., Petry, P., Rocha, L.A., 2016. Fish biodiversity and conservation in South America. J Fish Biol 89, 12–47. https://doi.org/10.1111/jfb.13016

Rocha, J., Yletyinen, J., Biggs, R., Blenckner, T., Peterson, G., 2015. Marine regime shifts: drivers and impacts on ecosystems services. Philosophical Transactions of the

Royal Society B: Biological Sciences 370, 20130273. https://doi.org/10.1098/rstb.2013.0273

Rocha, J.C., Peterson, G., Norström, A., Biggs, R. (Oonsie), 2017. Regime Shifts DataBase Large persistent changes in ecosystem services [WWW Document]. Coral Transitions. URL www.regimeshifts.org (accessed 12.4.21).

Roos, N., Pennino, M., Lopes, P., Carvalho, A., 2016. Multiple management strategies to control selectivity on parrotfishes harvesting. Ocean Coast Manag 134, 20–29. https://doi.org/10.1016/j.ocecoaman.2016.09.029

Roos, N.C., Longo, G.O., Taylor, B.M., Carvalho, A.R., 2020. Demography of the largest and most endangered Brazilian parrotfish, Scarus trispinosus, reveals overfishing. Endanger Species Res 41, 319–327. https://doi.org/10.3354/esr01024

RStudio, 2021. R version 4.0.4. RStudio-The R Foundation for Statistical Computing Platform.

Sadovy de Mitcheson, Y., Craig, M.T., Bertoncini, A.A., Carpenter, K.E., Cheung, W.W.L., Choat, J.H., Cornish, A.S., Fennessy, S.T., Ferreira, B.P., Heemstra, P.C., Liu, M., Myers, R.F., Pollard, D.A., Rhodes, K.L., Rocha, L.A., Russell, B.C., Samoilys, M.A., Sanciangco, J., 2013. Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. Fish and Fisheries 14, 119–136. https://doi.org/10.1111/j.1467-2979.2011.00455.x

Sáenz-Arroyo, A., Revollo-Fernández, D., 2016. Local ecological knowledge concurs with fishing statistics: An example from the abalone fishery in Baja California, Mexico. Mar Policy 71, 217–221. https://doi.org/10.1016/j.marpol.2016.06.006

Sampaio, A., Bianchini, A., 2002. Salinity effects on osmoregulation and growth of the euryhaline flounder Paralichthys orbignyanus. J Exp Mar Biol Ecol 269, 187–196.

Scheffer, M., Carpenter, S., Foley, J.A., Folke, C., Walkerk, B., 2001. Catastrophic shifts in ecosystems. National Academies Press 413, 591–596. https://doi.org/10.1130/0-8137-2366-3.167

SCImago, 2020. SJR — SCImago Journal & Country Rank [Portal] [WWW Document]. URL http://www.scimagojr.com (accessed 10.21.20).

Simon, T., Pinheiro, H.T., Santos, S., Macieira, R.M., Ferreira, Y.S.S., Bernardi, G., Rocha, L.A., Floeter, S.R., Ferreira, C.E.L., Joyeux, J.C., 2022. Comparative phylogeography of reef fishes indicates seamounts as stepping stones for dispersal and diversification. Coral Reefs 41, 551–561. https://doi.org/10.1007/s00338-021-02178-8

Siqueira, A.C., Oliveira-Santos, L.G.R., Cowman, P.F., Floeter, S.R., 2016. Evolutionary processes underlying latitudinal differences in reef fish biodiversity. Global Ecology and Biogeography 25, 1466–1476. https://doi.org/10.1111/geb.12506

Spalding, M., Burke, L., Wood, S.A., Ashpole, J., Hutchison, J., zu Ermgassen, P., 2017. Mapping the global value and distribution of coral reef tourism. Mar Policy 82, 104–113. https://doi.org/10.1016/j.marpol.2017.05.014

Spalding, M., Fox, H., Allen, G., Davidson, N., Ferdaña, Z., Finlayson, M., Halpern, B., Jorge, M., Lombana, A., Lourie, S., Martin, K., McManus, E., Molnar, J., Recchia, C., Robertson, J., 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. Bioscience 57, 573–583. https://doi.org/10.1641/B570707

Stoddart, D.R., 1969. Ecology and morphology of recent coral reefs. Biological Reviews 44, 433–498. https://doi.org/10.1111/j.1469-185X.1969.tb00609.x

Trindade-Santos, I., Moyes, F., Magurran, A.E., 2020. Global change in the functional diversity of marine fisheries exploitation over the past 65 years: Fisheries and Functional Diversity. Proceedings of the Royal Society B: Biological Sciences 287. https://doi.org/10.1098/rspb.2020.0889/rspb20200889

UNESCO, 2020. United Nations Decade of Ocean Science for Sustainable Development (2021-2030) [WWW Document]. Decade of Ocean Science for Sustainable. URL https://en.unesco.org/ocean-decade#:~:text=The United Nations has proclaimed,support countries in creating improved

van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84, 523–538. https://doi.org/10.1007/s11192-009-0146-3

Verbeek, A., Debackere, K., Luwel, M., Zimmermann, E., 2002. Measuring progress and evolution in science and technology - I: The multiple uses of bibliometric indicators. International Journal of Management Reviews 4, 179–211. https://doi.org/10.1111/1468-2370.00083

Visbeck, M., 2018. Ocean science research is key for a sustainable future. Nat Commun. https://doi.org/10.1038/s41467-018-03158-3

Waltman, L., van Eck, N.J., Noyons, E.C.M., 2010. A unified approach to mapping and clustering of bibliometric networks. J Informetr 4, 629–635. https://doi.org/10.1016/j.joi.2010.07.002

Woodhead, A.J., Hicks, C.C., Norström, A. v., Williams, G.J., Graham, N.A.J., 2019. Coral reef ecosystem services in the Anthropocene. Funct Ecol 33, 1365-2435.13331. https://doi.org/10.1111/1365-2435.13331

Zapelini, C., Bender, M.G., Giglio, V.J., Schiavetti, A., 2019. Tracking interactions: Shifting baseline and fisheries networks in the largest Southwestern Atlantic reef system. Aquat Conserv 29, 2092–2106. https://doi.org/10.1002/aqc.3224

## SUPPLEMENTARY MATERIAL

### Bibliometric research approach

#### *Researched areas*

1) Applied Ecology & Conservation

Research about the design of marine protected areas, management, marine policy agenda, resource use and reef resilience. Articles related to Conservation Planning (human behavior; local ecological knowledge; tourism management), Fishing Management, and Anthropogenic Disturbances (pollution & contaminants).

2) Biogeography, Macroecology, Phylogeography

Descriptive studies that had the entire Western South Atlantic as a sample unit, with focus on patterns of biodiversity distribution, endemism, evolution, and diversification of clades (phylogenetic divergence; phenotypic variation). Articles about Macroecology with focus on a single community, ecosystems, and reef diversity gradients. In Phylogeography, studies incorporating elements of species trees.

2) Biodiversity

Descriptive studies that map the distribution and diversity of reef fish species, environment descriptors of biodiversity, community distribution, and comparisons of species amongst environments.

3) Biology

Articles related mainly to biological descriptors, reproduction, recruitment, settlement, establishment, survivorship, demography (age, growth, and mortality), diet, ecophysiology, memory retention and metabolism.

5) Ecology & Evolution

Articles about original research, opinions, letters, genetics of species, and populations. Articles that researched ecological and evolutionary insights about the natural world and anthropogenic impacts, that have been acting as drivers of change in reef fish species.

6) Ecology

Articles researched about the spatial-temporal structure and dynamics of species and community distribution. Articles related to connectivity between ecosystems, characterization of habitats – including nursery areas, energy pathways, functional redundancy, niche, structural complexity and taxonomic nestedness.

7) Ecotoxicology

Publications about mechanisms and processes whereby chemicals exert their effects on reef fish and the impact caused at the population, community, or ecosystem levels.

8) Ethnobiology/Ethnoecology

Articles about new methodologies used in investigations concerning the interactions between human societies and nature. Publications that included the human, cultural, and social dimensions to the wider understanding of the biological and ecological dimensions of reef fishes.

9) Ethology

Articles related to understanding reproductive behavior (nesting behavior; spawning aggregations), social behavior (agonistic interaction; escape; mimetic; mutualism). Publications that researched the behavior of trophic interactions (feeding ecology; nuclear–follower associations; cleaning; predation and parasites).

10) Food webs

Publications about trophic relationships and cascading effects between levels of a community and multi-species interactions; models explaining food web structure and trophic relationships.

11) Taxonomy, Systematic and Phylogenetics

We included in this category only research of species delimitation, nomenclature, and records of new occurrences. Also, articles about new species and the morphological characterization of reef fish species were included. In addition, we also included research on the Systematic and Phylogenetic review of species.

***Ecological processes studied***

1) Biodiversity Conservation & Management

Publications which researched processes about citizen monitoring, citizen science, human engagement and behavior, local ecological knowledge, management effectiveness, stock assessment, fishing management, overexploitation, and the Shifting Baseline Syndrome.

2) Biogeography

Publications about the process of dispersion, diversification, colonization, range expansion, speciation, and extinction risks.

3) Social behavior

Publications about all kind of animal behavior supporting effective foraging, predation avoidance, fitness, reproduction, and aggregation.

4) Ecological

Articles related to descriptors of structural complexity, spatial-temporal distribution and dynamics of species and community, connectivity between ecosystems, energetic pathways, niche partitioning, structural-functional redundancy and taxonomic nestedness. This category also included processes related to stock production, consumption, fishery, and overexploitation of natural resources.

5) Species biology

Publications of processes related to diet, ecophysiology, metabolism, establishment, survivorship, demography, memory retention and settlement.

# 4 CAPÍTULO II: CORAL REEF FISH, FISHERIES, AND PEOPLE ON A TROPICAL ISLAND IN THE ANTHROPOCENE


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## Highlights

- Human stressors are drivers of multiple basins of attraction for phase shifts.
- Coral reefs support food for hundreds of traditional fishing communities.
- The shifting baseline syndrome detected changes in catches of target species.
- There are decreasing trends in carnivorous and piscivorous fish stocks.
- Local ecological knowledge detected phase shifts in coral reefs.


## Abstract

Coral reefs regulate the global climate, and their biodiversity promotes the maintenance of ecosystem goods and services (ESs) that are essential for the social and economic well-being of millions of people in coastal and marine regions. However, the co-occurrence of anthropogenic stressors, such as climate change and overfishing, act as basins of attraction for phase changes, affecting the resilience of this ecosystem. Overfishing compromise, the balance between primary productivity and consumption, altering competition patterns, and top-down and bottom-up trophic interactions, reducing the supply of SEs. Understanding the contributions of these ES to people and identifying the stressors that affect their provision is a priority for the conservation, management, and governance of reef biodiversity. In this study, we approach the local ecological knowledge (LEK) of three generations of fishermen from a tropical island in the Southwest Atlantic (SWA) as an alternative knowledge to investigate the SEs provided by reef fish and fisheries, to detect the occurrence of the Shifting Baseline Syndrome (SBS), and identify which stressors promote phase shifts, and prospects for solutions. We hypothesize that SBS is occurring in relation to carnivore, piscivore, and herbivore captures over time, and we assume that multiple stressors promote the phase shifts. We identified that multispecific fisheries are sources of food, materials, work, and recreation. However, we detected a deviation of perception in captures, and a gradual replacement of target species over time from larger carnivorous species to smaller herbivores. Overfishing, habitat degradation and unmanaged tourism were identified as the main stressors. The main alternative solutions pointed out were the management and monitoring of fisheries and tourism. Spatial planning through ecosystem-based management is an alternative to minimize stressors and adopting a multilevel network governance can contribute to combating and mitigating multiple basins of attraction for phase shifts.

**Keywords:** Ecosystem services, Local Ecological Knowledge, Shifting Baseline Syndrome.

## 4.2 INTRODUCTION

The Anthropocene marks a period of acceleration and intensification of the co-occurrence of multiple stressors at different space-time scales, where humanity has become a major geological force systematically impacting the ocean (Steffen et al., 2011). The development and exponential growth of human populations and economies are intensifying climate change, pollution, overfishing, habitat degradation and the global biodiversity decline of marine life (Malhi, 2017; Steffen et al., 2011).

The co-occurrence of these multiple stressors acts as a mechanism that disturbs the functioning processes of natural ecosystems and their biological components, affecting their resilience and stability (Holling C. S, 1973; J. C. Rocha, 2022). Stressors lead to changes that dramatically and abruptly alter the ecosystem structure, and are persistent over time, on large geographic scales, impacting ecological interactions at different levels of the food webs (Conversi et al., 2015; Möllmann and Diekmann, 2012).

In coral reefs, the pervasive interactions of stressors lead to a decrease in the patterns of abundance and taxonomic and functional diversity, and of genetics, compromising the functioning of trophic webs (Gilarranz et al., 2016; Santos et al., 2021) and resulting in resource depletion with no historical precedents (Steffen et al., 2015). These multiple stressors on the coral reefs trigger phase shifts by altering the composition of benthic populations and communities that impact reef fish assemblages (Bellwood et al., 2004; Hughes et al., 2017), perturbing the balance between primary productivity and consumption, and affecting top-down and bottom-up control interactions (Daskalov et al., 2007; Möllmann & Diekmann, 2012; Scheffer et al., 2005).

Among these stressors, overfishing is one of the main mechanisms that trigger trophic cascades and the consequent phase shifts (Möllmann et al., 2015; Pershing et al., 2015; Scheffer et al., 2005). In reefs, different types of phase shifts can lead to critical transitions from a steady state of stony coral dominance to a gradual replacement by macroalgae (Graham, 2015; Scheffer & van Nes, 2004), sea urchins, sponges, zoanthids, and ascidians (Bellwood et al., 2004; Norström et al., 2009; Nyström et al., 2012).

Trophic groups such as piscivorous, carnivorous, and herbivorous fish play key roles in reef trophodynamics, promoting the maintenance of resilience and stability of food webs (Bellwood, Pratchett, et al., 2019; Estes et al., 2011; Graham, 2015; P. J. Mumby et al., 2006). Different social groups such as traditional fishing communities, “quilombolas” (afro-descendants) and tourism enterprises depend on the set of cosystem Services (ESs) derived from coral reefs for the development of goods and services for their activities and overfishing and phase shifts severely impact these Socio-Ecological Systems (SESs) (Hughes et al., 2017; IPCC, 2022; Steffen et al., 2015).

The contributions of coral reef biodiversity to people are expressed by the myriad of material and immaterial ESs that promote the regulation and maintenance of biological processes, food production, materials, and labor, and supporting identities (e.g., recreational, cultural, and spiritual) (Díaz et al., 2018; Holmlund & Hammer, 1999; MEA, 2005; Moberg & Folke, 1999). Globally, millions of people benefit from coral reefs for food, to boost economies, for well-being, and by psychological experiences and inspirations that shape cultures (Díaz et al., 2018; FAO, 2017; IPBES, 2016; Spalding et al., 2017).

Coral reef fish and fisheries ensure health, nutrition, food security, generation of jobs and income for different SESs, that are highly dependent on these ecosystems in coastal regions, on islands and in archipelagos (J. Cinner, 2014; Cruz-Trinidad et al., 2014; Elliff & Kikuchi, 2017). Given the local scenario, it is a priority to collect past information to help understand the changes that have occurred in the reef ecosystem (Jackson et al., 2001; Möllmann & Diekmann, 2012). From this perspective, the Local Ecological Knowledge (LEK) has been widely used to assess the occurrence of Shifting Baseline Syndrome (SBS) (Knowlton & Jackson, 2008). The SBS describes the gradual tendency that new generations have to disregard past changes in biomass and richness in fisheries, accepting with each new generation a lower standard as a norm (Pauly, 1995b). Detection of SBS is an important step in proposing reef biodiversity conservation programs, in addition to participatory and adaptive management for resilience (Duarte et al., 2020; Knowlton & Jackson, 2008; Soga & Gaston, 2018).

Fishers LEK is behavior-oriented knowledge derived from fishing activities, which helps to understand the dynamics, structure, functions, and perceptions of the marine environment (Begossi, 2015; Berkes, 2021). The use of the LEK to understand the multiple basins of attraction for phase shifts and the impacts of such changes in the set of reef ESs for people is little known in research (Woodhead et al., 2021), particularly in the Southwestern Atlantic (SWA) (C. M. C. Rocha & Sampaio, 2022; J. C. Rocha, 2022) which has one of the largest semi-continuous reef ecosystems in the world (Carneiro et al., 2022).

The SWA coral reefs have a high number of endemic species (Leão et al., 2016; Pinheiro et al., 2018). However, despite this, accessing the contributions of these ecosystems to the SESs (Díaz et al., 2018; Hughes et al., 2017), identifying the multiple basins of attraction for phase shifts associated with overfishing, is a priority for maintaining biodiversity (C. M. C. Rocha & Sampaio, 2022) and the multiple uses by the SESs (Hicks, 2011).

In this study, the hypothesis that SBS is occurring among different generations of fishers on a tropical island, regarding the catches of species from the trophic groups of piscivorous, carnivorous, and herbivorous fish, was evaluated, assuming that multiple stressors act as mechanisms that serve as basins of attraction for phase shifts. We tested this hypothesis through the LEK and investigated: (i) the material and immaterial benefits of reef fish and fisheries for people; (ii) the occurrence of SBS among different generations of fishers in relation to decreasing or increasing catches, years of best fisheries and catches, largest individuals ever caught, and the effect of fisheries on trophic groups and on different reef zones; (iii) multiple basins of attraction for phase shifts; and (iv) conservation and management solutions.

## 4.2. MATERIALS AND METHODS

### 4.2.1 Study area

The Island of Boipeba (BI) is one of 36 islands in the archipelago of the insular municipality of Cairu (13° 40' S/ 39° 03' W), located in the state of Bahia (Bahia, 1992). Due to its high ecological relevance and constant anthropic pressure exerted by growing tourism since 1950 (Oliveira, 2009), Boipeba was decreed jointly with the island of Tinharé as an Environmental Protection Area (APA), with an area of 433 km² (Bahia, 1992; Lei No. 9.985, de 18 de Julho de 2000. Sistema Nacional de Unidades de Conservação/SNUC, 2000) (IUCN category V; Dudley, 2008). An APA aims to provide opportunities for large-scale biodiversity conservation, in heavily used landscapes (Dudley, 2008) in which the processes of use, occupation, and public visitation are allowed and must be regulated by the managing body (Lei No. 9.985, de 18 de Julho de 2000. Sistema Nacional de Unidades de Conservação/SNUC, 2000).

The population of the municipality of Cairu is estimated at around 18,666 inhabitants (IBGE, 2022), and on the BI, according to the health department, the population is estimated at around 4,036 inhabitants. Before Portuguese colonization in the 16th century, the population of the BI was composed of Indigenous “Tupinambás” and “Tupiniquins” later, descendants of Portuguese and African peoples settled in the island (Oliveira, 2009; Ott, 1944). Since the 19th century, sewage and garbage were transported in barrels and thrown into the sea (Oliveira, 2009). Currently, it is estimated that only 45% of households have basic sanitation in the municipality (IBGE, 2022). Pollution from domestic effluents is a serious threat to water quality in the BI (Elliff & Kikuchi, 2017; Loiola et al., 2014).

The IB integrates a large landscape mosaic constituting a central biodiversity corridor that connects to the Atlantic Forest on a regional scale (Arruda & de Sá, 2003). The BI has numerous hydrographic micro-basins bordered by an extensive estuary with channels and sea inlets, mangroves, dunes, and vegetation of coastal sandy soils (“restinga”) (Bahia, 1992). Endemic coral species forming fringing reefs occur in shallow patches (5 and 10 m) throughout the coastal region of the island (Elliff & Kikuchi, 2017). The reef formations on this island have coral species that are part of the ecoregion with the greatest biodiversity in the SWA, and the highest occurrence of stony reefs in Brazil (Leão et al., 2010, 2016, 2019).

Fishing activities are small-scale, focusing mainly on reef formations of up to 20 m (Costa et al., 2005). These fisheries are mostly practiced by traditional peoples such as fishers and “quilombolas”, using small boats and canoes (Oliveira, 2009; Ott, 1944), most being low-income folk (ENSP, 2020). Fishing and shellfishing are artisanal activities that play a fundamental role as means of subsistence and income generation (Fischer, 2007).

Different SESs develop activities derived from nautical tourism in the IB for economic purposes (Fischer, 2007), which is pointed out as a constant stressor in coral reefs (Elliff & Kikuchi, 2017). The reef formations are exposed during the period of low tide, forming natural pools suitable for recreational activities such as free diving, swimming, and tour-trips with small boats and speedboats (Albuquerque et al., 2015; Rhormens et al., 2017).

### 4.2.2 Data collection

Between August 2021 and July 2022, we interviewed fishers using a semi-structured questionnaire with 36 open and closed questions (Full questionnaire is available in the Supplementary material). The Research Ethics Committee of the Federal University of Alagoas (Nº 40184420.0.0000.501) approved this study.

Prior to each interview, we presented the Informed Consent Form and upon consent to participate in the research, the fishers were interviewed individually or in the company of a family member by Rocha, C.M.C.

We used a catalog displaying images of 18 reef fish species, these being groupers (N=04), snappers (N=06) and herbivores (N=08) previously registered as targets of local fisheries, asking them to assign popular names to those known. Most of the species assessed in the interviews are currently under some category of regional (Frédou et al., 2009), national (PMMA, 2014) and international (IUCN, 2022) threat (Table 1). We registered the fishing gear used according to (FAO, 2022).

Table 1. Reef fish species targeted by fisheries considered in interviews with fishers at the Island of Boipeba.

| Species | Assessment* | Reference |
|---|---|---|
| *Acanthurus bahianus* (ocean surgeon) | Stable- LC | c |
| *Acanthurus chirurgus* (blue tag) | Stable- LC | c |
| *Acanthurus coeruleus* (doctorfish) | Stable- LC | c |
| *Epinephelus adcensionis* (rock hind) | Stable | c |
| *Epinephelus itajara* (Atlantic goliath grouper) | Critically Endangered | b; c |
| *Epinephelus morio* (red grouper) | Vulnerable | b; c |
| *Mycteroperca bonaci* (black grouper) | Vulnerable | b; c |
| *Scarus trispinosus* (greenback parrotfish) | Endangered | b; c |
| *Scarus zelindae* (Zelinda's parrotfish) | Vulnerable | b; c |
| *Sparisoma axillare* (gray parrotfish) | Vulnerable | b; c |
| *Sparisoma amplum* (reef parrotfish) | Vulnerable | c |
| *Sparisoma frondosum* (Agassiz's parrotfish) | Endangered/Vulnerable/ Data Deficient | c |
| *Lutjanus analis* (mutton snapper) | Overexploited | a; c |
| *Lutjanus alexandrei* (brazilian snapper) | Not evaluated | - |
| *Lutjanus cyanopterus* (cubera snapper) | Vulnerable | b; c |
| *Lutjanus synagris* (lane snapper) | Overexploited | a; c |
| *Lutjanus jocu* (dog snapper) | Fully exploited | a; c |
| *Ocyurus chrysurus* (yellowtail snapper) | Severely overexploited | c |

*Assessments are regional, national, and international

#### 4. 2.3 Semi-structured questionnaire

In the first stage, we addressed socioeconomic information (age, sex, education, income, and the number of people in the family), in addition to the time dedicated to fishing activities, fishing gear used and type of fishing (professional, amateur, sport). We investigated (i) the benefits of coral reefs for people, such as: food production (trophic groups of reef fish), materials and labor (fisheries) and supporting identities (recreation, cultural and spiritual).

The second stage was designed to identify, through the LEK of the different generations of fishers, (ii) the best day catch reported by each respondent (kg) and the year of catch; iii) the larger individual ever caught by the respondent (kg) and the year of catch; iv) the year of the best catches made by all generations of fishers and the year of that catch; and v) catches made by all generations of fishers (kg) in each reef area (Inner reefs < 10 m) in distant reefs (Outer reefs > 11 m) (> 11 m) and the year (Elliff and Kikuchi, 2017).

In the last stage consisting of open questions, we investigated the perception of different generations of fishers about: (vi) multiple basins of attraction for phase shifts; and (vii) solutions for the conservation and management of reef ecosystems.

The Research Ethics Committee of the Federal University of Alagoas (Nº 40184420.0.0000.501) approved this study.

#### 4.2.4 Data analysis

We created three categories for the different generations of fishers according to the time of experience in fishing activities in years: beginner (≤ 15 years of practice, 11 fishers); intermediate (16-30 years of practice, 13 fishers); and experienced (> 31 years of practice, 20 fishers). We analyzed the captures and types of gear most used by the different generations (Table 2). The less mentioned fishing gear was grouped under the miscellaneous gear category.

The information obtained in the first stage of the questionnaire was analyzed in terms of mean ± standard deviation (Woodhead et al., 2021). We assigned a number (i) to each of the benefits of the coral reefs for people, according to the responses obtained.

Logistic Regression Analysis-RL was applied to verify the occurrence of the (ii) decrease (0) or increase (1) in catches of piscivore, carnivore and herbivore species (kg), according to the generational category of the fishers (independent variable).

We applied one-way ANOVA ($p < 0.05$; Tukey's post-hoc test) to investigate the occurrence of SBS regarding iii) the best day catch reported by each respondent (kg) and the year; iv) the year of the best catches made by all generations of fishers and the year of that catch (dependent variables), using the fishers' experience category as independent variable.

We applied simple linear regressions (Kolmogorov-Smirnov $p < 0.05$) to test (v) the effects of fisheries on piscivore, carnivore and herbivore species (kg), undertaken by all fishers over time; and in the Inner reefs or Outer reefs, where they occurred and the year.

In the last step, we investigated the perception of all fishers about the (vi) multiple basins of attraction for phase shifts (Nyström et al., 2012). We used the LEK of all fishers to identify (vii) alternative solutions for the conservation and management of coral reefs, which were analyzed according to the number of responses assigned.

All analyzes were performed in the RStudio Team (2022) development environment. RL analysis was performed in the BioEstat (Ayres et al., 2007).

## 4. 3. RESULTS

We interviewed 20 experienced fishers, 13 intermediate and 12 beginners, where 38 were male and 07 female, aged between 18 and 82 years (44.7±14 years mean/standard deviation). During 301 hours of interviews, we identified a total of 30 species of fish captured (Supplementary material), totaling 26 genera distributed in 19 families.

### 4.3.1 Local ecological knowledge and ecosystem services of coral reef fish and fisheries

For this study, we selected 18 target fish from the fisheries (Table 1). The trophic groups of these species were carnivores (bony fish, mobile invertebrate feeders, and sessile invertebrate feeders), piscivores (bony fish), and herbivores (benthic algae, detritus, weeds) (Froese & Pauly, 2022) (Supplementary material).

The predominant types of fishing gear used by different generations of fishers were gillnet, handline, pole and line, and speargun (Figure 1). We identified some simple gear traditionally used by native indigenous peoples, such as beating a rod, torch fishing, hand fishing, corrals ("camboa") and wattle and daub ("pau a pique") (Ott, 1944). These were included in the miscellaneous category, along with falling gear, hooks and lines, and trawls because they were the least cited.

We observed that the experienced fishers used the greatest diversity of gear both in the past (4.65 ± 2.9) and currently (4.5 ± 2.3) (Figure 1), and it was the only generation that used coastal corrals made of coconut straw and wattle and daub and practiced blast fishing in the 80's. Handline was the gear that captured the largest biomass (4,505 kg) and was the most used by all generations.

Among the fishers (N=45), 51% consider themselves professionals and 40% have professional fisherman document, 42% practice underwater fishing using a speargun, and 11% fish exclusively for sport purposes.

We identified that ESs of fish and fisheries provide multiple benefits for hundreds of people in the IB (Figure 15). Fisheries are multispecific and multitrophic, and the experienced, intermediate and beginner generations responded that the greatest importance of fishing is for food, (95%; 100%; 75% respectively). Fishing activities are the main means of subsistence and income through fish markets (75%; 77%), and of materials and labor (65%; 77%), for the experienced and intermediate generations. However, for the beginner generation, fisheries are for the purpose of recreation (67%) and obtained the highest number of responses (N=08). The experienced generation had the highest number of responses attributed to fisheries as cultural and spiritual ESs (30%; 15% respectively).

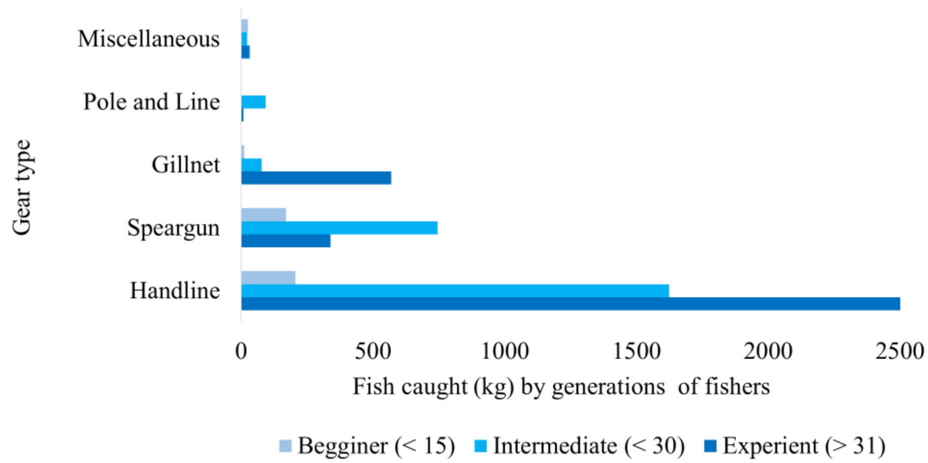


**Figure 15.** Average number (±) of types of fishing gear used by the different generations of fishers, and the total biomass (kg) captured according to the type of gear on the Island of Boipeba.

We identified that ESs of fish and fisheries provide multiple benefits for hundreds of people in the IB (Figure 16). Fisheries are multispecific and multitrophic, and the experienced, intermediate and beginner generations responded that the greatest importance of fishing is for food, (95%; 100%; 75% respectively). Fishing activities are the main means of subsistence and income through fish markets (75%; 77%), and of materials and labor (65%; 77%), for the experienced and intermediate generations. However, for the beginner generation, fisheries are for the purpose of recreation (67%) and obtained the highest number of responses (N=08). The experienced generation had the highest number of responses attributed to fisheries as cultural and spiritual ESs (30%; 15% respectively).

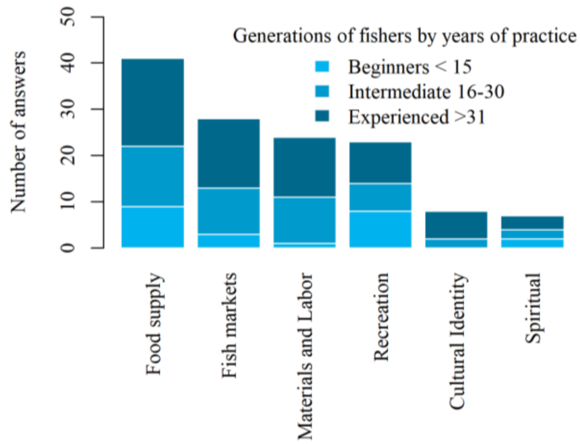


**Figure 16** Ecosystem Services of coral reef fish and fisheries according to the responses of different generations of fishers (N=45) on the Island of Boipeba over time.

### 4.3.2 Shifting Baseline Syndrome and local ecological knowledge about fisheries of trophic groups

The RL results showed that perception deviations are occurring between the three generations in relation to the decrease and increase in catches over time (Table 2). The perception of the decrease in catches was significant only for the intermediate category (Odss=77%; $p$ < 0.009), differing from the experienced (Odss= 1.07%; $p$= 0.07) and beginner (Odss= 1.07%; $p$= 0.48). However, the experienced generation had a significant perception that there is currently an increase in catches (Odss= 9%; $p$ < 0.005), different from the perceptions of the other generations (intermediate: Odss= 1%; $p$= 0.1, and beginner: Odss=90%; $p$=0.31).

**Table 2.** Logistic Regression of the perception of different generations of fishers (N=45) on the probability of a decrease (0) or increase (1) in reef fish catches on the Island of Boipeba over time. Odss (%) represents the probability of chances that changes in perception are occurring. *significance ($p$ < 0.5).

| Generations | Decrease | Increase |
|---|---|---|
| Beginner | Odss=1.07%; *p*=0.48 | Odss=90%; *p*=0.31 |
| Intermediate | Odss=77%; *p*<0.009 | Odss=1%; *p*=0.1 |
| Experienced | Odss=1.07%; *p*=0.07 | Odss=9%; *p*<0.005 |

The year of the best fish catches of carnivores, piscivores, and herbivores by time of experience among the three generations of fishers were significantly different (F= 3.69; *p*=0.02; Figure 17 (A)). Significant differences in mean catches (Tukey= 269 kg; $p < 0.05$) were observed between the experienced generation (334 ± 339 kg) and the beginner (53 ± 84 kg). While the mean fish catches of the experienced and intermediate generations (180 ± 273 kg) did not differ (Tukey= 120 kg; *p*= n.s). Multispecific captures were higher for the experienced generation (taxonomic richness, 3 ± 3) than for the intermediate (2.8 ± 2) and beginner (2.9 ± 1.6).

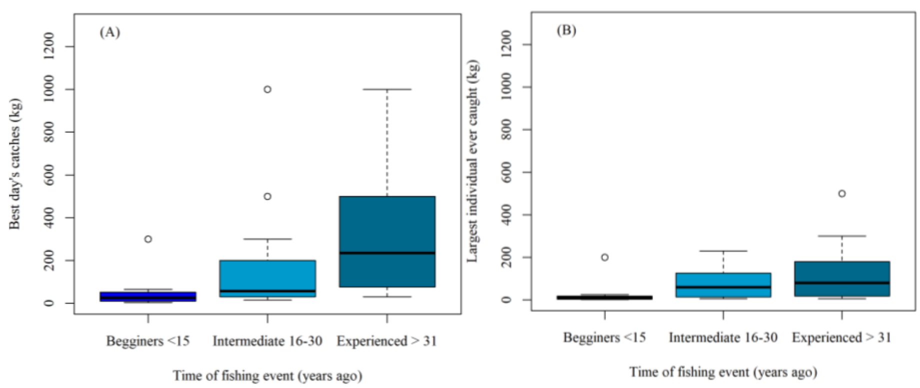


**Figure 17**. Year of the best fishing ever carried out among different generations of fishers (N= 45) on the Island of Boipeba over time (A). Year of the best catches of the largest individuals among the different generations of fishers over time (B). The median (darker line on the boxplot), minimum and maximum values (vertical lines), and the outer lines of the boxplots show the quartiles (25% and 75%). Circles are outliers.

The years of the best captures of the largest individuals (kg) showed significant changes over time amongst the three categories (F= 3.2, $p$ = 0.04; Figure 17 (B)). However, the mean differences were significant (Tukey= 90.8 kg; $p < 0.05$) between the experienced category (116 ± 124 kg) and the beginner (26 ± 56 kg). Between the intermediate generation (81± 80 kg) and the beginner (25 ± 56 kg), these mean differences were not significant (Tukey= 56 kg; $p$= n.s).

The experienced generation reported catches of the largest individuals of piscivores (116± 124 kg), compared to the other generations, such as hammerhead shark (*Sphyrna* sp., 250 kg), bull shark (*Carcharhinus leucas*, 185 kg), Atlantic goliath grouper (*Epinephelus itajara*, 180; 150 kg), black grouper (*Mycteroperca bonaci*, 15 kg), oceanic manta ray (*Mobula birostris*, 500 kg) and whitespotted eagle ray (*Aetobatus narinari*, 65 kg). The intermediate generation (81 ± 80 kg) also captured Elasmobranchii such as the Atlantic nurse shark (*Ginglymostoma cirratum*, 68 kg) and white shark (*Carcharhinus* sp., 190 kg), and reported catches of the largest *E. itajara* (230 kg and 200 kg). The beginner generation reported the greatest weight variations among captured species (25 ± 56 kg), including species such as cobia (*Rachycentron canadum*, 18 kg), black grouper (*Mycteroperca bonaci* 5 kg), dog snapper (*Lutjanus jocu*; 1.1 kg) and the gray parrotfish (*Sparisoma axillare*; 0.5 kg). We emphasize that species such as *E. itajara*, *G. cirratum* and *M. birostris* are currently protected by law and their capture are prohibited.

The results showed that catches of piscivorous and carnivorous species of groupers with habits in fisheries are decreasing over the analyzed period (adjusted R2= 0.03; $p < 0.0001$; Figure 4 (A)). The main target species of these fisheries were the Atlantic goliath grouper (*Epinephelus itajara*), red grouper (*Epinephelus morio*), black grouper (*Mycteroperca bonaci*), and also the rock hind (*Epinephelus adcensionis*). Effects of fisheries were most evident between 1952 and 1997 (124 ± 134 kg) and between 2000 and 2010 (55 ± 99 kg). From 2012 until 2022 we observed a decrease in average catches (34 ± 64 kg). Multiple sorts of gear were employed in fishing for groupers, the hand line with a hook being the most used (72 ± 101 kg).

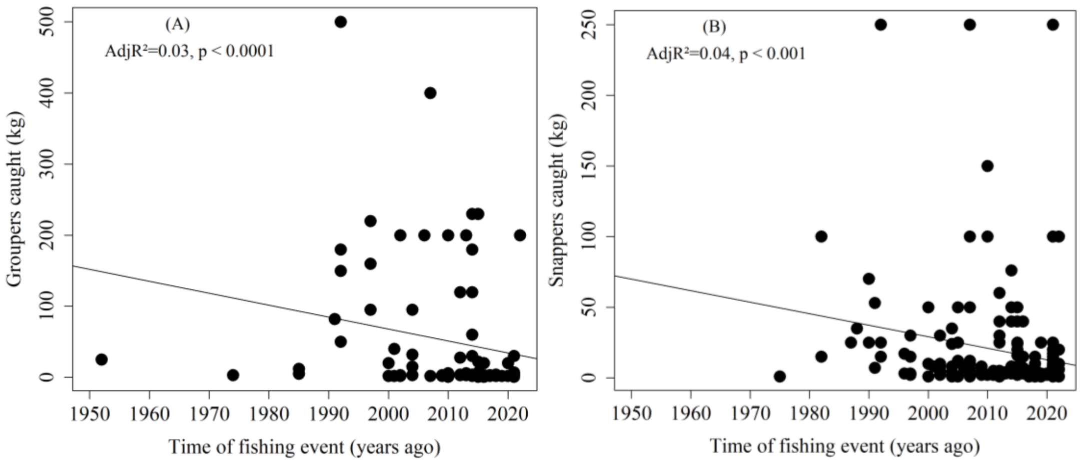


**Figure 18.** Relationship between all catches of carnivorous and piscivorous species (kg) of groupers (A) and snappers (B) already carried out on the Island of Boipeba by all generations of fishers (N= 45) over time.

The results showed that catches of snapper species in fisheries also showed a significant decline over the analyzed period (adjusted R2=0.04, *p* <0.001, Figure 18 (B)). Target species in these fisheries included the Brazilian snapper (*Lutjanus alexandrei*), mutton snapper (*Lutjanus analis*), cubera snapper (*Lutjanus cyanopterus*), dog snapper (*Lutjanus Jocu*), lane snapper (*Lutjanus synagris*) and the yellowtail snapper (*Ocyurus chrysurus*) (Table 1). The results showed that the main fisheries for *L. cyanopterus*, *L. jocu* and *L. synagris* occurred between 1975 and 1997 (39 ± 55 kg). There were two periods of decrease in catches, between the years 2000 and 2010 (26 ± 48 kg), and 2011 and 2022 (14 ± 25 kg). The most used fishing gear for snapper captures were gill nets (14 ± 12 kg).

The results showed that catches of herbivorous fish species (parrotfishes and surgeonfishes) (adjusted R2= 0.06; *p*< 0.17; Figure 19) did not show the same patterns observed for carnivorous and piscivorous species of the groupers and snappers groups. The target species of these fisheries were the greenback parrotfish (*Scarus trispinosus*), Zelinda's parrotfish (*Scarus zelindae*), gray parrotfish (*Sparisoma axillare*), reef parrotfish (*Sparisoma amplum*), ocean surgeon (*Acanthurus bahianus*), blue tag (*Acanthurus* *coeruleus*) and the doctorfish (*Acanturus chirurgus*) (Table 1). We observed an upward trend in parrotfish catches between 1980 and 1998 (9.8 ± 12 kg), 2000 and 2010 (13 ± 14 kg), and between 2011 and 2021 (12 ± 21 kg). On the other hand, in relation to surgeonfishes, there was a trend towards an increase in catches between 1952 and 1999 (15 ± 37 kg), with the highest averages occurring between 2002 and 2010 (27 ± 40 kg), however, there was a decrease between 2012 and 2021 (6 ± 9 kg). The use of the speargun in the first fisheries of herbivorous fish was reported in 1990 (22 ± 23 kg).

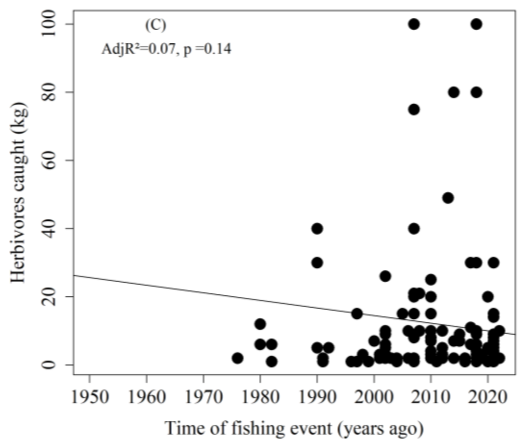


**Figure 19.** Relationship between all herbivorous fish catches (kg) already carried out by all generations of fishers on the Island of Boipeba (N= 45) over time.

The results showed a downward trend in catches of all species in the Inner reefs (adjusted R2=0.28; *p*= 0.006, Figure 20 (A)) in the analyzed period. The experienced generation reported that the best fisheries carried out were in this reef zone, for example when capturing an individual of *E. itajara* weighing 160 kg in 1997. Despite the results of fisheries not having shown a significant trend in the Outer reef (adjusted R2= 0.03; *p*= 0.20; (B)), we observed that there was an increase in catches over time. The best catches were of *E. itajara,* of 180 kg and 200 kg, between the years 2002 and 2013, by fishers of the intermediate and beginner generations, respectively.

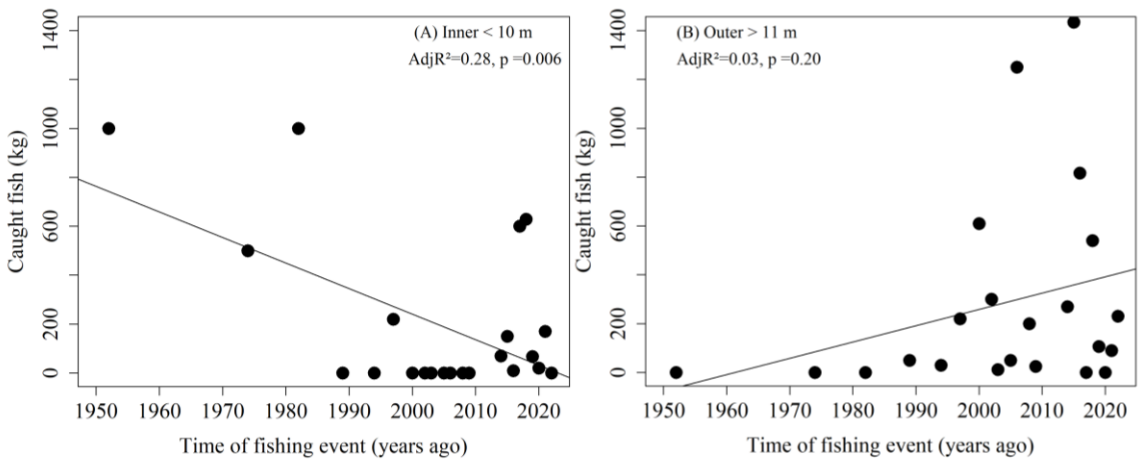


**Figure 20.** Relation between the best reported fisheries of all trophic groups already carried out on the Island of Boipeba, by all generations of fishers (N= 45) over time, in the (A) Inner reefs (up to < 10 m depth) and (B) Outer reefs (> 11 m depth) from the reefs.

### 4.3.3 Local ecological knowledge about multiple basins of attraction for phase shifts

The perceptions of the different generations of fishers showed the co-occurrence of anthropogenic stressors (N=11) that are mechanisms for the multiple basins of attraction for phase shifts on the IB (Figure 21 (A)). The most reported stressor by the three generations was overfishing (N=56), characterized by fishers as the increase in the number of fishing efforts, the use of illegal equipment (e.g., use of dive compressor, blasting fishing, reduced net meshes) and catches of immature and juvenile specimens. Habitat degradation (N=32) were reported by all fishers, especially experienced ones (N=18). The main characteristics of this degradation were the rupture of reef structures by anchoring, shrimp fishing with motorized boats using trawl nets and the increase in tourism activities. Pollution and contamination (N=23) were cited mostly by the intermediate generation (N=12), as the increase in the volume of solid waste such as plastic bags, ghost nets, and bottles. The experienced generation reported the co-occurrence of the largest number of simultaneous stressors, such as unmanaged tourism (N=10; 80%), poor stewardship (N=09; 45%) and climate change (N=07; 72%), as well as changes in the regime of winds and ocean currents. The coral bleaching events stressor (N=06) received an equal number of responses across all generations, as did the high coverage of macroalgae (N=05).

### 4.3.4 Local ecological knowledge about solutions for the multiple basins of attraction for phase shifts

The LEK of the three generations of fishers identified that there are solutions for the co-occurrence of stressors that are multiple basins of attraction for phase shifts (N=09) (Figure 22 (B)). Fisheries management (N=44) was the main solution pointed out by all fishers. The need to reduce bottom trawl fisheries for shrimp fishing and to regulate the sizes of the mesh openings of the cast nets were emphasized.

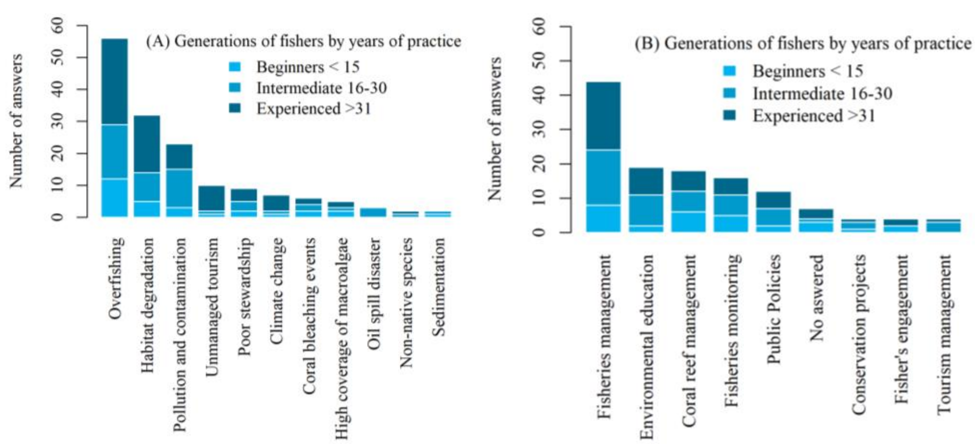


**Figure 22.** (A) Number of responses according to the perception of all generations of fishers (N=45) about the co-occurrence of anthropic stressors that are multiple basins of attraction for phase shifts, occurring in coral reefs on the Island of Boipeba, and (B) the number of answers to the possible solutions.

The LEK of the three generations of fishers identified that there are alternative solutions for the co-occurrence of stressors that are multiple basins of attraction for phase shifts (N=09) (Figure 22 (B)). Fisheries management (N=44) was the main solution pointed out by all fishers. The need to reduce bottom trawl fisheries for shrimp fishing and to regulate the sizes of the mesh of the gill nets were emphasized. The three generations of fishers identified that coral reef management (N=18) is necessary for ordering tourism activities. Monitoring of fisheries (N=16), according to the fishers, would include the inspection of inappropriate fishing gear, which degrade and destroy coral reefs, and banning bottom trawl fisheries close to the coast. Public policies (N=12) received an equal number of responses by the intermediate and experienced categories (N=05). This was pointed out as a solution to be subsidized by the government for multi-specific reef fisheries, in cases of reproductive periods of the target species, and for limiting fishing efforts.

## 4.4 DISCUSSION

### 4.4.1 Local ecological knowledge about the ecosystem services of coral reef fish and fisheries

Fishers' perceptions through the LEK showed that for more than six decades hundreds of families have benefited from the ESs of different reef fish, especially through multi-specific fisheries. Fishers of all generations responded that ESs are essential primarily for food, fish markets, and materials and labor, however, recreational, cultural, and spiritual purposes were also identified as being important.

The perception of fishers regarding the understanding of the changes that coral reefs are undergoing in the Anthropocene are rarely addressed in research (Woodhead et al., 2021). Fishers' LEK has the potential to identify the benefits of reef fish to people in the SWA and may aid research for the conservation of these ecosystems. There is an urgent need to identify the potential contributions of these ecosystems to people (Díaz et al., 2018; Hughes et al., 2017), and research must include an interdisciplinary understanding, emphasizing the several aspects of the ESs, considering the different SESs that depend on them (Hicks, 2011).

On the IB, traditional people as well as low-income people extract, in addition to fish, other resources from the marine biodiversity, and depend on these protein sources for their nutrition (ENSP, 2020; Fischer, 2007). Globally, millions of people in tropical countries benefit from the ESs of healthy coral reef fisheries as a nutritional source (Cinner, 2014; FAO, 2017). Over 500 million people in African, Asian, and Indo-Pacific countries are highly dependent on reef fisheries ESs for their nutritional necessities and for ensuring food security (Cruz-Trinidad et al., 2014; Selig et al., 2019).

The material ESs such as the fish market, materials, and labor, for the fishers of the IB have economic and labor importance. In many other coastal regions and tropical islands in more than twenty countries, fisheries are practiced for these same purposes, moving millions of dollars annually (Hicks, 2011; Lopes et al., 2015; Selig et al., 2019; Tilley A et al., 2021). In addition, hundreds of other indirect benefits from materials and labor ESs directly or indirectly promote the well-being of local populations (Hicks, 2011).

Immaterial recreational, cultural, and spiritual ESs were little mentioned, recreation being the most mentioned, followed by the other two. Immaterial ESs derived from recreation are important for the development of social and individual identity (Cinner, 2014; Cinner, McClanahan, Daw, et al., 2009), in addition to promoting collective well-being in these coastal regions (Woodhead et al., 2021). The tourism industry boosts regional economies by exploiting the benefits of these ESs, whose revenues exceed US$35 billion annually (Spalding et al., 2017). On the IB, an estimated US$700,000 are generated annually by tourism activities (Prefeitura Cairu, 2022).

Locally, immaterial ESs such as the cultural and spiritual sorts promote the fishing communities' sense of place (Hicks, 2011). Sense of place strengthens the identity of a community and can influence the governance of Marine Protected Areas (MPAs), the specific zoning of areas and the proper uses of coral reefs in the IB, aiming at their conservation including culture and customs (Muhl et al., 2020). Few experienced fishers mentioned the spiritual ESs of fisheries. This suggests a change in the perception of the importance of these ESs for the other generations, for whom the economic purposes of the fish market, materials and labor were more cited.

Our results suggest that there is dependence upon the ESs of carnivorous, piscivorous, and herbivorous reef fish. However, the trends of decreases in catches were evident in the IB. The decrease in fisheries for different trophic groups is a mechanism for the multiple basins of attraction for phase shifts, and which acts as trap accentuating the poverty of thousands of people (Barrett et al., 2011; Cinner & McClanahan, 2006; McClanahan et al., 2008). Investigating the main social drivers (e.g., fish markets for key species, unmanaged tourism activities) that influence critical transitions in coral reefs, in order to monitor them, can help managers and conservation practitioners to anticipate solutions to mitigate their impact at the local scale (Hicks et al., 2016).

In the IB, study suggests that fishing communities are highly dependent on the ESs from coral reefs (Elliff & Kikuchi, 2017), a reality similar to that observed in tropical regions around the world (Hicks, 2011; Selig et al., 2019). However, due to the increasing degradation of these environments and the reduction of these reef covered areas (Setter et al., 2022; Loiola et al., 2014), that are under constant global threat from climate change (Hughes et al., 2017; IPCC, 2022), overfishing, pollution and unmanaged tourism, the maintenance of these ESs may be impaired and may increase social vulnerability (Cinner et al., 2012).

#### 4.4.2. Shifting baseline syndrome and local ecological knowledge about coral reef fish and fisheries

We observed that there is a shift in perception about fisheries by different generations of fishers, suggesting that SBS among fishers in the IB may be occurring. The targets of traditional fisheries of the experienced generation, consisting of large piscivorous and carnivorous fish such as elasmobranchs (Sphyrnidae and Carcharhinidae), groupers (*E. itajara*) and snappers (*L. cyanopterus*), showed declining trends. The experienced generation carried out their best fisheries on the inner reefs. They changed targets and used multiple fishing gear, almost twice as much as the others, suggesting a greater knowledge and capacity for adaptation in the face of declines in target species. Currently, there is a change in target species by intermediate and beginner fishers towards the already rare large herbivores, such as the greenback parrotfish (*S. trispinosus*), historically abundant locally.

The intermediate generation was the only one that detected a significant decrease in captures of all trophic groups investigated, but it showed a shift in perception, not being aware of the *Epinephelus morio*, and mentioning that the *Scarus trispinosus* is a rare key species. The reduction in catches, together with the non-recognition of carnivore species and traditional targets, as well as the findings of low densities of large herbivore species that have become alternatives, such as *S. trispinosus*, corroborates that intermediate fishers recognize the fishing down of food webs. The beginner generation category, almost never saw Elasmobranchii, large groupers or snappers, and commonly fish in the Outer reefs, capturing smaller herbivorous fish, such as the juvenile *Sparisoma axillare* and the sea chub, *Kyphosus* sp.

The perception of experienced fishers about declines in catches differed from the others, especially those of the intermediate generation, which observed more significant changes occurring in catches, contrasting with the results obtained by Bender et al., (2013) and Giglio et al., (2015). Apparently, the transmission of knowledge between the different generations and the perceptions of rapid changes in fisheries, overexploited species and marine degradation are changing rapidly, corroborating with Woodhead et al., (2021).

Since Pauly (1995) proposed SBS as a frequent phenomenon among different generations of scientists, the access to the effects associated with its occurrence has been recurrent (Guerrero-Gatica et al., 2019; Papworth et al., 2009; Soga & Gaston, 2018) for the elaboration of measures for the conservation, management, and restoration of ecosystems. The detection of SBS from the LEK of fishers indicates that there is a pattern of younger generations accepting biodiversity declines (Ainsworth et al., 2008; Sáenz-Arroyo et al., 2006; Turvey et al., 2010).

In the South Atlantic, since the late 1990s there has been a decrease in the abundance of carnivorous and piscivorous fish, and stocks do not reach the required sustainability to maintain catches (Hilborn et al., 2020). A similar pattern was observed in the SWA, where in addition to substantial declines in richness and abundance since the 1970s, at different regional scales in the open sea, the phenomenon of fishing down of food webs was reported (Freire & Pauly, 2010; Pauly & Zeller, 2016).

The application of methodologies combined with the LEK of different generations of fishers, demonstrated that since the 50's there has been an increase in the number of fishers, gear, and vessels, leading to a decrease, with consequent local extinction of megafauna species in archipelagos and islands isolated oceanic species (eg: *Carcharhinus* spp.), in MPAs (eg: *Pristis pristis*, *E. itajara*) (Giglio, Luiz, & Gerhardinger, 2015; Luiz & Edwards, 2011; Pinheiro et al., 2010; Reis-Filho et al., 2016). The LEK from different generations showed deviations in perception, showing a reduction in captures of carnivorous species, such as *E. itajara*, *E. morio*, *L. analis*; piscivores species, such as *M. bonaci*, *L. jocu*, *O. chrysurus*; and the large herbivore *S. trispinosus,* that is declining substantially (Barbosa-Filho et al., 2020; M. G. Bender et al., 2014; Giglio, Luiz, & Schiavetti, 2015; Roos, Longo, Taylor, et al., 2020; Zapelini et al., 2020). The decrease in catches of large carnivores and piscivores and the gradual tendency for these targets to change to large and small herbivores in the IB reinforce the patterns observed in studies in the SWA and other regions of the world.

The selectivity in fisheries for carnivorous, piscivorous, and herbivores can induce phase shifts due to the absence of control of the macroalgae growth and other invertebrates, our argument is in line with Conversi et al., (2015), and Scheffer et al., (2005). Fishing pressure directed at top predators (Jackson et al., 2001; Myers & Worm, 2003) and herbivore functional groups (Bellwood et al., 2004), triggers the mechanisms of trophic cascades. Herbivores induce algal turf cropping, excavating, crevice-feeding and the removal of structural carbonates (Bellwood et al., 2019b; Clements et al., 2016). Trophic cascade interactions compromise top-down interactions favoring bottom-up ones (Daskalov et al., 2007; Estes et al., 2011; P. J. Mumby et al., 2012; Pershing et al., 2015).

In this context, there is an urgent need to manage fisheries and tourism activities in the coral reefs of the IB. This would represent an advancement for biodiversity conservation, for the protection of local and regional ecosystem resilience, and for the maintenance of the ESs (Mcleod et al., 2019; Nyström et al., 2000, 2008).

### 4.4.3 Local ecological knowledge about multiple basins of attraction for phase shifts

The LEK of fishers identified the co-occurrence of stressors that drive the multiple basins of attraction for phase shifts. In the last forty years, according to the interviews, in addition to the increase in the number of fishers, destructive fishing gear and captures of juvenile carnivores, piscivores and herbivores, the unmanaged tourism activities have increased. The lack of fisheries monitoring, the incipient management by the administrative body, and the poor stewardship demonstrate the need to implement strategies to respond and shape the SESs to adapt to the uncertainties and environmental changes imposed by these stressors.

The co-occurrence of overfishing, habitat degradation, pollution and contamination, and unmanaged tourism induces severe disturbances on coral reefs, whose speeds may exceed the tolerance of these ecosystems to maintain their resilience (Lenton, 2020; Setter et al., 2022). This combination of multiple basins of attraction alters the processes and functions of ecosystem components that are responsible for promoting the self-renewal and self-reorganization of the ecosystem and its resilience (Folke, 2006; Holling C. S, 1973).

For centuries, reef ecosystems around the world (Jackson, 1997; Pandolfi et al., 2003), including some lesser known ones such as those in the SWA, have been exposed to an alarming array of anthropogenic stressors (Gallardo et al., 2021; Soares et al., 2021), contributing to a significant decrease in stony coral cover areas (Cruz et al., 2018; Soares et al., 2022).

There is a consensus that overfishing is one of the main stressors in coral reefs (Jackson et al., 2001; Möllmann & Diekmann, 2012; Scheffer et al., 2005). Fishing pressure works as a basin of attraction for positive feedbacks to amplify changes (e.g., increased macroalgae and zoanthids cover, decreased competition and stony corals), leading the ecosystem towards a shift in assemblages and populations, and into a phase shift (Nyström et al., 2012; Scheffer and van Nes, 2004).

Pollution and contamination were recognized as constant stressors that threaten the water quality of coral reefs due to poor sanitation, increased solid waste and fuel oils from intense nautical traffic. It should be noted that the IB lacks infrastructure such as ports and a marina, and that the maintenance of vessels is carried out in the vicinity of coral reefs and natural tidal pools.

The increase in the volume of domestic effluents leads to eutrophication, the lack of sanitation in the IB is worrying (Elliff & Kikuchi, 2017). The input of nutrients promotes an increase in turbidity and a decrease in water quality. The fishing pressure exerted on large herbivorous species contributes to the lack of control over primary production, accelerating the deterioration of the ecosystem (Daskalov et al., 2007).

The volume and quantity of solid waste (microplastics) scattered among coastal-marine environments is a serious global threat, which has led countries to agree on mitigation strategies (ONU-UNEP, 2022). Hundreds of reef species are impacted, and the ingestion of plastics are transferred to other trophic levels (Santos et al., 2021). Entanglement (Nunes et al., 2018) and captures through “ghost fishing” (Soares et al., 2021) contribute to a decrease in the richness and biomass of fish and other reef organisms (Carvalho-Souza et al., 2018). Monitoring the effects of pollution and contamination on reef fish is one of the main challenges for the conservation of biodiversity in the SWA (C. M. C. Rocha & Sampaio, 2022; Soares et al., 2022). There is an urgent need to implement integrated solid waste management in coastal regions, especially on tropical islands like IB, which lack basic sanitation.

Habitat degradation was identified as a stressor that causes damage to the reef substrate. The degradation of reef habitats leads to a decrease in heterogeneity and structural complexity (Graham, 2014; Kovalenko et al., 2012). The decrease in environmental heterogeneity compromises the creation and maintenance of new habitats for shelter, foraging, spawning, abundance, biomass, and interactions of reef fish (Nash et al., 2012; Oakley-Cogan et al., 2020). It is important to establish zoning and ordering of fishing and tourism activities to maintain the integrity of seascapes, and to increase their resilience and prevent phase shifts.

Since the 1950s, unmanaged tourism has systematically impacted the coral reefs of IB, but according to the LEK, it was about 20 years ago that the intensity of co-occurring stressors increased. Studies have shown that the impacts resulting from tourism activities have contributed to the increase in sedimentation rates, trampling and the supply of food for fish (Kikuchi et al., 2010; Leão et al., 2016). The coastal reefs of IB are under strong pressure from fishing and tourism activities (Albuquerque et al., 2015; Elliff & Kikuchi, 2017) that bring more than 1,600 people and hundreds of boats daily. Although nautical activities are the main economic source of the IB, fishers have recognized that poor management reflects the rapid changes and degradation of the reef ecosystems in the IB, leading to poor-stewardship.

Ecosystem stewardship consists of a series of strategies for the conservation of biodiversity whose purpose is to shape the SESs to adapt to the conditions of uncertainty and constant change (Chapin III et al., 2010; Young et al., 2006). One of the assumptions of ecosystem stewardship is to recognize that people and society, as ecosystem components that benefit from ESs, need to take responsibility for taking care of it, as it constitutes the resources on which they depend on (Chapin III et al., 2015). Due to the poor stewardship indicated by the fishers, it becomes imperative to create democratic spaces for the establishment of dialogue among the SESs, stakeholders, public authorities, educational institutions, non-governmental organizations, and civil society, to elaborate strategies to resolve the main impacts observed in the IB.

Perceptions that climate change and coral bleaching events are affecting the reefs in IB are similar to other research conducted in the coastal region of the SWA (Pereira et al., 2022), including tropical islands (Appadoo et al., 2022; Woodhead et al., 2021), suggesting that these events have become more frequent.

Climate change directly impacts coral reefs that depend on narrow temperature ranges for their development (Lenton, 2020). Sea surface warming triggers coral bleaching events responsible for serious diseases, tissue damage and coral deaths, representing one of the main current challenges for the conservation of reefs, which have serious risks of disappearance (Hughes et al., 2017; Lenton, 2020). Climate change and multiple other anthropogenic stressors in coastal zones of the SWA, contribute significantly to decreasing the resilience of coral reefs, favoring phase shifts (Cruz et al., 2015, 2018) whose positive feedbacks can interact at different spatial scales affecting other areas (Nyström et al., 2012).

### 4.4.4 Local Ecological Knowledge about solutions for the multiple basins of attraction for phase shifts

Fishers proposed multiple local and alternative solutions to stressors such as coral reef management, fisheries management, fisheries monitoring, and the establishment of public policies for multispecific and multitrophic fisheries. Despite the creation of the Boipeba Environmental Protected Area three decades ago, it lacks a management plan for the conservation of reef biodiversity (CEPRAM, 1998).

Spatial planning through the creation of marine protected areas (MPAs) is one of the main pillars to promote the management plan for the conservation of coral reefs and the maintenance of biodiversity processes (Dudley, 2008; Magris et al., 2017), helping to promote resilience in coral reefs and reduce extinction risks (Duarte et al., 2020). Ecosystem connectivity through MPAs functions as a spillover source for fish and coral larvae, providing the demographic and population aspects to support multiple ESs (Mumby & Steneck, 2008).

Considering that the MPAs in the SWA receive few human resources and funding to carry out monitoring, which favors fisheries that promote negative impacts on coral reefs

(Oliveira Júnior et al., 2016), the elaboration of ecosystem-based management has been advocated an adaptive co-management mechanism for environmental and social resilience (Armitage et al., 2009; Hughes et al., 2005; Knowlton, 2021). Ecosystem-based management through co-management and LEK, are part of the global goals to achieve sustainable development in the decade of ocean science (FAO, 2020; UN, 2015).

The success of this management and governance model will depend on the democratization of the initiative and on the different collaborative and social institutional arrangements whose interests are collective (Armitage, 2017; Maretti et al., 2019). The adoption of multi-level network institutional arrangements has the potential to both expand access to scientific knowledge and to engage society (Armitage, 2017; Jentoft, 2005; Mumby and Steneck, 2008). These arrangements can mitigate conflict scenarios and achieve success through the broad participation of government, educational institutions, and society (Maretti et al., 2019; Oliveira Júnior et al., 2016).

In view of the solutions proposed by the fishers' LEK, we observed that there is a need to strengthen the management and local governance of these ecosystems. According to the LEK, there must be a reduction in the use of non-selective fishing gear and a ban of those that are destructive, as measures for the effectiveness of fisheries management and fisheries monitoring, which will need to be debated between managers, government, and fishers. These measures are important so that an ecosystem-based management unit can promote the maintenance of resilience by avoiding overfishing of key trophic groups, and the preservation of the ESs promoted by coral reefs (Cinner et al., 2020, 2009b; Fischer et al., 2015).

Fisheries management based on limiting fishing gear has the potential to be an adaptive and resilient response to climate change scenarios, because in addition to preventing a decrease in the capture of key species, it can promote a reduction in coral mortality (J. E. Cinner, McClanahan, Graham, et al., 2009; Darling et al., 2019). In addition, fisheries management through selection of hook sizes, gill net mesh and the development of research on the functional and reproductive biology of target species, are some measures that can help avoid the selective removal of those species that have reduced functional redundancy and greater fecundity (N. Roos et al., 2016; N. C. Roos, Longo, Pennino, et al., 2020).

There is an urgent need to break with the current paradigm of coral reef conservation in order to maintain sustained resilience, mainly in the management of trophic groups, such as herbivores (Bellwood et al., 2004; Bellwood, Streit, et al., 2019; Hughes et al., 2005). Ecosystem-based management is a pathway that can reverse approaches to key species to minimize the impacts of overfishing (Cinner et al., 2020; Darling et al., 2019).

The conservation of marine biodiversity has advanced enormously and successfully in the last century (Duarte et al., 2020; Knowlton, 2021). However, the Anthropocene marks an unprecedented multiplicity of governance crises. Thus, breaking with the outdated vision of a utilitarian governance, centered on the sustainable management of simple stocks of species and ecosystems (Jacquet & Pauly, 2022), and moving towards an Ocean-centered one is a new and promising path for improved and more integrated conservation (Bender et al., 2022).

Ocean-centric governance will require the creation of legal mechanisms to lead humanity to rethink the Ocean as an interdependent living system interconnected with the planet (Bender et al., 2022). This is important to achieve the goals for sustainable development and transform the world collectively in this Decade of Ocean (UNESCO, 2020). Locally, to achieve the effective governance of coral reefs, tackling the chronic impacts of the multiple basins of attraction for phase shifts will require the strategic involvement of multi-level networks (Cinner et al., 2020; Darling et al., 2019; Hughes et al., 2005).

There is an urgent need to break with the current paradigm of coral reef conservation in order to maintain sustained resilience, mainly in the management only centered in trophic groups, such as herbivores (Bellwood et al., 2004; Bellwood, Streit, et al., 2019; Hughes et al., 2005). Ecosystem-based management is a pathway that can reverse approaches to key species to minimize the impacts of overfishing (Cinner et al., 2020; Darling et al., 2019).

The conservation of marine biodiversity has advanced enormously and successfully in the last century (Duarte et al., 2020; Knowlton, 2021). However, the Anthropocene marks an unprecedented multiplicity of governance crises. Thus, breaking with the outdated vision of a utilitarian governance, centered on the sustainable management of simple stocks of species and ecosystems (Jacquet & Pauly, 2022), and moving towards an Ocean-centered one is a new and promising path for improved and more integrated conservation of all marine ecosystems (Bender et al., 2022).

## 4.5. CONCLUSIONS

We based our hypothesis on the occurrence of fishers' generational shifting baseline syndrome, specifically the deviations in perception in relation to the decrease in carnivorous and piscivorous fish and increase in herbivore catches. The premise that fisheries impacts reduce catches of these trophic groups of reef fish, acting as a mechanism that serves as a basin of attraction for phase shifts, was supported by the LEK, perceptions of the co-occurrence of multiple stressors and the scientific literature.

In view of the scenario where traditional local communities are highly dependent on fish and fisheries, as well as tourism activities on the coral reefs, public policy incentives can significantly contribute to the reduction of overfishing, habitat degradation and social vulnerability.

Within a context of multiple governance crises in the Anthropocene, coastal-marine spatial planning, and the inclusion of ecosystem-based management through adaptive and participatory co-management are essential. They are solutions and alternatives that can accommodate the activities practiced by the different socio-ecological systems and the mitigation of stressors.

However, the need to break with the current global vision of utilitarian governance, towards one focused on the ocean as a living system, is a transformative alternative in this Decade of Ocean Science and for humanity as a whole. Locally, this approach can strengthen the sense of place, and the cultural and spiritual ecosystem services of coral reef. To tackle the multiple basins of attraction for phase shifts effectively, the involvement of multi-level networks is paramount.


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## AUTHORS' CONTRIBUTIONS

Cacilda M. C. Rocha: Conceptualization; Investigation; Funding acquisition; Writing - original draft; Methodology; Writing - review & editing; Data curation; Software; Formal analysis. Taciana P. Kramer: Methodology; Validation; Writing - review & editing; Supervision; Software; Formal analysis; Visualization; Resources. Cláudio L. S. Sampaio: Conceptualization; Methodology; Funding acquisition; Validation; Visualization; Writing - review & editing; Supervision; Resources.

## REFERENCES


Ainsworth, C. H., Pitcher, T. J., & Rotinsulu, C. (2008). Evidence of fishery depletions and shifting cognitive baselines in Eastern Indonesia. *Biological Conservation*, *141*(3), 848–859. https://doi.org/10.1016/j.biocon.2008.01.006

Albuquerque, T., Loiola, M., Nunes, J. de A. C. C., Reis-Filho, J. A., Sampaio, C. L. S., & Leduc, A. O. H. C. (2015). In situ effects of human disturbances on coral reef-fish assemblage structure: temporary and persisting changes are reflected as a result of intensive tourism. *Marine and Freshwater Research*, *66*(1), 23. https://doi.org/10.1071/MF13185

Appadoo, C., Sultan, R., Simier, M., Tandrayen-Ragoobur, V., & Capello, M. (2022). Artisanal fishers in small island developing states and their perception of environmental change: the case study of Mauritius. *Reviews in Fish Biology and Fisheries*. https://doi.org/10.1007/s11160-022-09735-6

Armitage, D., Alexander, S., Andrachuk, M., Berdej, S., Brown, S., Nayak P., Pittman, J., & Rathwell, K. (2017). Communities, multi-level networks and governance transformations in the coastal commons. In D. Armitage, A. Charles, & F. Berkes (Eds.), *Governing the coastal commons: Communities, Resilience and Transformation* (pp. 231–251). Taylor & Francis Group by Routledge.

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Diduck, A. P., Doubleday, N. C., Johnson, D. S., Marschke, M., McConney, P., Pinkerton, E. W., & Wollenberg, E. K. (2009). Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment*, *7*(2), 95–102. https://doi.org/10.1890/070089

Arruda, M. B., & de Sá, L. F. S. N. (2003). *Corredores ecológicos: uma abordagem integradora de ecossistemas no Brasil* (Ministério do Meio Ambiente, Ed.). Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis.

Bahia. (1992). *Decreto Nº 1.240 de 05 de Junho de 1992*.

Barbosa-Filho, M. L. V., Seminara, C. I., Tavares, D. C., Siciliano, S., Hauser-Davis, R. A., & da Silva Mourão, J. (2020). Artisanal fisher perceptions on ghost nets in a tropical South Atlantic marine biodiversity hotspot: Challenges to traditional fishing culture and implications for conservation strategies. *Ocean & Coastal Management*, *192*(October 2019), 105189. https://doi.org/10.1016/j.ocecoaman.2020.105189

Barrett, C. B., Travis, A. J., & Dasgupta, P. (2011). On biodiversity conservation and poverty traps. In *Proceedings of the National Academy of Sciences of the United States of America* (Vol. 108, Issue 34, pp. 13907–13912). https://doi.org/10.1073/pnas.1011521108

Begossi, A. (2015). Local ecological knowledge (LEK): understanding and managing fisheries. In J. , Fischer, J. , Jorgensen, H. , Josupeit, D. Kalikoski, & C. M. Lucas (Eds.), *Fishers' knowledge and the ecosystem approach to fisheries: applications, experiences and lessons in Latin America: Vol. No. 591.* (pp. 7–18). FAO Fisheries and Aquaculture .

Bellwood, D. R., Hughes, T. P., Folke, C., & Nyström, M. (2004). Confronting the coral reef crisis. *Nature*, *429*(6994), 827–833. https://doi.org/10.1038/nature02691

Bellwood, D. R., Pratchett, M. S., Morrison, T. H., Gurney, G. G., Hughes, T. P., Álvarez-Romero, J. G., Day, J. C., Grantham, R., Grech, A., Hoey, A. S., Jones, G. P., Pandolfi, J. M., Tebbett, S. B., Techera, E., Weeks, R., & Cumming, G. S. (2019). Coral reef conservation in the Anthropocene: Confronting spatial mismatches and prioritizing functions. *Biological Conservation*, *236*(May), 604–615. https://doi.org/10.1016/j.biocon.2019.05.056

Bellwood, D. R., Streit, R. P., Brandl, S. J., & Tebbett, S. B. (2019). The meaning of the term 'function' in ecology: A coral reef perspective. *Functional Ecology*, *33*(6), 948–961. https://doi.org/10.1111/1365-2435.13265

Bender, M., Bustamante, R., & Leonard, K. (2022). Living in relationship with the Ocean to transform governance in the UN Ocean Decade. *PLOS Biology*, *20*(10), e3001828. https://doi.org/10.1371/journal.pbio.3001828

Bender, M. G., Floeter, S. R., & Hanazaki, N. (2013). Do traditional fishers recognise reef fish species declines? Shifting environmental baselines in Eastern Brazil. *Fisheries Management and Ecology*, *20*(1), 58–67. https://doi.org/10.1111/fme.12006

Bender, M. G., Machado, G. R., Silva, P. J. A. de, Floeter, S. R., Monteiro-Netto, C., Luiz, O. J., & Ferreira, C. E. L. (2014). Local Ecological Knowledge and Scientific Data Reveal Overexploitation by Multigear Artisanal Fisheries in the Southwestern Atlantic. *PLoS ONE*, *9*(10), e110332. https://doi.org/10.1371/journal.pone.0110332

Berkes, F. (2021). IV Indigenous Peoples and Traditional Ecological Knowledge: 12. Traditional Ecological Knowledge: An Overview. In *Toward A New Social Contract: Community-based Resource Management and Small-scale Fisheries* (pp. 175–182). Too Big To Ignore Global-Small-Scale Fisheries are Too Big To Ignore. https://doi.org/10.1093/oso/9780197549230.003.0013

Lei No. 9.985, de 18 de Julho de 2000. Sistema Nacional de Unidades de Conservação/SNUC, Diário Oficial da União 1 (2000).

Carneiro, P. B. M., Ximenes Neto, A. R., Jucá-Queiroz, B., Teixeira, C. E. P., Feitosa, C. v., Barroso, C. X., Matthews-Cascon, H., de Morais, J. O., Freitas, J. E. P., Santander-Neto, J., de Araújo, J. T., Monteiro, L. H. U., Pinheiro, L. S., Braga, M. D. A., Cordeiro, R. T. S., Rossi, S., Bejarano, S., Salani, S., Garcia, T. M., … Soares, M. O. (2022). Interconnected marine habitats form a single continental-scale reef system in South America. *Scientific Reports*, *12*(1), 17359. https://doi.org/10.1038/s41598-022-21341-x

CEPRAM. (1998). *Resolução N.º 1.692 de 19 de junho de 1998*.

Chapin III, F. S., Carpenter, S. R., Kofinas, G. P., Folke, C., Abel, N., Clark, W. C., Olsson, P., Smith, D. M. S., Walker, B., Young, O. R., Berkes, F., Biggs, R., Grove, J. M., Naylor, R. L., Pinkerton, E., Steffen, W., & Swanson, F. J. (2010). Ecosystem stewardship: sustainability strategies for a rapidly changing planet. *Trends in Ecology & Evolution*, *25*(4), 241–249. https://doi.org/10.1016/j.tree.2009.10.008

Chapin III, F. S., Sommerkorn, M., Robards, M. D., & Hillmer-Pegram, K. (2015). Ecosystem stewardship: A resilience framework for arctic conservation. *Global Environmental Change*, *34*, 207–217. https://doi.org/10.1016/j.gloenvcha.2015.07.003

Cinner, J. (2014). Coral reef livelihoods. *Current Opinion in Environmental Sustainability*, *7*, 65–71. https://doi.org/10.1016/j.cosust.2013.11.025

Cinner, J. E., & McClanahan, T. R. (2006). Socioeconomic factors that lead to overfishing in small-scale coral reef fisheries of Papua New Guinea. *Environmental Conservation*, *33*(1), 73–80. https://doi.org/10.1017/S0376892906002748

Cinner, J. E., McClanahan, T. R., Daw, T. M., Graham, N. A. J., Maina, J., Wilson, S. K., & Hughes, T. P. (2009). Linking Social and Ecological Systems to Sustain Coral Reef Fisheries. *Current Biology*, *19*(3), 206–212. https://doi.org/10.1016/j.cub.2008.11.055

Cinner, J. E., McClanahan, T. R., Graham, N. A. J., Daw, T. M., Maina, J., Stead, S. M., Wamukota, A., Brown, K., & Bodin, O. (2012). Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change*, *22*(1), 12–20. https://doi.org/10.1016/j.gloenvcha.2011.09.018

Cinner, J. E., McClanahan, T. R., Graham, N. A. J., Pratchett, M. S., Wilson, S. K., & Raina, J. B. (2009). Gear-based fisheries management as a potential adaptive response to climate change and coral mortality. *Journal of Applied Ecology*, *46*(3), 724–732. https://doi.org/10.1111/j.1365-2664.2009.01648.x

Cinner, J. E., Zamborain-Mason, J., Gurney, G. G., Graham, N. A. J., MacNeil, M. A., Hoey, A. S., Mora, C., Villéger, S., Maire, E., McClanahan, T. R., Maina, J. M., Kittinger, J. N., Hicks, C. C., D’agata, S., Huchery, C., Barnes, M. L., Feary, D. A., Williams, I. D., Kulbicki, M., … Mouillot, D. (2020). Meeting fisheries, ecosystem function, and biodiversity goals in a human-dominated world. *Science*, *368*(6488), 307–311. https://doi.org/10.1126/science.aax9412

Clements, K. D., German, D. P., Piché, J., Tribollet, A., & Choat, J. H. (2016). Integrating ecological roles and trophic diversification on coral reefs: multiple lines of evidence identify parrotfishes as microphages. *Biological Journal of the Linnean Society*, *120*, 729–751. https://doi.org/10.1111/bij.12914

Conversi, A., Dakos, V., Gårdmark, A., Ling, S., Folke, C., Mumby, P. J., Greene, C., Edwards, M., Blenckner, T., Casini, M., Pershing, A., & Möllmann, C. (2015). A Holistic view of Marine Regime shifts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1659), 1–8. https://doi.org/10.1098/rstb.2013.0279

Costa, P. A. S., Martins, A. S., & Olavo, G. (2005). *Série Livros 13 Pesca e potenciais de exploração de recursos vivos na região central da Zona Econômica Exclusiva brasileira* (Issue December 2014).

Cruz, I. C. S., de Kikuchi, R. K. P., Longo, L. L., & Creed, J. C. (2015). Evidence of a phase shift to Epizoanthus gabrieli Carlgreen, 1951 (Order Zoanthidea) and loss of coral cover on reefs in the Southwest Atlantic. *Marine Ecology*, *36*(3), 318–325. https://doi.org/10.1111/maec.12141

Cruz, I. C. S., Waters, L. G., Kikuchi, R. K. P., Leão, Z. M. A. N., & Turra, A. (2018). Marginal coral reefs show high susceptibility to phase shift. *Marine Pollution Bulletin*, *135*(July), 551–561. https://doi.org/10.1016/j.marpolbul.2018.07.043

Cruz-Trinidad, A., Aliño, P. M., Geronimo, R. C., & Cabral, R. B. (2014). Linking Food Security with Coral Reefs and Fisheries in the Coral Triangle. *Coastal Management*, *42*(2), 160–182. https://doi.org/10.1080/08920753.2014.877761

Darling, E. S., McClanahan, T. R., Maina, J., Gurney, G. G., Graham, N. A. J., Januchowski-Hartley, F., Cinner, J. E., Mora, C., Hicks, C. C., Maire, E., Puotinen, M., Skirving, W. J., Adjeroud, M., Ahmadia, G., Arthur, R., Bauman, A. G., Beger, M., Berumen, M. L., Bigot, L., … Mouillot, D. (2019). Social–environmental drivers inform strategic management of coral reefs in the Anthropocene. *Nature Ecology and Evolution*, *3*(9), 1341–1350. https://doi.org/10.1038/s41559-019-0953-8

Daskalov, G. M., Grishin, A. N., Rodionov, S., & Mihneva, V. (2007). Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts.

*Proceedings of the National Academy of Sciences*, *104*(25), 10518–10523. https://doi.org/10.1073/pnas.0701100104

de Carvalho-Souza, G. F., Llope, M., Tinôco, M. S., Medeiros, D. v., Maia-Nogueira, R., & Sampaio, C. L. S. (2018). Marine litter disrupts ecological processes in reef systems. *Marine Pollution Bulletin*, *133*, 464–471. https://doi.org/10.1016/j.marpolbul.2018.05.049

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M. A., Baste, I. A., Brauman, K. A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., van Oudenhoven, A. P. E., van der Plaat, F., Schröter, M., Lavorel, S., … Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359*(6373), 270–272. https://doi.org/10.1126/science.aap8826

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.-P., Fulweiler, R. W., Hughes, T. P., Knowlton, N., Lovelock, C. E., Lotze, H. K., Predragovic, M., Poloczanska, E., Roberts, C., & Worm, B. (2020). Rebuilding marine life. *Nature*, *580*(7801), 39–51. https://doi.org/10.1038/s41586-020-2146-7

Dudley, N. (2008). Guidelines for Applying Protected Area Management Categories. In *IUCN WCPA Best Practice Guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types: Vol. Series No. 21* (pp. 1–143). www.iucn.org/pa_guidelines

Elliff, C. I., & Kikuchi, R. K. P. (2017). Ecosystem services provided by coral reefs in a Southwestern Atlantic Archipelago. *Ocean and Coastal Management*, *136*, 49–55. https://doi.org/10.1016/j.ocecoaman.2016.11.021

ENSP. (2020). *Mapa de conflitos envolvendo injustiça ambiental e saúde no Brasil*. Breves Considerações Conceituais e Metodológicas Sobre o Mapa de Conflitos Envolvendo Injustiça Ambiental e Saúde No Brasil. http://mapadeconflitos.ensp.fiocruz.br/?page_id=1759

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., Carpenter, S. R., Essington, T. E., Holt, R. D., Jackson, J. B. C., Marquis, R. J., Oksanen, L., Oksanen, T., Paine, R. T., Pikitch, E. K., Ripple, W. J., Sandin, S. A., Scheffer, M., Schoener, T. W., … Wardle, D. A. (2011). Trophic Downgrading of Planet Earth. *Science*, *333*(6040), 301–306. https://doi.org/10.1126/science.1205106

FAO. (2015). *Fishers' knowledge and the ecosystem approach to fisheries: Applications, experiences and lessons in Latin America* (J. Fischer, J. Jorgensen, H. Josupeit, D. Kalikoski, & C. M. Lucas, Eds.; No. 591). FAO Fisheries and Aquaculture Technical Paper .

FAO. (2017). *FAO Working for SDG 14: Healthy oceans for food security, nutrition and resilient communities*. https://www.fao.org/3/i7298e/i7298e.pdf

FAO. (2020). Meeting the Sustainable Development Goals. In *The State of World fisheries and aquaculture* (Vol. 29, Issue 3).

Fischer, F. (2007). *Baixo Sul da Bahia: uma proposta de desenvolvimento territorial (Coleção Gestão Social)*. https://www.researchgate.net/publication/349988614

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, *16*(3), 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Food and Agriculture Organization of the United Nations-FAO. (2022, December 9). *Fishing gear classification*. Coordinating Working Party on Fishery Statistics.

Frédou, T., Ferreira, B. P., & Letourneur, Y. (2009). Assessing the stocks of the primary snappers caught in Northeastern Brazilian reef systems. 1: Traditional modelling approaches. *Fisheries Research*, *99*(2), 90–96. https://doi.org/10.1016/j.fishres.2009.05.008

Freire, K. M. F., & Pauly, D. (2010). Fishing down Brazilian marine food webs, with emphasis on the east Brazil large marine ecosystem. *Fisheries Research*, *105*(1), 57–62. https://doi.org/10.1016/j.fishres.2010.02.008

Froese, R., & Pauly, D. (2022). *FishBase*. Editors. www.fishbase.org

Gallardo, S., Fossile, T., Herbst, D., Begossi, A., Silva, L., & Colonese, A. (2021). 150 years of anthropogenic impact on coastal and ocean ecosystems in Brazil revealed by historical newspapers. *Ocean & Coastal Management*, *209*, 105662. https://doi.org/10.1016/j.ocecoaman.2021.105662

Giglio, V. J., Luiz, O. J., & Gerhardinger, L. C. (2015). Depletion of marine megafauna and shifting baselines among artisanal fishers in eastern Brazil. *Animal Conservation*, *18*(4), 348–358. https://doi.org/10.1111/acv.12178

Giglio, V. J., Luiz, O. J., & Schiavetti, A. (2015). Marine life preferences and perceptions among recreational divers in Brazilian coral reefs. *Tourism Management*, *51*, 49–57. https://doi.org/10.1016/j.tourman.2015.04.006

Gilarranz, L. J., Mora, C., & Bascompte, J. (2016). Anthropogenic effects are associated with a lower persistence of marine food webs. *Nature Communications*, *7*(1), 10737. https://doi.org/10.1038/ncomms10737

Graham, N. A. J. (2014). Habitat complexity: Coral structural loss leads to fisheries declines. *Current Biology*, *24*(9), R359–R361. https://doi.org/10.1016/j.cub.2014.03.069

Graham, N. A. J. (2015). Phase shifts and coral reef fishes. *Ecology of Fishes on Coral Reefs*, *May*, 191–198. https://doi.org/10.1017/CBO9781316105412.021

Guerrero-Gatica, M., Aliste, E., & Simonetti, J. (2019). Shifting Gears for the Use of the Shifting Baseline Syndrome in Ecological Restoration. *Sustainability*, *11*(5), 1458. https://doi.org/10.3390/su11051458

Hicks, C. C. (2011). How Do We Value Our Reefs? Risks and Tradeoffs Across Scales in “Biomass-Based” Economies. *Coastal Management*, *39*(4), 358–376. https://doi.org/10.1080/08920753.2011.589219

Hicks, C. C., Crowder, L. B., Graham, N. A., Kittinger, J. N., & Cornu, E. le. (2016). Social drivers forewarn of marine regime shifts. *Frontiers in Ecology and the Environment*, *14*(5), 252–260. https://doi.org/10.1002/fee.1284

Hilborn, R., Amoroso, R. O., Anderson, C. M., Baum, J. K., Branch, T. A., Costello, C., de Moor, C. L., Faraj, A., Hively, D., Jensen, O. P., Kurota, H., Little, L. R., Mace, P., McClanahan, T., Melnychuk, M. C., Minto, C., Osio, G. C., Parma, A. M., Pons, M., Ye, Y. (2020). Effective fisheries management instrumental in improving fish stock status. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(4), 2218–2224. https://doi.org/10.1073/pnas.1909726116

Holling C. S. (1973). Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.*, *41*(23), 1–24. www.annualreviews.org

Holmlund, C. M., & Hammer, M. (1999). Ecosystem services generated by fish populations. *Ecological Economics*, *29*, 253–268.

Hughes, T. P., Barnes, M. L., Bellwood, D. R., Cinner, J. E., Cumming, G. S., Jackson, J. B. C., Kleypas, J., van de Leemput, I. A., Lough, J. M., Morrison, T. H., Palumbi, S. R., van Nes, E. H., & Scheffer, M. (2017). Coral reefs in the Anthropocene. *Nature*, *546*(7656), 82–90. https://doi.org/10.1038/nature22901

Hughes, T. P., Bellwood, D. R., Folke, C., Steneck, R. S., & Wilson, J. (2005). New paradigms for supporting the resilience of marine ecosystems. *Trends in Ecology and Evolution*, *20*(7), 380–386. https://doi.org/10.1016/j.tree.2005.03.022

Portaria MMA Nº 445, De 17 De Dezembro de 2014, Diário Oficial da União-Ministério do Meio Ambiente 01 (2014). https://www.icmbio.gov.br/cepsul/images/stories/legislacao/Portaria/2014/p_mma_445_2014_lista_peixes_amea%C3%A7ados_extin%C3%A7%C3%A3o.pdf

Instituto Brasileiro de Geografia e Estatística-IBGE. (2022, September 5). *Cidades e Estados: Cairu-BA*. Cidades e Estados.

IPBES-Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2016). *The methodological assessment report on Scenarios and Models Ecosystem Services* (S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L. A. Acosta, H. R. Akçakaya, L. Brotons, W. W. L. Cheung, V. Christensen, K. A. Harhash, J. Kabubo-Mariara, C. Lundquist, M. Obersteiner, H. M. Pereira, G. Peterson, R. Pichs-Madruga, N. Ravindranath, C. Rondinini, & B. A. Wintle, Eds.). Secretariat of the Intergorvenamental Science-Policy Platform on Biodiversity and Ecosystem Services.

IPCC. (2022). Changing Ocean, Marine Ecosystems, and Dependent Communities. In *The Ocean and Cryosphere in a Changing Climate* (pp. 447–588). Cambridge University Press. https://doi.org/10.1017/9781009157964.007

IUCN- International Union for Nature Conservation. (2022). *Red List of Threatened Species*. Red List of Threatened Species. https://www.iucnredlist.org/

Jackson, J. B. C. (1997). Reefs since Columbus. *Coral Reefs*, *16*(Suppl.: 16), S23–S32. https://doi.org/10.1007/s003380050238

Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., Bradbury, R. H., Cooke, R., Erlandson, J., Estes, J. A., Hughes, T. P., Kidwell, S., Lange, C. B., Lenihan, H. S., Pandolfi, J. M., Peterson, C. H., Steneck, R. S., Tegner, M. J., & Warner, R. R. (2001). Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science*, *293*(5530), 629–637. https://doi.org/10.1126/science.1059199

Jacquet, J., & Pauly, D. (2022). Reimagining sustainable fisheries. *PLoS Biology*, *20*(10), e3001829. https://doi.org/10.1371/journal.pbio.3001829

Jentoft, S. (2005). Fisheries co-management as empowerment. *Marine Policy*, *29*(1), 1–7. https://doi.org/10.1016/j.marpol.2004.01.003

Kikuchi, R. K. P., Leão, Z. M. A. N., & Oliveira, M. D. M. (2010). Conservation status and spatial patterns of AGRRA vitality indices in Southwestern Atlantic reefs. *Revista de Biologia Tropical*, *58*(SUPPL. 1), 1–31. https://doi.org/10.15517/rbt.v58i1.20021

Knowlton, N. (2021). Ocean Optimism: Moving Beyond the Obituaries in Marine Conservation. *Annual Review of Marine Science*, *13*(1), 479–499. https://doi.org/10.1146/annurev-marine-040220-101608

Knowlton, N., & Jackson, J. B. C. (2008). Shifting baselines, local impacts, and global change on coral reefs. *PLoS Biology*, *6*(2), 0215–0220. https://doi.org/10.1371/journal.pbio.0060054

Kovalenko, K. E., Thomaz, S. M., & Warfe, D. M. (2012). Habitat complexity: approaches and future directions. *Hydrobiologia*, *685*(1), 1–17. https://doi.org/10.1007/s10750-011-0974-z

Leão, Z. M. A. N., Kikuchi, R. K. P., Ferreira, B. P., Neves, E. G., Sovierzoski, H. H., Oliveira, M. D. M., Maida, M., Correia, M. D., & Johnsson, R. (2016). Brazilian coral reefs in a period of global change: A synthesis. *Brazilian Journal of Oceanography*, *64*(Special Issue 2), 97–116. https://doi.org/10.1590/S1679-875920160916064sp2

Leão, Z. M. A. N., Kikuchi, R. K. P., & Oliveira, M. D. M. (2019). The Coral Reef Province of Brazil. In *World Seas: an Environmental Evaluation* (Second Edi, Vol. 1, pp. 813–833). Elsevier Ltd. https://doi.org/10.1016/B978-0-12-805068-2.00048-6

Leão, Z. M. A. N., Kikuchi, R. K. P., Oliveira, M. D. M., & Vasconcelos, V. (2010). Status of Eastern Brazilian coral reefs in time of climate changes. *Pan-American Journal of Aquatic Sciences*, *5*(2), 224–235.

Lenton, T. M. (2020). Tipping positive change. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1794), 0–2. https://doi.org/10.1098/rstb.2019.0123

Loiola, M., Cruz, I. C. S., Leão, Z. M. A. N., & Kikuchi, R. K. P. (2014). Definition of priority areas for the conservation of a coastal reef complex in the eastern Brazilian coast. *Revista de Gestão Costeira Integrada*, *14*(4), 611–624. https://doi.org/10.5894/rgci449

Lopes, P. F. M., Pacheco, S., Clauzet, M., Silvano, R. A. M., & Begossi, A. (2015). Fisheries, tourism, and marine protected areas: Conflicting or synergistic interactions? *Ecosystem Services*, *16*, 333–340. https://doi.org/10.1016/j.ecoser.2014.12.003

Luiz, O. J., & Edwards, A. J. (2011). Extinction of a shark population in the Archipelago of Saint Paul’s Rocks (equatorial Atlantic) inferred from the historical record. *Biological Conservation*, *144*(12), 2873–2881. https://doi.org/10.1016/j.biocon.2011.08.004

Magris, R. A., Pressey, R. L., Mills, M., Vila-Nova, D. A., & Floeter, S. (2017). Integrated conservation planning for coral reefs: Designing conservation zones for multiple conservation objectives in spatial prioritisation. *Global Ecology and Conservation*, *11*, 53–68. https://doi.org/10.1016/j.gecco.2017.05.002

Malhi, Y. (2017). The Concept of the Anthropocene. *Annual Review of Environment and Resources*, *42*(August), 77–104. https://doi.org/10.1146/annurev-environ-102016-060854

Maretti, C. C., Leão, A. R., Prates, A. P., Simões, E., Silva, R. B. A., Ribeiro, K. T., Geluda, L., Sampaio, M. S., Marques, F. F. C., Lobo, A. C., de Lima, L. H., Pacheco, L. M., Manfrinato, W. A., Lezama, A. Q., Couto, M. T. P., Pereira, P. M., Giasson, M. M., Carneiro, P. H. M., de Oliveira Filho, A. L., … Subirá, R. J. (2019). Marine and coastal protected and conserved areas strategy in Brazil: Context, lessons, challenges, finance, participation, new management models, and first results. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(S2), 44–70. https://doi.org/10.1002/aqc.3169

McClanahan, T. R., Hicks, C. C., & Darling, E. S. (2008). Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. *Ecological Applications*, *18*(6), 1516–1529. https://doi.org/10.1890/07-0876.1

Mcleod, E., Anthony, K. R. N., Mumby, P. J., Maynard, J., Beeden, R., Graham, N. A. J., Heron, S. F., Hoegh-Guldberg, O., Jupiter, S., MacGowan, P., Mangubhai, S., Marshall, N., Marshall, P. A., McClanahan, T. R., Mcleod, K., Nyström, M., Obura, D., Parker, B., Possingham, H. P., … Tamelander, J. (2019). The future of resilience-based management in coral reef ecosystems. *Journal of Environmental Management*, *233*(August 2018), 291–301. https://doi.org/10.1016/j.jenvman.2018.11.034

MEA. (2005). *Living Beyound Our Means: Natural Assets and human well-being*.

MMA. (2022). *Ministério do Meio Ambiente-Portaria MMA Nº 148, de 07 de junho de 2022*.

Moberg, F., & Folke, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological Economics*, *29*, 215–233. https://doi.org/10.1016/S0921-8009(99)00009-9

Möllmann, C., & Diekmann, R. (2012). Marine Ecosystem Regime Shifts Induced by Climate and Overfishing: A Review for the Northern Hemisphere. In *Advances in*

*Ecological Research* (Vol. 47, pp. 303–347). Academic Press Inc. https://doi.org/10.1016/B978-0-12-398315-2.00004-1

Möllmann, C., Folke, C., Edwards, M., & Conversi, A. (2015). Marine regime shifts around the globe: theory, drivers and impacts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1659), 20130260. https://doi.org/10.1098/rstb.2013.0260

Muhl, E.-K., Esteves Dias, A. C., & Armitage, D. (2020). Experiences With Governance in Three Marine Conservation Zoning Initiatives: Parameters for Assessment and Pathways Forward. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00629

Mumby, P. J., Dahlgren, C. P., Harborne, A. R., Kappel, C. v., Micheli, F., Brumbaugh, D. R., Holmes, K. E., Mendes, J. M., Broad, K., Sanchirico, J. N., Buch, K., Box, S., Stoffle, R. W., & Gill, A. B. (2006). Fishing, trophic cascades, and the process of grazing on coral reefs. *Science*, *311*(5757), 98–101. https://doi.org/10.1126/science.1121129

Mumby, P. J., Steneck, R. S., Edwards, A. J., Ferrari, R., Coleman, R., Harborne, A. R., & Gibson, J. P. (2012). Fishing down a Caribbean food web relaxes trophic cascades. *Marine Ecology Progress Series*, *445*, 13–24. https://doi.org/10.3354/meps09450

Mumby, P., & Steneck, R. (2008). Coral reef management and conservation in light of rapidly evolving ecological paradigms. *Trends in Ecology & Evolution*, *23*(10), 555–563. https://doi.org/10.1016/j.tree.2008.06.011

Myers, R. A., & Worm, B. (2003). Rapid worldwide depletion of predatory fish communities. *Nature*, *423*(6937), 280–283. https://doi.org/10.1038/nature01610

Nash, K. L., Graham, N. A. J., Januchowski-Hartley, F. A., & Bellwood, D. R. (2012). Influence of habitat condition and competition on foraging behaviour of parrotfishes. *Marine Ecology Progress Series*, *457*, 113–124. https://doi.org/10.3354/meps09742

Norström, A., Nyström, M., Lokrantz, J., & Folke, C. (2009). Alternative states on coral reefs: beyond coral–macroalgal phase shifts. *Marine Ecology Progress Series*, *376*, 295–306. https://doi.org/10.3354/meps07815

Nunes, J. A. C. C., Sampaio, C. L. S., Barros, F., & Leduc, A. O. H. C. (2018). Plastic debris collars: An underreported stressor in tropical reef fishes. *Marine Pollution Bulletin*, *129*(2), 802–805. https://doi.org/10.1016/j.marpolbul.2017.10.076

Nyström, M., Folke, C., & Moberg, F. (2000). Coral reef disturbance and resilience in a human-dominated environment. *TREE*, *15*(10), 413–417.

Nyström, M., Graham, N. A. J., Lokrantz, J., & Norström, A. v. (2008). Capturing the cornerstones of coral reef resilience: Linking theory to practice. *Coral Reefs*, *27*(4), 795–809. https://doi.org/10.1007/s00338-008-0426-z

Nyström, M., Norström, A. v., Blenckner, T., de la Torre-Castro, M., Eklöf, J. S., Folke, C., Österblom, H., Steneck, R. S., Thyresson, M., & Troell, M. (2012). Confronting Feedbacks of Degraded Marine Ecosystems. *Ecosystems*, *15*(5), 695–710. https://doi.org/10.1007/s10021-012-9530-6

Oakley-Cogan, A., Tebbett, S. B., & Bellwood, D. R. (2020). Habitat zonation on coral reefs: Structural complexity, nutritional resources and herbivorous fish distributions. *PLoS ONE*, *15*(6), 1–23. https://doi.org/10.1371/journal.pone.0233498

Oliveira, E. O. da S. (2009). *Valença: Dos primórdios à Contemporaneidade*. JM-Gráfica Editora LTDA.

Oliveira Júnior, J. G. C., Ladle, R. J., Correia, R., & Batista, V. S. (2016). Measuring what matters – Identifying indicators of success for Brazilian marine protected areas. *Marine Policy*, *74*, 91–98. https://doi.org/10.1016/j.marpol.2016.09.018

ONU-UNEP. (2022). End plastic pollution: Towards an international legally binding instrument. In *United Nations Environment Programme*. https://papersmart.unon.org/resolution/uploads/k1900699.pdf

Ott, C. F. (1944). Elementos culturais da pescaria Baiana. In Boletim do Museu Nacional- Antropologia (Ed.), *Boletim do Museu Nacional* (N. 4, Vol. 4). Ministério da Educação e Saúde.

Pandolfi, J. M., Bradbury, R. H., Sala, E., Hughes, T. P., Bjorndal, K. A., Cooke, R. G., McArdle, D., McClenachan, L., Newman, M. J. H., Paredes, G., Warner, R. R., & Jackson, J. B. C. (2003). Global trajectories of the long-term decline of coral reef ecosystems. *Science*, *301*(5635), 955–958. https://doi.org/10.1126/science.1085706

Papworth, S. K., Rist, J., Coad, L., & Milner-Gulland, E. J. (2009). Evidence for shifting baseline syndrome in conservation. *Conservation Letters*, *2*, 93–100. https://doi.org/10.1111/j.1755-263x.2009.00049.x

Pauly, D. (1995a). Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution*, *10*(10), 430. https://doi.org/10.1016/S0169-5347(00)89171-5

Pauly, D. (1995b). Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution*, *10*(10), 430. http://www.ncbi.nlm.nih.gov/pubmed/21237093

Pauly, D., & Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications*, *7*. https://doi.org/10.1038/ncomms10244

Pereira, P. H. C., Lima, G. v., Pontes, A. V. F., Côrtes, L. G. F., Gomes, E., Sampaio, C. L. S., Pinto, T. K., Miranda, R. J., Cardoso, A. T. C., Araujo, J. C., & Seoane, J. C. S. (2022). Unprecedented Coral Mortality on Southwestern Atlantic Coral Reefs Following Major Thermal Stress. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.725778

Pershing, A. J., Mills, K. E., Record, N. R., Stamieszkin, K., Wurtzell, K. v., Byron, C. J., Fitzpatrick, D., Golet, W. J., & Koob, E. (2015). Evaluating trophic cascades as drivers of regime shifts in different ocean ecosystems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1659), 20130265. https://doi.org/10.1098/rstb.2013.0265

Pinheiro, H. T., Martins, A. S., & Gasparini, J. L. (2010). Impact of commercial fishing on Trindade Island and Martin Vaz Archipelago, Brazil: characteristics, conservation status of the species involved and prospects for preservation. *Brazilian Archives of*

*Biology and Technology*, *53*(6), 1417–1423. https://doi.org/10.1590/S1516-89132010000600018

Pinheiro, H. T., Rocha, L. A., Macieira, R. M., Carvalho-Filho, A., Anderson, A. B., Bender, M. G., di Dario, F., Ferreira, C. E. L., Figueiredo-Filho, J., Francini-Filho, R., Gasparini, J. L., Joyeux, J.-C., Luiz, O. J., Mincarone, M. M., Moura, R. L., Nunes, J. de A. C. C., Quimbayo, J. P., Rosa, R. S., Sampaio, C. L. S., … Floeter, S. R. (2018). South-western Atlantic reef fishes: Zoogeographical patterns and ecological drivers reveal a secondary biodiversity centre in the Atlantic Ocean. *Diversity and Distributions*, *24*(7), 951–965. https://doi.org/10.1111/ddi.12729

Prefeitura de Cairu. (2022, November 25). *Portal do cidadão: Receita*. Outros Serviços - Tarifa Por Uso Do Patrimônio Do Arquipélago - TUPA. https://www.municipioonline.com.br/ba/prefeitura/cairu/cidadao/receita

Reis-Filho, J., Freitas, R., Loiola, M., Leite, L., Soeiro, G., Oliveira, H., Sampaio, C., Nunes, J., & Leduc, A. (2016). Traditional fisher perceptions on the regional disappearance of the largetooth sawfish Pristis pristis from the central coast of Brazil. *Endangered Species Research*, *29*(3), 189–200. https://doi.org/10.3354/esr00711

Rhormens, M. S., Pedrini, A. de G., & Ghilardi-Lopes, N. P. (2017). Implementation feasibility of a marine ecotourism product on the reef environments of the marine protected areas of Tinharé and Boipeba Islands (Cairu, Bahia, Brazil). *Ocean & Coastal Management*, *139*, 1–11. https://doi.org/10.1016/j.ocecoaman.2017.01.022

Rocha, C. M. C., & Sampaio, C. L. S. (2022). A review of the knowledge of reef fish in the Southwest Atlantic. *Marine Environmental Research*, *182*(105769), 1–13. https://doi.org/10.1016/j.marenvres.2022.105769

Rocha, J. C. (2022). Ecosystems are showing symptoms of resilience loss. *Environmental Research Letters*, *17*(065013), 1–14. https://doi.org/10.1088/1748-9326/ac73a8

Roos, N. C., Longo, G. O., Pennino, M. G., Francini-Filho, R. B., & Carvalho, A. R. (2020). Protecting nursery areas without fisheries management is not enough to conserve the most endangered parrotfish of the Atlantic Ocean. *Scientific Reports*, *10*(19143), 1–11. https://doi.org/10.1038/s41598-020-76207-x

Roos, N. C., Longo, G. O., Taylor, B. M., & Carvalho, A. R. (2020). Demography of the largest and most endangered Brazilian parrotfish, Scarus trispinosus, reveals overfishing. *Endangered Species Research*, *41*, 319–327. https://doi.org/10.3354/esr01024

Roos, N., Pennino, M., Lopes, P., & Carvalho, A. (2016). Multiple management strategies to control selectivity on parrotfishes harvesting. *Ocean & Coastal Management*, *134*, 20–29. https://doi.org/10.1016/j.ocecoaman.2016.09.029

Sáenz-Arroyo, A., Roberts, C. M., Torre, J., Cariño-Olvera, M., & Hawkins, J. P. (2006). The value of evidence about past abundance: Marine fauna of the Gulf of California through the eyes of 16th to 19th century travellers. *Fish and Fisheries*, *7*(2), 128–146. https://doi.org/10.1111/j.1467-2979.2006.00214.x

Santos, R. G., Machovsky-Capuska, G. E., & Andrades, R. (2021). Plastic ingestion as an evolutionary trap: Toward a holistic understanding. *Science*, *373*(6550), 56–60. https://doi.org/10.1126/science.abh0945

Scheffer, M., Carpenter, C., & Young, B. de. (2005). Cascading effects of overfishing marine systems. *Trends in Ecology and Evolution*, *20*(11), 579–581. https://doi.org/10.1016/j.tree.2005.08.007

Scheffer, M., & van Nes, E. H. (2004). Mechanisms for marine regime shifts: Can we use lakes as microcosms for oceans? In *Progress in Oceanography* (Vol. 60, Issues 2–4, pp. 303–319). https://doi.org/10.1016/j.pocean.2004.02.008

Selig, E. R., Hole, D. G., Allison, E. H., Arkema, K. K., McKinnon, M. C., Chu, J., Sherbinin, A., Fisher, B., Glew, L., Holland, M. B., Ingram, J. C., Rao, N. S., Russell, R. B., Srebotnjak, T., Teh, L. C. L., Troëng, S., Turner, W. R., & Zvoleff, A. (2019). Mapping global human dependence on marine ecosystems. *Conservation Letters*, *12*(2). https://doi.org/10.1111/conl.12617

Setter, R. O., Franklin, E. C., & Mora, C. (2022). Co-occurring anthropogenic stressors reduce the timeframe of environmental viability for the world's coral reefs. *PLoS Biology*, *20*(10), 1–12. https://doi.org/10.1371/journal.pbio.3001821

Soares, M. O., Kitahara, M. V., Santos, M. E. A., Bejarano, S., Rabelo, E. F., & Cruz, I. C. S. (2022). The flourishing and vulnerabilities of zoantharians on Southwestern Atlantic reefs. *Marine Environmental Research*, *173*, 105535. https://doi.org/10.1016/j.marenvres.2021.105535

Soares, M. O., Rossi, S., Gurgel, A. R., Lucas, C. C., Tavares, T. C. L., Diniz, B., Feitosa, C. V., Rabelo, E. F., Pereira, P. H. C., Kikuchi, R. K. P. de, Leão, Z. M. A. N., Cruz, I. C. S., Carneiro, P. B. de M., & Alvarez-Filip, L. (2021). Impacts of a changing environment on marginal coral reefs in the Tropical Southwestern Atlantic. *Ocean and Coastal Management*, *210*(May). https://doi.org/10.1016/j.ocecoaman.2021.105692

Soga, M., & Gaston, K. J. (2018). Shifting baseline syndrome: causes, consequences, and implications. *Frontiers in Ecology and the Environment*, *16*(4), 222–230. https://doi.org/10.1002/fee.1794

Spalding, M., Burke, L., Wood, S. A., Ashpole, J., Hutchison, J., & zu Ermgassen, P. (2017). Mapping the global value and distribution of coral reef tourism. *Marine Policy*, *82*(January), 104–113. https://doi.org/10.1016/j.marpol.2017.05.014

Steffen, W., Grinevald, J., Crutzen, P., & Mcneill, J. (2011). The anthropocene: Conceptual and historical perspectives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1938), 842–867. https://doi.org/10.1098/rsta.2010.0327

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/science.1259855

Tilley A, Cohen PJ, Akester M, Batalofo M, Boso D, Cinner J, dos Reis Lopes J, Duarte A, Eriksson H, & Gomese C. (2021). Increasing social and ecological resilience of coastal fisheries Penang, Malaysia. In *CGIAR Research Program on Fish Agri-Food Systems*.

Turvey, S. T., Barrett, L. A., Yujiang, H., Lei, Z., Xinqiao, Z., Xianyan, W., Yadong, H., Kaya, Z., Hart, T., & Ding, W. (2010). Rapidly Shifting Baselines in Yangtze Fishing Communities and Local Memory of Extinct Species. *Conservation Biology*, *24*(3), 778–787. https://doi.org/10.1111/j.1523-1739.2009.01395.x

UN. (2015). General Assembly. In *Resolution adopted by the General Assembly on 25 September 2015* (Vol. 17, Issues 15–116). https://doi.org/10.1163/157180910X12665776638740

UNESCO. (2020). *United Nations Decade of Ocean Science for Sustainable Development (2021-2030)*. Decade of Ocean Science for Sustainable. https://en.unesco.org/ocean-decade#:~:text=The United Nations has proclaimed,support countries in creating improved

Woodhead, A. J., Graham, N. A. J., Robinson, J. P. W., Norström, A. v., Bodin, N., Marie, S., Balett, M. C., & Hicks, C. C. (2021). Fishers perceptions of ecosystem service change associated with climate-disturbed coral reefs. *People and Nature*, *3*(3), 639–657. https://doi.org/10.1002/pan3.10220

Young, O. R., Berkhout, F., Gallopin, G. C., Janssen, M. A., Ostrom, E., & van der Leeuw, S. (2006). The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change*, *16*(3), 304–316. https://doi.org/10.1016/j.gloenvcha.2006.03.004

Zapelini, C., da Silva, P. S., & Schiavetti, A. (2020). Shifting baseline syndrome highlighted by anecdotal accounts from snapper (Ocyurus chrysurus) fishery. *Ethnobiology and Conservation*, *9*(March), 1–12. https://doi.org/10.15451/ec2020-03-9.07-1-12

# 5 CONCLUSÃO GERAL

Em um contexto geral, é possível afirmar que o conhecimento científico multidisciplinar sobre as espécies, famílias e grupos tróficos de peixes recifais avançaram substancialmente nas últimas cinco décadas no Atlântico Sudoeste. A demonstração de que o Conhecimento Ecológico Local (CEL) de pescadores pode ser utilizado como uma ferramenta participativa e inclusiva em pesquisas científicas foi evidenciada neste estudo. A inclusão da percepção humana em pesquisas, através da integração entre o conhecimento científico e dos pescadores representa um avanço da sociedade em busca de soluções alternativas para mitigar a co-ocorrência de estressores antrópicos, como a sobrepesca, que promovem a degradação, transições ecossistêmicas, e mudanças de fase.

Na ilha de Boipeba, o CEL de pescadores, suas percepções sobre as mudanças pretéritas das pescarias, e dos impactos dos usos e ocupação não manejados dos recifes de coral, destaca que há um sentimento de preocupação com as atividades pesqueiras e com o Oceano. Particularmente, porque há uma ausência de políticas públicas para o monitoramento, fiscalização das atividades pesqueiras, e projetos objetivando a conservação da biodiversidade localmente. Há riscos do esgotamento de estoques de espécies de peixes de recifes de coral, como as garoupas, vermelhos e os budiões, para os quais há planos de recuperação de estoques por parte do Governo Federal.

Diferentes grupos tróficos de peixes recifais cumprem papéis ecológicos distintos nos recifes de coral participando do equilíbrio de processos ecossistêmicos na teia trófica. Peixes herbívoros, tem sua importância bem reportada e reconhecida para a manutenção da saúde e resiliência recifal. Entretanto, foi possível identificar que pouca ênfase tem sido dada em pesquisas para o entendimento das funções ecológicas de peixes recifais carnívoros e piscívoros, dos impactos, e os possíveis cenários da ausência desses grupos na teia trófica recifal, conjuntamente com os herbívoros.

As populações de peixes carnívoros, piscívoros e herbívoros declinaram nos últimos 40 anos no Atlântico Sul e Sudoeste. Na ilha de Boipeba, este estudo demonstra que houve uma mudança de alvos nas pescarias para os grandes e médios peixes herbívoros, os quais atualmente está ocorrendo a pescaria de juvenis e menores. Esta tese demonstrou a necessidade da criação de estratégias de manejo das pescarias de base ecossistêmica voltadas para os diferentes grupos tróficos de peixes recifais através da inclusão dos CEL dos pescadores efetivando sua participação nas pesquisas.

Há uma urgência em estabelecer cenários para dialogar pela busca por soluções entre a coletividade, para o futuro dos recifes de coral, e do provimento de bens e Serviços Ecossistêmicos da biodiversidade costeira e marinha na ilha de Boipeba. A Terra está passando por rápidas transformações geológicas e ecológicas derivadas das ações humanas em diferentes escalas espaciais, que é o Antropoceno. O enfrentamento da co-ocorrência de estressores que levam a degradação dos recifes de coral localmente, transições, e mudança de fase consiste em desafios. Para seu enfrentamento eficaz é necessário que haja o envolvimento multinível entre as diferentes esferas administrativas do poder público, diferentes setores da sociedade e das comunidades tradicionais pesqueiras em redes de cooperação.

Soluções para a mitigação dos estressores reside no estabelecimento de medidas de conservação através da criação de áreas marinhas protegidas com múltiplos zoneamentos, e do manejo baseado no ecossistema das pescarias. Soluções de médio e de longo prazo são prioritárias para uma adaptabilidade às mudanças climáticas, visando a manutenção da resiliência ecológica, social e mitigação do aceleramento da degradação dos recifes de coral.

Localmente, existem oportunidades para a ampliação da participação de pescadores e sociedade para avançar em práticas conservacionistas, representando um caminho no campo científico e social. Uma vez, que os diferentes Sistemas Sócio-ecológicos fazem usos e ocupação dos recifes de coral durante suas atividades de trabalho. Ao torná-las cientes dos impactos negativos de algumas práticas e atividades, evidenciadas a partir da repercussão de estressores nos processos ecológicos da biodiversidade, é possível sensibilizá-las, pois; a degradação e mudança de fase dos recifes de coral representa um escasseamento dos recursos que promovem a geração de alimentos, trabalho, e de rendimentos econômicos.

A inclusão dos pescadores e dos diferentes setores da sociedade na busca por soluções práticas e inovadoras para mitigar os estressores nos recifes de coral para o desenvolvimento sustentado das pescarias e das atividades turísticas, é uma abordagem que pode promover o senso de pertencimento das pessoas pelo Oceano. Onde a ampliação de informações científicas e a disseminação das ameaças globais que estão ocorrendo localmente para a sociedade, tem potencial de promover sua sensibilização e para a importância da vida marinha.

A necessidade de implementar ações práticas para o planejamento espacial costeiro-marinho, conservação, manejo dos recifes de coral e dos peixes, representam avanços, e oportunidades necessárias para gestão e governança desses recursos naturais, visando atingir os Objetivos para o Desenvolvimento Sustentável na Década das Ciências e do Oceano e para o futuro das próximas gerações.

# APÊNDICES

UNIVERSIDADE FEDERAL DE ALAGOAS

UNIVERSIDADE FEDERAL DE ALAGOAS
INSTITUTO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE - ICBS
**Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos – PPGDIBICT**

DIBICT UFAL

**Responsável pela pesquisa: MSc. Cacilda M. C. Rocha Cela**
**Orientador da pesquisa: Prof. Dr. Cláudio L. S. Sampaio**

## QUESTIONÁRIO DE PESQUISA

**Número do Certificado de Apresentação de Apreciação Ética:**

**40184420.0.0000.5013**

<table>
<tr><td colspan="2">Idade:</td><td>Sexo: ( ) F ( ) M</td></tr>
<tr><td colspan="3">Educação:</td></tr>
<tr><td colspan="3">( ) < 8 Pouca inexperiência ( ) Início de carreira 8-15 ( ) Intermediário 16-30 ( ) Experiente >30</td></tr>
<tr><td>( ) Pesca profissional<br>Petrechos:</td><td>( ) Pesca Amadora/ Esportiva<br>Petrechos:</td><td>Pesca Subaquática<br>( ) Free diving<br>( ) SCUBA<br>( ) compressor</td></tr>
</table>

## PERGUNTAS

### Pesca (alimento, trabalho e renda)

1. A pesca é importante para você? ( ) SIM ( ) NÃO. Por quê? ( ) Não desejo responder
2. A pesca é a sua principal fonte de renda? SIM ( ) Se sim, quantas pessoas se sustentam com a sua pesca? NÃO ( ) Não desejo responder
3. Você exerce outras atividades além da pesca? SIM ( ) Quais? ( ) NÃO ( ) Não desejo responder

4. Quantos Kg no total você conseguia tirar em média a cada pescaria no início da sua carreira? (   ) E agora (   ) Não desejo responder ( )

5. Quanto você ganha em média por mês com a pesca? ( ) Não desejo responder

6. Quanto custava o kg do peixe budião azul (  ) banana ( ) batata ( ) bandeira ( ) sinaleiro ( ) dentuço ( )

baúna ( ) ariocó (  ) dentão (  ) caranha (  ) cioba (  ) badejo ( ) mero ( ) quando você começou a pescar? Não desejo responder

7. E agora quanto custa o kg do peixe budião azul ( ) banana ( ) batata ( ) bandeira ( ) sinaleiro ( ) dentuço ( ) baúna ( ) ariocó (  ) dentão (  ) caranha (  ) cioba (  ) badejo ( ) mero ( ) quando você começou a pescar? Não desejo responder

8. Qual arte de pesca/petrecho que você utilizava no início da sua carreira? ( ) Não desejo responder

9. Qual usa agora? ( ) Não desejo responder

10. Você utiliza algum equipamento especial para pescar? ( ) Não desejo responder

11. Você ainda pesca nos mesmos lugares de antigamente? ( ) Não desejo responder

12. Qual a distância (em média) que você percorria para pescar antigamente? E hoje? ( ) Não desejo responder

13. Você pesca sozinho ou acompanhado? Se for acompanhado quantas pessoas pescam contigo? ( ) Não desejo responder

14. Se você pudesse indicar uma área para ser protegida da pesca, qual seria essa área? Por quê? ( ) Não desejo responder

15. A pesca é produtiva na sua região? ( ) SIM ( ) NÃO ( ) Não desejo responder

16. Qual medida você considera importante para melhorar a produtividade da pesca na sua região? ( ) Não desejo responder

17. Você sabe o que é uma APA? ( ) SIM ( ) NÃO ( ) Não desejo responder

18. Se a pesca fosse proibida na sua localidade o que você faria? ( ) Não desejo responder

**Pescarias (Síndrome de Deslocamento de Referencial)**

19.Nas áreas que você pesca hoje tem ( ) menos, ( ) mais ou a ( ) mesma quantidade de peixe budião/garoupa/vermelho que antigamente (tempo de experiência) ( ) Não desejo responder

20. Qual peixe budião/garoupa/vermelho é o mais comum de pescar hoje? ( ) Não desejo responder

21. Qual peixe budião/garoupa/vermelho que era comum de pescar antigamente e hoje é raro? ( ) Não desejo responder

22. Qual peixe budião/garoupa/vermelho tem a pesca proibida hoje? ( ) Não desejo responder

23. Qual o tamanho médio do peixe budião/garoupa/vermelho que é pescado atualmente (kg)? ( ) Não desejo responder

24. Qual o tamanho médio do maior peixe budião/garoupa/vermelho que já foi pescado por você (kg)? ( ) Não desejo responder

25. Onde e quando esse maior peixe budião/garoupa/vermelho foi pescado? ( ) Não desejo responder

26.Quando e onde ocorreu a melhor pescaria de budião/garoupa/vermelho já realizada por você (localização)? ( ) Não desejo responder

**Ecossistemas recifais (Percepção de mudanças ocorridas)**

27. Você acha que mudou alguma coisa nos locais que você pesca? ( ) Não desejo responder

28. Se sim, o que aconteceu? ( ) Não desejo responder

29. Foi desde quando que começaram a ocorrer essas mudanças? ( ) Não desejo responder

30. Você sabe o que é um recife de coral? ( ) SIM ( ) NÃO ( ) Não desejo responder

31. Como era essa paisagem nos recifes que você conhece? ( ) Não desejo responder

32. Qual o principal problema acha que o ser humano faz nos recifes? ( ) Não desejo responder

33. E nas águas dos recifes. Você consegue perceber se ocorreu alguma mudança? ( ) Não desejo responder

34. Se você pudesse propor alguma solução para esses problemas que você percebeu qual seria? ( ) Não desejo responder

## TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO-TCLE

Eu, (nome nacionalidade, idade, estado civil, profissão, endereço, RG), estou sendo convidado a participar de um estudo denominado: Peixes Recifais Herbívoros: Pesca & Conservação, cujo objetivo: Investigar como o Conhecimento Ecológico Local pode ser acessado para informar a conservação da biodiversidade marinha sobre a Síndrome de Deslocamento de Referencial (SDR) sobre a pesca de peixes recifais herbívoros, justificando a utilização do Conhecimento Ecológico Local como ferramenta para a tomada de decisões sobre o Co-Manejo de espécies-chave em áreas marinhas protegidas. A minha participação no referido estudo será no sentido de responder algumas perguntas através de um questionário.

Fui alertado de que, da pesquisa a se realizar, posso esperar alguns benefícios diretos esperados estão: os de disseminar meus conhecimentos obtidos divulgando seus resultados nas comunidades, também poderão ser acessados pelos gestores das Áreas Protegidas onde a pesquisa ocorrerá, bem como para o conhecimento de toda a sociedade civil. As estratégias para alcançar esses benefícios serão principalmente através de palestras nas comunidades, reuniões com os conselhos gestores das APAs, elaboração de comunicados para divulgação em mídias sociais online (Instagram e Facebook) e por meio de publicações científicas.

Recebi, por outro lado, os esclarecimentos que os resultados positivos ou negativos somente serão obtidos após a sua realização. Assim, tornar públicas as práticas, artes de pesca, tipo de peixes que pesco nos ecossistemas recifais e oceano podem nos ajudar a pensar no oceano que queremos no futuro.

Estou ciente de que minha privacidade será respeitada, ou seja, meu nome ou qualquer outro dado ou elemento que possa, de qualquer forma, me identificar, será mantido em sigilo. Também fui informado de que posso me recusar a participar do estudo, ou retirar meu consentimento a qualquer momento, sem precisar justificar, e de, por desejar sair da pesquisa, não sofrerei qualquer prejuízo. Foi-me esclarecido, igualmente, que eu posso optar por métodos alternativos, que seria a filmagem e gravação da pesquisa.

Os pesquisadores envolvidos no referido projeto são Cacilda Michele Cardoso Rocha Cela e Cláudio Luis Santos Sampaio, da Universidade Federal de Alagoas como estudante e orientador. Com eles poderei manter contato pelos telefones (75) 99933-04750 e (82) 3551-2784.

Enfim, tendo sido orientado quanto ao teor de todo o aqui mencionado e compreendido a natureza e o objetivo do já referido estudo, manifesto meu Livre Consentimento Livre e Esclarecido em participar, estando totalmente ciente de que não há nenhum valor econômico, a receber ou a pagar, por minha participação. De igual maneira, caso ocorra algum dano decorrente da minha participação no estudo, serei devidamente indenizado, conforme determina a lei.

Qualquer dúvida ou problema deve entrar em contato com a Universidade Federal de Alagoas (82) 3551 2784.

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Nome e assinatura do sujeito da pesquisa

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Nome(s) e assinatura(s) do(s) pesquisador (es) responsável(responsáveis)

UNIVERSIDADE FEDERAL DE ALAGOAS

INSTITUTO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE - ICBS

**Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos – PPGDIBICT**

## CATÁLOGO DE FOTOS DE ESPÉCIES DE PEIXES RECIFAIS

## SCARIDAE


## ACANTHURIDAE

## SERRANIDAE




**LUTJANIDAE**


## GÊNEROS E ESPÉCIES DE PEIXES RECIFAIS IDENTIFICADAS NAS PESCARIAS DESTE ESTUDO

| **Família** | **Gênero e espécie** | **Grupo trófico** | **Itens alimentares** |
|---|---|---|---|
| Acanthuridae | *Acanthurus bahianus* | Herbivores | Benthic algae, weeds |
| Acanthuridae | *Acanthurus chirurgus* | Herbivores | Benthic algae, weeds |
| Acanthuridae | *Acanthurus coeruleus* | Herbivores | Benthic algae, weeds |
| Ariidae | *Genidens* sp. | Carnivores | Mobile invertebrate feeders |
| Carangidae | *Caranx* sp. | Carnivores | Mobile invertebrates |
| Carangidae | *Caranx hippos* | Carnivores | Bony fishes, mobile invertebrates |
| Carangidae | *Selene vomer* | Carnivore | Bony fish, mobile invertebrates |
| Carangidae | *Trachinotus* sp. | Piscivores | Bony fish, mobile invertebrates |
| Carcharhinidae | *Carcharhinus leucas* | Piscivores | Bony fishes, piscivore |
| Centropomidae | *Centropomus undecimalis* | Carnivores | Bony fish, mobile invertebrates |
| Coryphaenidae | *Coryphaena hippurus* | Piscivores | Bony fish, piscivore |
| Gerreidae | *Diapterus* sp. | Carnivore | Copepods, ostracods, polychaets |
| Ginglymostomatidae | *Ginglymostoma cirratum* | Carnivore | Bony fishes,rays, mobile invertebrates |
| Lutjanidae | *Lutjanus alexandrei* | Carnivores | Bony fishes, mobile invertebrates |
| Lutjanidae | *Lutjanus analis* | Carnivores | Bony fishes, mobile invertebrates |
| Lutjanidae | *Lutjanus cyanopterus* | Piscivores | Bony fishes |
| Lutjanidae | *Lutjanus jocu* | Carnivores | Bony fishes, mobile invertebrates |
| Lutjanidae | *Lutjanus synagris* | Carnivores | Bony fishes, crabs, annelids |
| Lutjanidae | *Ocyurus chrysurus* | Carnivores | Bony fishes, zoobenthos |
| Muraenidae | *Gymnothorax* sp. | Piscivores | Bony fishes, piscivore |
| Mugilidae | *Mugil* sp. | Carnivores | Mobile invertebrates |
| Myliobatidae | *Aetobatus narinari* | Carnivores | Mobile invertebrates |
| Myliobatidae | *Mobula birostris* | Carnivores | Bony fishes, mobile invertebrates |
| Rachycentridae | *Rachycentron canadum* | Piscivores | Bony fishes |
| Scaridae | *Scarus trispinosus* | Herbivores | Benthic algae,weeds |
| Scaridae | *Scarus zelindae* | Herbivores | Benthic algae,weeds |
| Scaridae | *Sparisoma amplum* | Herbivores | Benthic algae,weeds |
| Scaridae | *Sparisoma axillare* | Herbivores | Benthic algae,weeds |
| Scaridae | *Sparisoma frondosum* | Herbivores | Benthic algae,weeds |
| Scombridae | *Acanthocybium solandri* | Piscivores | Bony fishes |
| Scombridae | *Scomberomorus* sp. | Piscivore | Bony fishes |
| Serranidae | *Epinephelus adscensionis* | Carnivores | Bony fishes, mobile invertebrates |
| Serranidae | *Epinephelus itajara* | Carnivores | Bony fishes, mobile invertebrate |

| | | | |
|---|---|---|---|
| Serranidae | *Epinephelus morio* | Carnivores | Bony fishes, mobile invertebrate |
| Serranidae | *Mycteroperca bonaci* | Piscivores | Bony fishes |
| Sparidae | *Calamus penna* | Carnivores | Benthic invertebrates, mobile invertebrate feeders |
| Sphyraenidae | *Sphyraena barracuda* | Piscivores | Bony fishes |
| Sphyrnidae | *Sphyrna* sp. | Piscivores | Bony fishes |

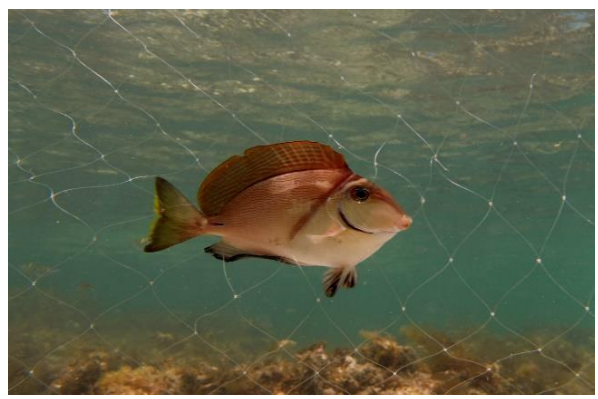
**MÚLTIPLOS ESTRESSORES ANTRÓPICOS NOS RECIFES DE CORAL**

**Pescarias de peixes recifais juvenis de grupos tróficos carnívoros, piscívoros e herbívoros (Todas as fotos abaixo foram cedidas pelo Prof. Dr. Claúdio Sampaio)**

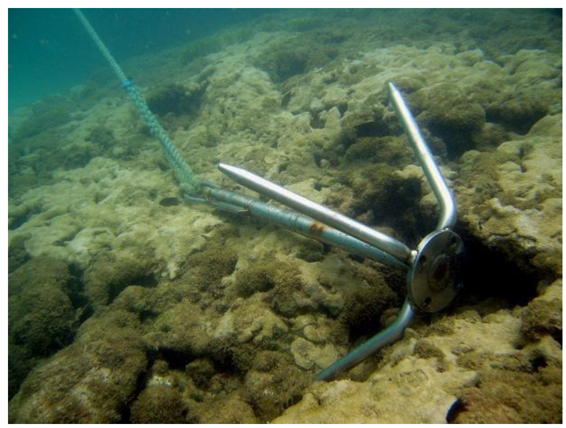
**Poluição e contaminação**





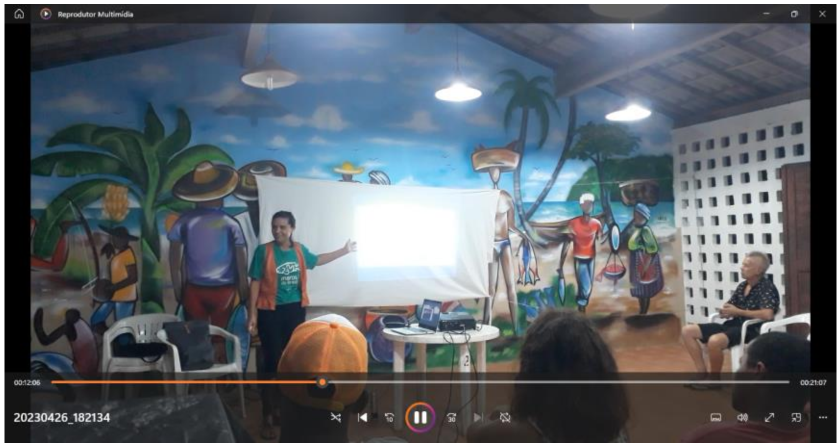



## Degradação de habitats recifais

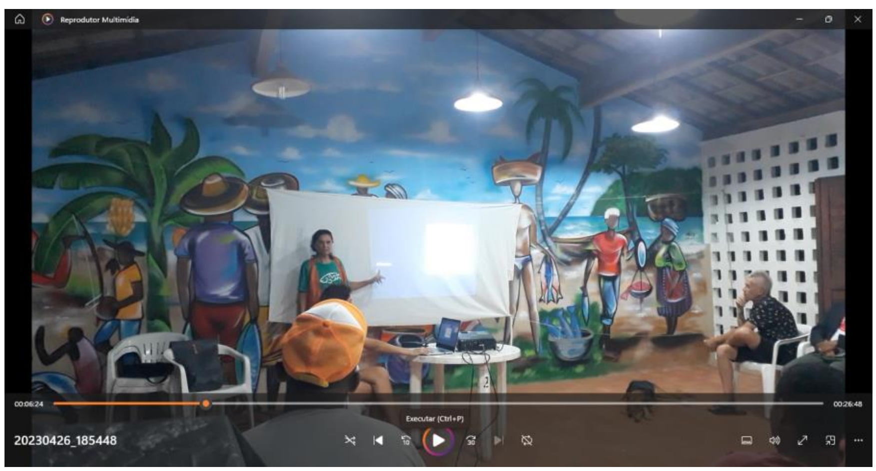


## REGISTROS DA APRESENTAÇÃO DA TESE NAS COMUNIDADES DE MORERÉ E VELHA BOIPEBA

### Momento da devolutiva da pesquisa nas comunidades que participaram da pesquisa do Capítulo-II




**Centro Comunitário de Moreré**




**Centro Comunitário de Moreré**

**Associação de Pescadores da Velha Boipeba**

**Associação de Pescadores da Velha Boipeba**