UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO DE CIÊNCIAS BIOLÓGICAS
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

Bruna Santos da Silva

MUDANÇAS NA PESCA ARTESANAL COM OS BOTOS E O PAPEL DAS INTERAÇÕES COOPERATIVAS ENTRE OS PESCADORES

Florianópolis
2021

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Dissertação submetida ao Programa de Pós-Graduação em Ecologia da Universidade Federal de Santa Catarina para a obtenção do título de Mestre em Ecologia.
Orientador: Prof. Dr. Maurício Cantor
Coorientadora: Prof. Dra. Natalia Hanazaki

Florianópolis
2021

Ficha de identificação da obra elaborada pelo autor, através do Programa de Geração Automática da Biblioteca Universitária da UFSC.

Silva, Bruna Santos da
Mudanças na pesca artesanal com os botos e o papel das interações cooperativas entre os pescadores / Bruna Santosda Silva ; orientador, Maurício Cantor, coorientadora, Natalia Hanazaki, 2021.
100 p.

Dissertação (mestrado) - Universidade Federal de SantaCatarina, Centro de Ciências Biológicas, Programa de Pós Graduação em Ecologia, Florianópolis, 2021.

Inclui referências.

1. Ecologia. 2. Ecologia comportamental. 3. Etnoecologia. 4. Sistemas sócio-ecológicos. I. Cantor, Maurício. II. Hanazaki, Natalia. III. Universidade Federalde Santa Catarina. Programa de Pós-Graduação em Ecologia.
IV. Título.

Bruna Santos da Silva

Mudanças na pesca artesanal com os botos e o papel das interações cooperativas entre os Pescadores

O presente trabalho em nível de mestrado foi avaliado e aprovado por banca examinadora composta pelos seguintes membros:

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Prof. Dr. Maurício Cantor
Orientador

Florianópolis, 2021

“Aventura é encarar o desconhecido”

Autor desconhecido

AGRADECIMENTOS

Fazer ciência no Brasil não é fácil, mas ao mesmo tempo que desenvolvemos habilidades, conhecemos pessoas incríveis que tornam o "fazer ciência" algo mais leve e prazeroso. Porém, esse trabalho não seria possível sem a minha própria rede social. Tod@s que passaram pela minha jornada durante o mestrado desempenharam um papel muito importante no meu desenvolvimento como pesquisadora e como pessoa. Tenho um IMENSO agradecimento por cada ser que trouxe algum pedacinho seu para este trabalho.

Primeiramente, quero agradecer aos meus pais, Tânia e Paulo, que com muita humildade e apoio me ajudaram a chegar até aqui. Agradeço por terem me criado próxima à Natureza, onde as curiosidades por ela me fizeram traçar esse caminho. Agradeço ao meu irmão Paulo Henrique por todo apoio e incentivo. E é claro, a todos os integrantes da minha família! Não citarei nomes pois são mais de 25 pessoas entre avós, tios, tias, primos e primas. Vocês não só me aceitaram como sou, mas sempre me apoiaram em todas as escolhas. Até mesmo assistindo a SAPECO no youtube. Vocês são o verdadeiro significado de família, onde o amor, respeito, diferenças e união são sinônimos! Sabotage já dizia: um bom lugar se constrói com humildade, é bom lembrar...

Ao Gui, por me fazer ver e sentir o equilíbrio da natureza. Sou muito grata por todo amor, apoio, incentivo e companheirismo em todas as etapas deste processo (e em vários outros). Nunca esquecerei do dia que conhecemos a comunidade de pescadores *Ponta das Pedras* e ficamos horas conversando sobre os pescadores que conhecemos e suas vivências, foi um dia que eu senti que estava no caminho certo. Obrigada por ser meu numberone, em tudo!

Aos pescadores artesanais, pois sem eles, este trabalho não existiria. Obrigada por terem compartilhado seus conhecimentos, suas vivências e suas histórias, as quais me trouxeram curiosidades e motivações para continuar nesta caminhada. Ao Safico e ao Erea que sempre estiveram disponíveis para sanar minhas dúvidas e ajudar quando necessário. Ao Tito, que me motivou com sua história e me fez crer que precisamos continuar mesmo quando a maré não estiver boa.

Ao meu orientador Maurício Cantor, por ter me dado atenção lá em 2017 e ter me ajudado a chegar até aqui. Com suas orientações, apoio e incentivo, desenvolvi habilidades que jamais imaginei que conseguiria. Serei eternamente grata a você por ser quem abriu as portas do mundo científico para mim!

À minha coorientadora Natalia Hanazaki, por ter me aceitado primeiramente como orientanda e ter aberto as portas do ECOHE para mim. Muito obrigada por todo apoio, orientação e feedback, você me apresentou o lado humano da ciência e serei eternamente grata por isso!

Às minhas amigas Aline e Júlia que estiveram comigo em diversos momentos desta etapa. As conversas, risadas, apoios, conselhos e o amor que ocorre entre nós, principalmente em tempos pandêmicos, deixaram este processo mais leve. Sou muito grata pela nossa amizade e tenho certeza que vai ser para vida toda!

Às minhas amigas Bárbara e a Joana que dividiram um lugar tão especial comigo durante o primeiro ano de mestrado! Muito obrigada, gurias, por terem transformado aquele apartamento em um lugar tão bom de estar e de trabalhar!

Aos outros amigos e amigas que de alguma forma estiveram presentes neste trabalho, seja com conselhos, força, apoio e ideias, principalmente em tempos pandêmicos. Vocês sabem quem são! Muito obrigada!

Ao pessoal do ECOHE que fizeram eu me sentir parte de uma segunda família! Todas as reuniões e conversas me deram mais motivação e força para chegar até aqui. União e acolhimento são exemplos do que esse laboratório representa!

Ao pessoal do LAMAQ por todo auxílio e apoio nos dias de campo. Em especial ao Prof. Fábio e ao Ale que trouxeram muitas contribuições para este trabalho!

Aos colegas do programa por todas as trocas e aprendizados, em especial, a Liliam e a Thayusky que trabalharam comigo no livro de ecologia de campo, foi um processo muito mais leve com vocês. Ao Luiz por toda ajuda nas análises e também aprendizados no seu curso, descomplicando o R.

Ao pessoal da Comissão de Divulgação e Extensão: Natalia, Nivaldo, Michele, Lari e Dani. Agradeço por esta comissão ter sido um espaço de acolhimento e criatividade, foi muito bom fazer parte da equipe e desejo vida longa a divulgação científica do programa!

Aos membros da banca examinadora, por contribuírem suas perspectivas e comentários, os quais enriqueceram este trabalho.

E por fim, as instituições financiadoras que possibilitaram a execução deste trabalho: Animal Behaviour Society, National Geographic Society, Max Planck Society e a CAPES.

"*É uma convivência que vem de muito tempo*
É um lazer, um hobby
E também um vício

Ele ajuda o pescador e é amigo do pescador
É como um pai de família
E também patrimônio da cidade

O boto traz o pescado pra gente
Muitas pessoas vivem deste ambiente
O boto já matou muito a minha fome
E sem ele, o pescador não é nada

A beleza daqui já diz tudo
Mas o Rio Tubarão continua poluído
Por isso devemos preservar
Porque se não, o boto não vem trabalhar

Então isso aqui não pode ser perdido
Porque também é bom para o turismo
Amanhã vai ter pescadores jovens que seguirão
Mantendo a tradição"

Recorte de falas dos pescadores artesanais de Laguna entrevistados entre 2004-2020

RESUMO

Sistemas socioecológicos, como aqueles que envolvem a pesca artesanal, são sistemas adaptativos e complexos, onde natureza e cultura estão intimamente ligadas. As interações entre variáveis sociais e ecológicas em um sistema de pesca possuem um papel importante na formação de laços sociais entre os pescadores. Ao longo dos anos, alterações socioeconômicas, ambientais e culturais podem provocar mudanças em um sistema pesqueiro, incluindo mudanças no mecanismo de aprendizagem e no processo de transmissão dos conhecimentos técnicos e ecológicos da comunidade pesqueira. Essas mudanças podem influenciar no relacionamento social entre os pescadores, enquanto a transmissão do conhecimento depende das relações sociais entre pescadores, as características dos mesmos podem definir e estruturar tais relações sociais. No caso de pescadores artesanais, estabelecer relações sociais com outros pescadores pode resultar em pesca cooperativa – no qual pescadores pescam juntos e dividem os resultados (dinheiro ou peixe), que pode ser mais eficiente e menos custosa. No entanto, nem todos pescadores podem ver vantagem na pesca cooperativa, preferindo pescar sozinhos e manter todos os recursos da captura, ainda que tenham que competir por recursos. Em Laguna, Santa Catarina, existe um sistema socioecológico de pesca artesanal que envolve pescadores artesanais e alguns indivíduos da população residente de botos-da-tainha (*Tursiops truncatus gephyreus*). Alguns pescadores artesanais aprenderam a interpretar o comportamento de forrageio de botos-da-tainha para aumentar sua eficiência de pesca. Quando botos conduzem cardumes em direção à costa, esses pescadores conseguem identificar, através de movimentos estereotipados dos botos, o momento apropriado para o lançamento das tarrafas. Essa pesca acontece em diversos pontos do complexo lagunar, porém, nem todos pescadores pescam em todos os pontos. O principal ponto de pesca é a Tesoura, um local com fácil acesso em que vários pescadores de Laguna e outras cidades (turistas) interagem com os botos. Já outros pontos de pesca mais internos da lagoa são locais menos acessíveis, mas comumente utilizados por pescadores artesanais nativos de Laguna. No primeiro capítulo da dissertação, analiso mudanças nas características do sistema de pesca com o boto, com ênfase nos últimos 16 anos, usando um modelo conceitual para compreender sistemas socioecológicos. Para isso, categorizei algumas variáveis do sistema de pesca com o boto através de um banco de dados de entrevistas realizadas em quatro campanhas, entre 2004 e 2020, em diferentes pontos de pesca do

complexo lagunar. A transmissão do conhecimento sobre o sistema e os atributos socioeconômicos dos pescadores estão associados à localização do ponto de pesca. Porém, mesmo que a dependência econômica da pesca artesanal tenha diminuído entre os pescadores ao longo dos anos, o uso histórico do sistema se mantém devido ao aumento da aprendizagem social. Isto pode estar relacionado com a importância cultural e também social que essa pesca com os botos possui para os pescadores artesanais locais, amadores e oportunistas de Laguna e de toda a região. No segundo capítulo, descrevo a estrutura social dos pescadores artesanais no contexto de forrageio com os botos na Tesoura, e analiso o quanto essa estrutura social pode ser explicada por características individuais dos pescadores. Observei que a rede social dos pescadores que interagem com os botos é estruturada por duas táticas de forrageio na interação com os botos: pescar em grupos cooperativos ou pescar sozinhos. Dentre as diversas características analisadas (idade, reputação, parentesco, dependência econômica, experiência na pesca com o boto, frequência de pesca, número de amigos e a percepção individual dos benefícios), a reputação do pescador e a percepção do benefício em formar grupos durante o forrageio desempenharam papel pequeno, mas relevante, na decisão dos pescadores artesanais em cooperar com outros pescadores. Embora a formação de grupos cooperativos possa ser benéfica em termos de benefícios materiais (pescadores cooperativos tendem a pescar mais peixes *per capita* do que pescadores solitários), também discutimos como outros benefícios não materiais, como o senso de pertencimento e prestígio social, contribuem para a formação e manutenção desses grupos. Em face das mudanças ambientais nos sistemas socioecológicos e da redução da disponibilidade de recursos pesqueiros, é possível que tais mudanças possam tornar a persistência desta pescaria tradicional mais dependente de benefícios imateriais. Assim, mesmo que a dependência pelo recurso pesqueiro esteja diminuindo entre os pescadores, a continuidade desta tradição deve se manter devido ao aumento de pescadores que utilizam este sistema socioecológico como um espaço de recreação, socialização e lazer.

Palavras-chave: Sistemas socioecológicos, pescadores artesanais, características individuais, cooperação

ABSTRACT

Socioecological systems such as artisanal fishing are adaptive and complex systems, where nature and culture are intimately linked. The interactions between social and ecological variables in a fishery system play an important role in the formation of social bonds among fishers. Over the years, socioeconomic, environmental, and cultural changes can alter a fishery system, including the learning mechanism of fishers, the transmission of technical and ecological knowledge within the fishing community. These changes can ultimately influence the social relationships among fishers because while the transmission of knowledge depends on social relationships between individuals, their characteristics can define and structure such social relationships. In the case of artisanal fishers, establishing social relationships with other fishers lead to cooperative fishing—whereby groups of individuals fish together and share their catch—which can be more efficient and less costly for the individuals. However, not all fishers perceive benefits in cooperative fishing and prefer to fish alone and keep all their catch, even if they compete for fishing resources. In Laguna, Santa Catarina, there is a socioecological system of artisanal fishing that involves artisanal fishers and some individuals of bottlenose dolphins (*Tursiops truncatus gephyreus*). Some artisanal fishers have learned to interpret the foraging behavior of dolphins to increase their fishing efficiency. When dolphins approach the coast, these fishers can identify, through stereotyped movements of the dolphins, the appropriate time for casting nets. This fishing takes place in several sites along the lagoon, however, not all fishers use all sites. The main fishing site is the *Tesoura*, a beach with easy access where several fishers from Laguna and other cities (locally called 'tourists') interact with the dolphins. On the other hand, other fishing sites inside the lagoon are less accessible and commonly used by native fishers of Laguna. In the first chapter of the dissertation, I analyze changes and permanence in the characteristics of this traditional fishery system between net-casting fishers and dolphins, emphasizing the last 16 years, based on a conceptual model of socioecological systems. I characterized the fishing system using a database of semi-structured interviews carried out with the fishers during four campaigns, between 2004 and 2020, in different fishing sites of the lagoon, and focused on the changes and permanence of the users of this fishing system. I found that the socioeconomic attributes of the fishers, and the mode of transmission of knowledge about the system, are associated with the location of the fishing site. However, even though the economic dependence on

artisanal fishing has decreased among fishermen over the years, the historical use of the system remains due to the increase in social learning. These findings highlight the cultural and social importance that the traditional fishery with dolphins has for the local, amateur and opportunistic fishers in Laguna and the vicinities. In the second chapter, I investigate the social relationships among artisanal fishers in the context of foraging with the dolphins at *Tesoura* and analyze whether this social structure is influenced by the individual characteristics of fishers. I found that the social network of fishers is structured by two foraging tactics during the interaction with the dolphins: fishing in cooperative groups or fishing alone. Among the various individual traits analyzed (age, reputation, kinship, economic dependence, experience in fishing with dolphins, fishing frequency, number of friends, and perception of cooperation benefits), the fisher's reputation and the perception of the benefit of forming groups during foraging played a small but relevant role in the decision of artisanal fishers to cooperate with other fishers. While forming cooperative groups can be beneficial in terms of material benefits (cooperative fishers tend to catch more fish per capita than solitary fishers), we also discuss how other non-material benefits, such as a sense of belonging and social prestige, contribute to the formation and maintenance of these groups. Given the environmental changes in socioecological systems and the reduction in the availability of fisheries resources, it is possible that such environmental changes could make the persistence of this traditional fishery among fishers more dependent on non-material benefits they may accrue during social relationships with other fishers. Thus, even though the dependence on fishing resources is decreasing among fishers, this tradition may be maintained due to the increased number of fishers who use this socioecological system as a space for recreation, socialization, and leisure.

Keywords: Socioecological systems, artisanal fishers, individual characteristics, cooperation

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1 INTRODUÇÃO GERAL

Sistemas socioecológicos (ou *socioecological systems*, SES) enfatizam a integração das pessoas como parte da natureza. Este conceito é baseado na noção de que "a delimitação entre os sistemas sociais e naturais é artificial e arbitrária" (BERKES; FOLKE, 1998). Os sistemas sócio-ecológicos, são sistemas caracterizados por fortes conexões e retroalimentação dentro e entre os componentes sociais e ecológicos que determinam sua dinâmica geral (FOLKE et al., 2010;) Os processos sociais incluem componentes políticos, econômicos, culturais e tecnológicos, enquanto os processos ecológicos incluem componentes bióticos (e.g., dinâmica de populações, interação da cadeia alimentar) e abióticos (e.g., fluxo de nutrientes, padrões climáticos) (BIGGS et al., 2021). A pesca em pequena escala, por exemplo, é conceituada como um sistema socioecológico adaptativo (BERKES, 2006, 2011; GELCICH et al., 2010; PARTELOW, 2015), portanto não-linear e dinâmico (FOLKE, 2006), no qual pequenas mudanças em seus componentes podem levar a efeitos significativos e imprevisíveis no sistema (LEVIN et al. 2013). Em países em desenvolvimento, a pesca está particularmente sujeita a crescentes mudanças nas zonas costeiras, em diferentes escalas e velocidades, em seus processos sociais e ecológicos (BÉNÉ et al., 2016) como em fatores ambientais, climáticos, econômicos, tecnológicos, socioculturais, demográficos e de governança (ZOU; WEI, 2010; BENNETT et al., 2014).

Os SES compreendem muitas partes interdependentes que interagem e dão origem a padrões emergentes em todo o sistema. Desta maneira, esses padrões não podem ser previstos a partir das propriedades dos componentes individuais do sistema (BIGGS et al., 2021). Os SES também se caracterizam pela dificuldade ou alto custo de exclusão de potenciais usuários, e pela subtractabilidade do recurso (ou seja, o uso por um usuário reduz o benefício aos demais usuários; OSTROM, 1990). No contexto da pesca, estoques pesqueiros são considerados recursos de uso comum, e cada pescador subtrai da disponibilidade de peixes para outros pescadores. O modelo conceitual para diagnóstico de SES proposto por Ostrom (2009) reconhece um grande número de variáveis sociais e ecológicas relacionadas ao desempenho de governança de recursos comuns de um sistema. Essa estrutura é composta por quatro variáveis de primeiro nível—sistema de recursos, unidades de recursos, sistema de governança e usuários—as quais afetam e são afetadas pelas configurações sociais, econômicas e políticas, e pelos ecossistemas em que estão inseridos (Fig. 1). Cada uma das

quatro variáveis possui variáveis de segundo nível, com diferentes escalas e outros sub-níveis, que interagem e se retroalimentam (Fig. 1).

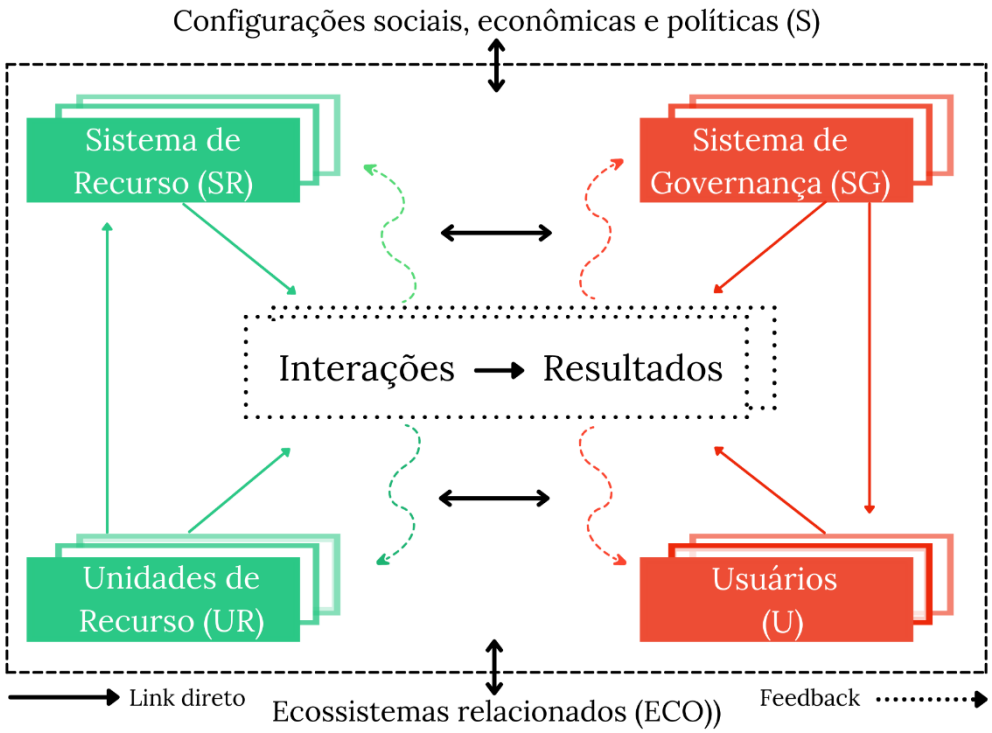

Fig. 1. Quadro de diagnóstico para sistemas socioecológicos com variáveis de primeiro nível, incluindo interações e resultados. Variáveis de segundo nível e variáveis de níveis subsequentes se enquadram em grupos de primeiro nível e podem ser expandidas ainda mais para contextualizar um SES específico. Adaptado de Ostrom (2009; 2011).

No caso dos pescadores de pequena escala, estudos conceituais utilizando a estrutura de diagnóstico do SES trouxeram refinamentos do conhecimentos sobre gestão e sustentabilidade na pesca (BASURTO; OSTROM, 2009; BASURTO; NENADOVIC, 2012; BASURTO et al., 2013; CINNER et al., 2013). A estrutura de diagnóstico dos SES pode ser usada de diferentes maneiras e propósitos, relacionados à avaliação e compreensão das práticas de gestão de um determinado momento ou para avaliar mudanças nos SES ao longo do tempo (PARTELOW; BODA, 2015). Evidências históricas e séries temporais de dados qualitativos permitem explorar como a estrutura de um SES de pesca pode ser analisada através da complexidade nas mudanças políticas e como isso se relaciona à ação coletiva em diferentes períodos (MCGINNIS; OSTROM, 2014).

A percepção das pessoas que vivem em um determinado ambiente e identificação dos elementos-chave para a comunidade são fatores que podem melhorar a gestão baseada no ecossistema e nos esforços adaptativos frente a diferentes perturbações (RUCKELSHAUS et al., 2008). Os pescadores, por exemplo, são detentores de um rico conhecimento sobre os sistemas marinhos com base nas interações de longo prazo com seus ambientes, físico e social (BERKES et al., 2000; LOPES, 2004; MOLLER, 2004). Parte deste conhecimento é construído a partir de experiências pessoais (aprendizado individual); outra parte é construída a partir das relações sociais com outros membros da comunidade (aprendizado social) (RAMIRES et al., 2007; PETERSON et al., 2008; ZAPPES et al., 2010). Tais conhecimentos possuem importância crucial na gestão de recursos de uso comum, uma vez que envolvem especificidades locais que podem refletir a situação dos ambientes a serem geridos eficiente e dignamente (BERKES et al., 1995). O conhecimento acumulado é uma importante fonte de informação sobre mudanças históricas nos recursos marinhos e nas mudanças sociais das condições socioecológicas marinhas (JOHANNES et al. 2000). A perda deste conhecimento pode resultar em menor capacidade de lidar com as alterações ambientais, e estar relacionada a uma mudança na percepção sobre os recursos naturais ('*shifting baselines*': HANAZAKI et al., 2013; MAIA et al., 2018; PAULY, 2019*)*. A forma e velocidade de transmissão de tal conhecimento ecológico tradicional (CET) responde a mudanças nas condições sociais e ambientais de um determinado sistema e, desta forma, pode ser considerado como um conhecimento adaptativo (GÓMEZ-BAGGETHUN et al., 2012; GÓMEZ-BAGGETHUN et al., 2013; REYES-GARCÍA, 2014). Essa capacidade adaptativa de um sistema socioecológico requer observação e entendimento dos processos do sistema, que são adquiridos pelos seus usuários através da experiência direta e também da memória (BERKES, 2009).

Em teoria, aprendizagem sobre um determinado ambiente e a importância deste conhecimento para o comportamento dos indivíduos podem afetar a estrutura e conectividade das relações sociais de uma população (e.g. KULAHCI; QUINN, 2019). Por exemplo, estar conectado socialmente a indivíduos bem-sucedidos proporciona maior oportunidade de observar e aprender com eles (KULAHCI et al., 2018). As relações sociais também podem fortalecer e influenciar o comportamento cooperativo entre membros de uma comunidade. Em um sistema de pesca, cooperar com os outros pescadores pode aumentar o sucesso da captura (BARNES et al., 2016; TURNER et al., 2014) e ganhos monetários (CARPENTER; SEKI, 2011). Como as relações sociais humanas são multifacetadas e moldadas por vários outros

fatores, podem render benefícios indiretos e não-materiais (HRUSCHKA, 2010). No caso de pescadores, os processos de tomada de decisão social durante forrageio são relativamente pouco estudados (FULTON et al., 2011; VAN PUTTEN et al., 2012; ANDREWS et al., 2021). Como as interações sociais desempenham um papel na aquisição de conhecimento ecológico local e técnicas de forrageio eficazes (GALEF; GIRALDEAU, 2001; REYES-GARCÍA et al., 2016), escolher com quais outros indivíduos formar laços sociais e forragear cooperativamente é uma decisão importante. Segundo o princípio da homofilia, indivíduos tendem a formar laços sociais com aqueles que compartilham características semelhantes (MCPHERSON et al., 2001). Características individuais também podem gerar atração social, como a reputação de um indivíduo dentro de uma comunidade. Desta maneira, indivíduos com baixa reputação podem construir relacionamentos de confiança e reciprocidade com indivíduos de alta reputação, gerando implicações no acesso privilegiado aos recursos (LYLE; SMITH, 2014; VON RUEDEN, 2020).

Em Laguna, Santa Catarina, sul do Brasil, há um sistema socioecológico que liga cultura e ambiente intimamente. A pesca artesanal com tarrafas é famosa devido a interação entre duas espécies com objetivo comum: capturar peixes. Pescadores artesanais aprenderam interpretar alguns movimentos de comportamento de forrageio dos botos (*Tursiops truncatus gephyreus*) como o momento apropriado para o lançamento das tarrafas (SIMÕES-LOPES et al., 1998; PETERSON et al., 2008). Os pescadores aguardam enfileirados, cada um ocupando uma vaga, em pé ou em pequenas embarcações às margens do canal lagunar à espera de tais comportamentos estereotipados dos botos, que por sua vez, conduzem cardumes (principalmente de tainha *Mugil* sp.) em direção à costa (SIMÕES-LOPES et al., 1998). Essa pesca acontece em diversos pontos do complexo lagunar, porém, nem todos pescadores pescam em todos os pontos. O principal ponto de pesca é a Tesoura, um local com fácil acesso em que vários pescadores de Laguna e de outras cidades (chamados localmente de "turistas") interagem com os botos. Já outros pontos de pesca mais internos do complexo lagunar são locais menos acessíveis, mas comumente utilizados por pescadores artesanais nativos de Laguna. Como a área de interação é limitada, esses pescadores possuem um sistema de regras informais durante suas atividades de pesca com os botos (PETERSON et al., 2008). Por exemplo, quando um pescador captura pelo menos dois peixes, eles devem deixar a linha para o próximo pescador que espera a sua vez na praia (PETERSON et al., 2008).

O reconhecimento de que os sistemas sociais e ecológicos são inseparáveis e funcionam como sistemas adaptativos complexos consiste em uma abordagem para estudar as interações entre pessoas e natureza (BINDER et al., 2013; PREISER et al., 2018; REYERS et al., 2018). Como o comportamento humano e as identidades individuais e sociais são construídas e coevoluem com o contexto biofísico (DÍAZ et al., 2015; CHAN et al., 2016; SCHILL et al., 2019), é interessante analisar as interações sociais que ocorrem dentro do sistema socioecológico de pesca porque estas podem moldar o comportamento dos pescadores. No ponto de pesca da Tesoura, as interações sociais que ocorrem entre os pescadores podem estar correlacionadas com a decisão de cooperar ou não com outros pescadores (PETERSON et al., 2008). Os pescadores cooperativos compartilham as vagas na linha e seus turnos, bem como os resultados materiais da pesca (peixe ou dinheiro). Por outro lado, os pescadores que pescam sozinhos devem esperar sua vez de entrar na água, mas ficam com toda a captura ou dinheiro para si (PETERSON et al., 2008). Entretanto, entre os pescadores artesanais, a compreensão de quais e o quanto as características individuais influenciam as preferências sociais que afetam as decisões de forrageio ainda é pouco conhecida.

Esta dissertação está dividida em dois capítulos, redigidos na forma de artigos. No primeiro capítulo analiso mudanças nas características do sistema socioecológico de pesca com o boto em Laguna nos últimos 16 anos com foco nos usuários do sistema (pescadores). Para isso, categorizei algumas variáveis deste sistema de pesca mediante um banco de dados de entrevistas realizadas em quatro campanhas pontuais, entre 2004 e 2020, em diferentes pontos de pesca do complexo lagunar. Usando o modelo conceitual de sistemas socioecológicos da Ostrom (2009), analisei o sistema de pesca artesanal com o boto e as mudanças e/ou permanências de suas características. No segundo capítulo, estudei as interações sociais entre os pescadores artesanais que pescam com os botos na Tesoura e avaliei como características individuais e os resultados (captura de peixes) desta interação influenciam no forrageio social. Por fim, nas Considerações Finais, sintetizo os principais resultados encontrados e discuto as principais mudanças e permanências nas características deste sistema ao longo dos anos, e as interações sociais e de forrageio na Tesoura.

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3 CAPÍTULO 1 – CHANGES IN THE CULTURAL TRANSMISSION AND SOCIOECONOMIC ATTRIBUTES OF FISHERS WHO INTERACT WITH DOLPHINS

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To be submitted to *Human Ecology*

ABSTRACT

Socioecological systems, such as artisanal fishing, are adaptive complex systems that undergo various changes within and between the components of the system. Economic, environmental and cultural changes in a socioecological system can also be related to transformations in the cultural transmission among the users of a system. Here, we analyze changes in the characteristics of the traditional fishing system involving artisanal net-casting fishers and wild dolphins in southern Brazil along 16 years, with focus on the fishers as users of this socioecological system. Based on a conceptual model for socioecological systems, we categorized multiple variables of this fishing system using a database of interviews carried out with fishers in four surveys between 2004 and 2020 at different fishing sites. We found that the transmission of the knowledge about this system, as well as the socioeconomic attributes of fishers, are associated with the location of the fishing site. Although the economic dependence on artisanal fishing has decreased among fishers over the years, the historical use of the system remains because fishers have been learning how to interact with dolphins by watching and copying other fishers. Changes in the composition of the fishing community that interacts with the dolphins may have implications for the transmission of this traditional knowledge, and potentially for the persistence of this tradition in years to come.

Keywords: socioecological system, artisanal fishing, dolphins, human-wildlife interaction, small scale fisheries, traditional ecological knowledge

INTRODUCTION

Socioecological systems (SES) emphasize the integration of people as part of nature (Berkes, Folke 1998). SES are cohesive systems characterized by strong connections and feedbacks within and between social (e.g. political, economic, cultural and technological) and ecological (biotic and abiotic) processes (Folke et al. 2010; Biggs et al., 2015; Biggs et al., 2021). Small-scale fisheries are examples of complex socioecological systems (Berkes, 2006,

2011; Gelcich et al., 2010; Partelow, 2015) that change over time (Folke, 2006). In developing countries, fishing resources are subject to growing anthropogenic pressures that affect socioecological systems (Béné et al., 2016). Changes in coastal zones occur at different temporal scales, and include environmental, climatic, economic, technological, sociocultural, demographic, and governance factors (Zou, Wei, 2010; Bennett et al., 2014). The ecosystems that fishing communities experience have been threatened in recent decades by large-scale overfishing (Pauly, Zeller 2016), while the artisanal fishers face marginalization and poverty (Nayak et al. 2014) as they tend to have limited access to markets, health, education, and other social services (Maru et al. 2014). Understanding the various components of these complex systems, as well as the changes within and between the system components, is necessary for designing efficient fishing management strategies.

Economic, environmental and cultural changes in a socioecological system can also be related to how the local ecological knowledge is transmitted. Fishers acquire an in-depth understanding of marine systems through long-term interactions with the environment and with other fishers (Berkes et al. 2000; Lopes, 2004, Moller, 2004). This cumulative knowledge is an important source of information on historical changes in marine resources, as well as a source of social changes in marine socioecological conditions (Johannes et al., 2000). Loss of local knowledge can diminish the fishers' ability to deal with environmental changes, and underpin a baseline shift in the perception of the status of natural resources (Hanazaki et al., 2013; Maia et al., 2018; Pauly, 2019). More than the disappearance of the sociocultural value itself and the declining income for fishers, the loss of traditional ecological knowledge in fisheries also limits the opportunities for scientists to better understand complex coastal ecosystems (Lloret et al., 2016).

Fisheries rely on 'common-pool' natural resources, such as fish stocks, that are subtractable and difficult or costly to manage (Ostrom, 1990). The SES diagnostic framework proposed by Ostrom (2009) recognizes the many social and ecological variables related to the performance of using a common resource of a socioecological system. This framework is composed of four first-layer variables (resource system, resource units, governance system, and users). Each variable has many second-tier variables, which have different scales and levels within the SES and they generate interactions and outcomes of a SES. In the case of small-scale fisheries, conceptual studies using the SES diagnostic framework brought contributions and applicability of the framework for cumulative knowledge and management

of small-scale fisheries (Basurto, Ostrom, 2009; Basurto, Nenadovic, 2012; Basurto et al., 2013; Cinner et al., 2013). The SES diagnostic framework can be used in different ways and purposes related to evaluating and understanding management practices and can be used at a given point in time, or to assess changes in SESs over time (Partelow; Boda, 2015). Historical evidence and qualitative time series of data allow exploring how the structure of a fisheries SES can be analyzed across changes in political narratives and how this relates to collective action in different periods (McGinnis; Ostrom, 2014).

In Brazil, artisanal fishing is an economically and culturally important activity and can include unique socioecological fishing systems, where culture and environment are intimately linked. For instance, in southern Brazil, artisanal net-casting fishers interact with some individuals from the resident population of dolphins, *Tursiops truncates gephyreus* (Simões-Lopes et al., 1998; Peterson et al., 2008; Daura-Jorge et al., 2012). Some artisanal fishers learned how to interpret the foraging behavior of dolphins as the appropriate time for casting the nets (Simões-Lopes et al., 1998; Peterson et al., 2008), thus they wait in line or in small moored canoes on the margins of the lagoon, waiting for dolphins to approach with fish schools (Simões-Lopes et al., 1998). We evaluate the changes and permanence in some characteristics of this traditional fishing over the last 16 years, focusing on the users of the system. Following Ostrom's framework (2009), in this SES, the resource system (RS) is the artisanal fishing with dolphins and the resource units (RU) are the resources involved in this interaction (fish and dolphins). Users of the system (U) are professional fisher (who are registered in n local institutions and rely on artisanal fishing as the main source of income), opportunistic fisher (who use cooperative fishing with dolphins as a complementary economic source of income) and amateur fisher (who use cooperative fishing with dolphins as a leisure activity) (Machado et al., 2019). The governance system (SG) includes characteristics of institutions and factors that shape the rules and governance arrangements in this type of fishing with dolphins.

MATERIAL AND METHODS

Study area and study system

The study area is located in the municipality of Laguna, southern Brazil (28°20’S; 48°50’W; Fig. 1), around the 300km² complex lagoon system comprising the Mirim, Imaruí

and Santo Antônio lagoons, the outfall of the Tubarão River and the channel connecting the lagoons to the sea. Laguna has approximately 47,000 inhabitants (IBGE, 2020). Artisanal fishing occurs in Laguna since the pre-Columbian times (Lacerda, 2003), when it harbored one of the largest coastal populations as testified by the presence of the shell mounds (*sambaquis*; Cadorin, 2013). Artisanal fisheries intensified with the arrival of Azoreans immigrants, many of whom immigrated as farmers and soon started to fish, replacing the consumption of wheat flour for cassava and red meat for fish (Oliveira, 2011). Since then, artisanal fishing has become one of the bases of the local economy and culture. Nowadays, artisanal fishing remains as one of most important economic activities in the channel and lagoons, where fishers use several commercial and traditional gears, including net-casting, angling, manual trawling, and fyke, stake and trammel netting (Iino, 2017). For instance, between 2003 and 2012, the artisanal fisheries in Laguna landed about 850 tons of mullet (*Mugil liza*), representing 10% of the total catch in the state of Santa Catarina (FEPESC, 2003-2012), and between 2017 and 2019, Laguna was the second most productive artisanal fisheries in the state (PMAP-SC).

A distinctive fishery in Laguna is the cooperative fishing between artisanal net-casting fishers and wild dolphins, which currently takes place in nine main sites along the lagoon system (Fig. 1). A report dating back more than 70 years is consistent with the same behavior of fishers and dolphins (Areão, 1949) suggests that this fisheries occurs at least since the beginning of the 20th century. There are almost 4,300 officially registered fishers in Laguna, however, the exact number of fishers who engage in cast-net fishing with dolphins is uncertain. The main fishing site for this activity is the *Tesoura*, an open and easily accessible beach; the other fishing sites are located inside the lagoon (*Areial*, *Iate Club*, *Ponta das Pedras*, *Arrebentão*, *Balsa*, *Toca da Bruxa*, *Areia* and *Rio Tubarão*) (Simões-Lopes et al., 1998; Peterson et al., 2008) (Fig. 1). The fish productivity of the dolphin-fisher system is poorly known, but in 2012 the fisheries at *Tesoura* beach was responsible for *ca.* 13 tons of mullets (Monteiro et al 2014).

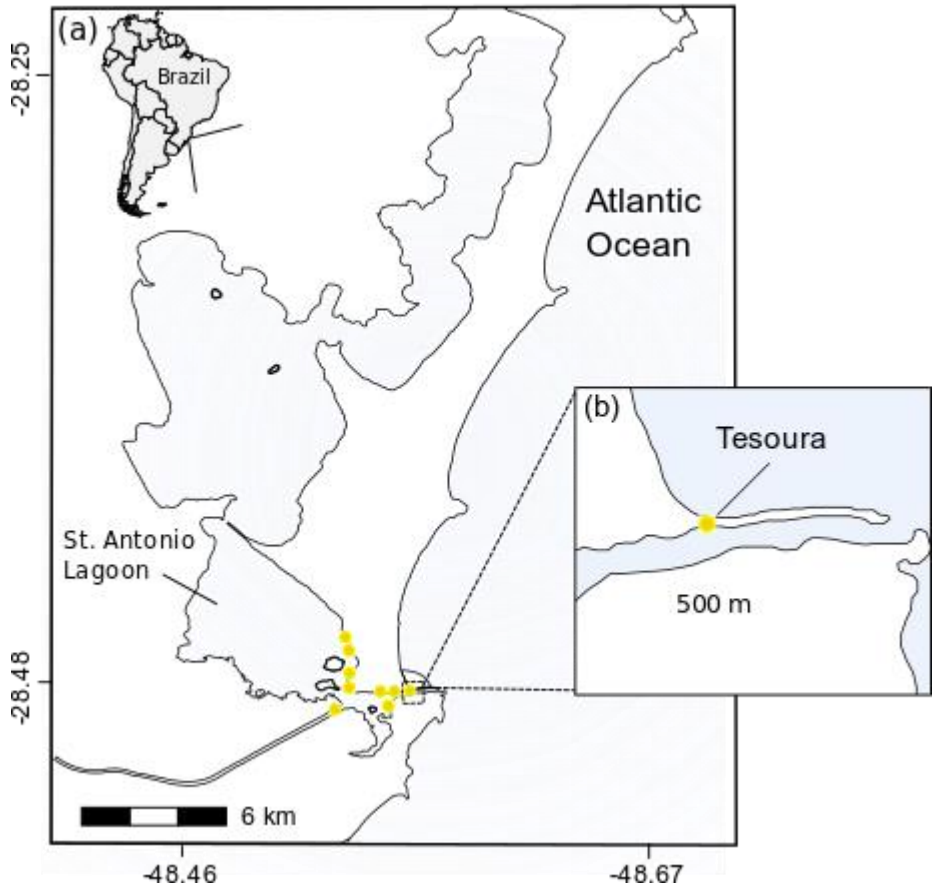

Fig. 1. The study area, Santo Antônio-Imaruí-Mirim lagoon system in Laguna, southern Brazil. (a) The nine yellow points are the main fishing sites where the dolphin-fisher interactions take place. (b) The main interaction site, *Tesoura* beach, where most of the interviews with the artisanal fishers were carried out.

Data collection

Over the past 16 years, four different surveys were carried out to interview the artisanal fishers who interact with dolphins in Laguna (Peterson et al., 2008; da Rosa et al., 2020; Machado et al., 2019; and the present study). Participants were interviewed individually and asked to sign a consent and data release form in all the surveys. The interviews included questions on the fishers' individual traits (age, sex), socioeconomic data (place of residence, experience in fisheries, frequency and economic dependence on fishing with dolphins), and about the fishing dynamics with dolphins. Questions about learning of fishing tactics with dolphins and if the fisher was native to Laguna or not, were common to three of the four surveys.

The first survey was carried out in 2004 and comprised 52 interviews focused on the dynamics of cooperative fishing and on the local institutions (Peterson et al., 2008). The second survey was carried out between 2008 and 2011 and comprised 38 interviews focused on the fishers' ability to recognize the individual dolphins with whom they interact and the factors that may influence such recognition (da Rosa et al., 2020). The third survey was conducted in 2014 and comprised 53 interviews focused on understanding the perceived ecosystem services derived from the cooperative fishing with dolphins (Machado et al., 2019). The fourth survey was carried out between 2019 and 2020 and comprised 80 interviews focused on the cooperation among fishers, fishing dynamics, conflicts and competition among fishers for fishing sites, and future perceptions about this traditional fishery.

The interviews were based on semi-structured questionnaires. The selection of participants was carried out using the technique of snowball and purposive sampling (Bernard, 2006). The snowball technique assumes that the researcher identifies key participants based on a set of criteria (e.g. be an artisanal fisher, practice the fishing with dolphins) and at the end of each interview, the researcher asks for recommendation of other potential fishers with similar background to be interviewed. In the purposive sampling, the researcher chose the fishers to be interviewed intentionally in the fishing sites.

We also considered open-ended questions applied in some of the surveys to add qualitative and contextual information about the users, the governance system, resource system and resource units (*sensu* Ostrom, 2009). We selected the following six questions: "*Which fishing methods interfere with the dolphin-fisher cooperative fishing?*" and "*Does pollution interfere with the dolphin-fisher cooperative fishing?*" (from the first survey); "*What are the current threats to the dolphins?*" (from the second survey); "*How was fishing with dolphins 15 years ago, and how do you imagine fishing with dolphins 15 years from now?"* and "*Did you use to fish on other fishing sites and why don't you fish there anymore*?" (from the fourth survey).

RESULTS

Users

The 222 interviews carried out between 2004 and 2020 comprise a total of 196 fishers who interact with dolphins. There were 26 fishers who were interviewed more than once: 21 fishers were interviewed in two different surveys and five in three surveys. All interviewed

fishers are male, of ages around 40 and 50 years in all surveys (Table 1). Their frequency of fishing with dolphins varied more widely across surveys (from 51 to 96% of the fishers reporting fishing all year) than their overall experience in fishing with the dolphins (Table 1).

Regarding the economic dependence, only fishers who depended (fully or partially) on artisanal fishing were interviewed in the first survey, disregarding fishers who did not consider their economic gains from fishing as an important source of their income (e.g. those who fish with dolphins only for leisure or recreation). In the other surveys, more than half of the interviewees did not depend economically on artisanal fishing (Table 1). The fishers who do not, or only partially, depend on fishing were either retirees or have another primary occupation (e.g. painters, security guards, policemen). We observed differences in the economic dependence on artisanal fishing between fishers interviewed at *Tesoura* and at other sites. Between 2008-2011, most fishers interviewed at *Tesoura* did not depend economically on fishing (63%), while in *Ponta das Pedras*, 66% of the fishers relied exclusively on artisanal fishing. This difference was also observed in the last survey (2019-2020), where 73% of the fishers interviewed in *Tesoura* did not depend economically on artisanal fishing, while in the other sites of the lagoon 71% of fishers depended on artisanal fishing (full or partial dependence).

As in other small-scale societies, the techniques and knowledge involved in fishing with the dolphins can be transmitted through social learning by watching other fishers interacting with the dolphins and imitating, emulating or copying their behavior. Such types of social learning can happen between parents and their children (vertical transmission), between individuals of the same generation (horizontal transmission); and between unrelated or non-parental individuals of different generations (oblique transmission) (Cavalli-Sforza, Feldman, 1981; Heyes, 1994). We found that the use of these transmission modes have changed across surveys. The incidence of individuals socially learning by imitation doubled between the first and the last survey, while oblique learning appeared to become more frequent recently (Table 1). The transmission mode also differed among fishing sites. During the second survey (2008-2011), nearly half (54%) of the fishers interviewed at *Tesoura* and 75% of fishers at *Ponta das Pedras* reported to have learned the tactic vertically, i.e. from their fathers. In the fourth survey (2019-2020), 51% of fishers interviewed at *Tesoura* reported to have learned the tactic horizontally, by watching the behavior of other fishers and the dolphins, while 28% of fishers reported learning vertically, from their fathers. In the other

fishing sites, 43% of all interviewed fishers reported having learned from their fathers, followed by learning by watching other fishers, both horizontally (30%) and obliquely (27%).

Table 1. Socioeconomic attributes of artisanal net-casting fishers who interact with wild dolphins in southern Brazil: age, frequency of fishing with dolphins, years of experience in fishing with dolphins, economic dependence on artisanal fishing, and how they learned how to fish with dolphins.

	2004-2005	2008-2011	2014	2019-2020
Number of interviewees	51	38	53	80
Age (mean±SD, years)	43.5 ± 14.61	50.7 ± 14.37	51.7 ± 13.52	48.72 ± 14.37
Interviewees who fish with dolphins all year	68%	51%	96%	81%
Experience of fishing with dolphins (mean±SD, years)	26.4 ± 15.54	29.5 ± 15.65	29.8 ± 13.68	31.3 ± 17.60
Total or partial lack of economic dependence on artisanal fishing	Not applicable	53%	53%	51%
Mode of social learning	Vertically: 37% Oblique: 4% Horizontally: 5% From unknown demonstrator: 21% No answer: 33%	Vertically: 48% Oblique: 13% Horizontally: 7% From unknown demonstrator: 26% No answer: 4%	Not applicable	Vertically: 31% Oblique: 21% Horizontally: NA From unknown demonstrator: 47% No answer: 1%

Twelve sites were used to fish with dolphins more than twenty years ago (Simões-Lopes et al., 1998), but nowadays, there are five to nine fishing sites commonly used by fishers. As the *Tesoura* is easily accessible, fishers mentioned that there are more fishers in this area than the other sites, especially during the reproductive migration of mullets, between the end of April and the beginning of July (e.g. Herbst, Hanazaki 2014). In this site, fishers adopt different foraging tactics: some cooperate with each other by sharing their vacancy in the water and the fish caught or the resulting money, while other fishers prefer to fish alone competing for a vacancy in the water and retaining all the outcomes (fish or money) to themselves (Peterson et al., 2008, Santos-Silva et al. *submitted*). This site is very competitive, where a fisher can spend hours waiting at the beach for his turn to get in the water (Peterson et al., 2008). Many fishers also arrive the night before and camp on the beach to get the best vacancies the next morning. In the first and last survey, fishers interviewed in *Tesoura* reported that each year there is a considerable increase in fishers at this fishing site.

The other fishing sites inside the lagoon (*Areial*, *Capitânia*, *Ponta das Pedras*, *Arrebentão*, *Toca da Bruxa*, *Balsa, Areial* and *Rio Tubarão*) are more difficult to access and so are used by artisanal fishers who live in the vicinities; it is rare for tourists to fish in these sites. Fishers recognize *Ponta das Pedras* as one of the traditional fishers' neighborhoods, where many families rely economically on artisanal fishing and share the catch with relatives and neighbors. In *Rio Tubarão* and *Ponta das Pedras* there is an ongoing cooperation between family members in which fishers' team up and alternate between resting on the boat while the others fish with dolphins. In the *Rio Tubarão* and *Toca da Bruxa*, fishers establish a shift rotation system, in which they mark their places in the order of arrival, and each fisher can cast his net three times (Peterson et al*.,* 2008). The fishers from *Ponta das Pedras* interviewed in the last survey (2019-2020), report that the number of fishers who do not depend on fishing in the *Rio Tubarão* has increased, causing conflicts among those who fish there. Unlike *Tesoura*, where fishers sell their catches directly to tourists at premium prices (Machado *et al.,* 2019), fishers at those more secluded sites sell their fish directly to resellers who impose the (lower) market value.

Governance

Fishers have developed their own operational, informal rules when fishing with dolphins, which can differ across fishing sites, especially in those where the fishing is done by

boat. These informal rules regulate the number and location of the fishing vacancies, the order of access and the time allowed for an individual to stay in a given vacancy, and fishing quotas. At the *Tesoura* beach, when a fisher catches more than one fish, regardless of the size, he must leave the vacancy for another fisher who waits at the beach—a rule described in the second survey (Peterson et al. 2008) that remains in place nowadays (forth survey). Similar informal rules were described for the fishing sites *Iate Club, Ponta do Aterro* and *Ponta do Guia* in the first survey (2004), but these rules were no longer in place in the last survey (2019-2020). The fishing interactions with dolphins became rare at the *Iate Club* recently, consequently, there were few fishers using that interaction site. The interviewed fishers in the last survey (2019-2020) reported the fishing with dolphins no longer take place at *Ponta do Aterro* and *Ponta do Guia*.

In Laguna, there are no official laws or norms that regulates who can fish with dolphins. Thus, this fishing system is open to anyone who possess a cast net and can access the fishing sites. Fishers from outside Laguna are opportunistic or amateur fishers and usually called "tourists" by native fishers (Peterson et al., 2008), who perceived these amateurs who do not depend economically on fishing as competitors (Machado et al. 2019). There is some disagreement between artisanal fishers from Laguna and these amateur fishers (Peterson et al., 2008). In the first survey, 80% of the fishers considered that amateurs interfered or disrupted the practice of fishing with dolphins, mainly because of competition for vacancies and consequent lower income. In the last survey (2019-2020), some fishers reported avoiding or quitting fishing at *Tesoura* due to the high number of amateur fishers.

There are also formal rules for the protection and maintenance of this fishery with dolphins implemented by governmental institutions. The municipal Law 521/1997 aims to promote conservation, tourism, research and avoid impacts of pollution on this tradition by considering the dolphins and the fishery as Natural Heritage of the Municipality. The Santa Catarina State Law 17.084/2017 establishes May 25th as the Day for the Preservation of Dolphin that interact with fishers, and aims to promote awareness actions about the importance of preserving the species for the cultural and economic development of the region. In 2018 the municipal law 033/2018 was proposed to protect the dolphin population through the prohibition of fishing gear that can cause incidental bycatch, such as gill and trammel nets. The full approval of this project is still pending. The monitoring and inspection of the municipal law 033/2018 is carried out by the local Port Authority (*Agência da Capitania dos*

Portos de Santa Catarina) and the administrative arm of the Brazilian Ministry of the Environment (*IBAMA*). Non-governmental institutions (such as *Instituto Boto Flipper*) also work to protect the artisanal fishery with dolphins and contribute with educational actions for the Laguna population. This NGO was recognized by Law 1357/2009 as an Institute of support, protection and preservation of the dolphins in Laguna.

Resource System and Resource Units

Systematic boat-based surveys have been carried out in the past 32 years to monitor the dolphin population dynamics (Simões-Lopes & Fabián1999; Daura-Jorge et al., 2013; Bezamat et al., 2018, 2019, 2020), revealed that the dolphin population is resident, small and fluctuates with no trends. However, it also revealed that dolphins are exposed to a wide range of threats in the last decade, including chemical pollution (Righetti et al., 2019), habitat loss (Agrelo et al., 2019), incidental bycatch in other fisheries (Bezamat et al., 2021), vessel traffic and noise pollution (Pelegrini et al., 2021). This long-term monitoring also showed a subtle increase in the probability of survival and reproductive success of dolphins that tend to cooperate frequently with artisanal fishermen (Bezamat et al., 2018, 2020). Informal monitoring of the fish caught can also be observed by fishers. In the last survey, 75% of the fishers reported that 15 years ago there were more fish and more dolphins in the lagoon and 87% of the interviewed fishers perceived that fishing conditions will worsen in the near future. For the interviewed fishers, the causes of this worsening are related to the incidental death of the dolphins in gill and trammel nets, chemical pollution from nearby rice farms, reduction in fish availability inside the lagoon, and an increase in the number of amateur fishers.

Changes in the socioecological system of artisanal cooperative fishing with dolphins

We used the SES framework (Ostrom et al. 2009) to summarize some of the changes in the socioecological system of artisanal fishing with dolphins in the last 16 years (Table 2). The main changes in this SES were the decrease in economic dependence on the resource of this system (U2, U8), changes in the transmission of local knowledge (U7), apparent decline in the mullet harvest (RU2), and new operational standards related to protection of dolphins (GS5). We also observe the permanence in the history of use of this system (U3) and in the

social norms in *Tesoura* (U6). The other second-tier variables of the framework were omitted due to lack of data or because they do not fit into this system.

Table 2. Selected components of the socioecological system of Artisanal Cooperative Fishing with Dolphins in Laguna, southern Brazil.

Selected framework components	**Main changes observed**
Users	
U1 – Number of users	Increasing number of opportunistic and amateur fishers at *Tesoura*'s site
U2 – Socioeconomic attributes of users	Decreasing economic dependence on cooperative fishing with dolphins
U3 – History of use	Permanence of the historical practice of cooperative fishing with dolphins
U4 – Location	Some fishing sites are no longer used for cooperative fishing with dolphins, while fishers keep fidelity to most of the remaining sites.
U6 – Norms/Social capital	Permanence of cooperation between fishers at *Tesoura*
U7 – Knowledge of SES/mental models	Increasing social learning and oblique transmission
U8 – Dependence on resource	Since 2008, less than half of the interviewed fishers depend on artisanal fishing
U9 – Technology used	Apparent use of new communication technology (e.g. social media) for learning the cooperative fishing with dolphins
Governance system	
GS1 – Government organizations	Governmental organizations defining regulations and norms, such as IBAMA and *Agência da Capitania dos Portos de Santa Catarina*

GS2 – Non-government organizations	Recognition of the 'Boto Flipper Institute' as an Institute of support, protection and preservation of Laguna's dolphins in 2009.
GS5 – Operational rules	Project of law for protection and maintenance of the cooperative fishing with dolphins by banning bycatch-prone fishing gear in 2018
GS6 – Collective choice rules	Permanence of fishers' autonomy to devise their own operational rules and norms when fishing with dolphins at *Tesoura, Toca das Bruxas* and *Rio Tubarão.*
Resource System (RS)	
RS5 – Productivity of system	Paucity of systematic data
Resource Units (RU)	
RU2 – Growth or replacement rate	Start of the ongoing systematic monitoring of the dolphin population in 2007; overexploitation and apparent decline of the mullet stock by the industrial and small-scale fisheries in southern Brazil since 2004.

DISCUSSION

Over the last 16 years, the traditional cooperative fishing between artisanal net-casting fishers and wild dolphins has persisted in southern Brazil, but by following the SES framework (Ostrom 2009), we identify the key attributes of this socioecological system that have changed. We found that the economic dependence on artisanal fishing has been decreasing over the years (U2), mainly at the main fishing site, while there has been an apparent increase in amateur fishers engaging in the cooperative fishing with dolphins in recent years (U1). Amateur fishers are more likely to engage in cooperative fishing with dolphins throughout the year, and they identify fishing as a hobby (Machado et al., 2019). However, the exact numbers of the users of this SES, such as the number of artisanal fishers (professionals, opportunists, and amateurs), tourists, and residents of the region, who use this system for different purposes remains uncertain. Due to the apparent increase of amateur and opportunistic fishers in the system, the history of use of the system (U3) is maintained through the various forms of knowledge transmission, with an increasing contribution of

social learning (U7), even with no strong economic dependence on fishing. Many fishers consider the importance of their livelihood as a way of life (Charles et al., 2012). In this context, the continuity of this tradition is also related to the cultural and social importance of fishing with dolphins, since artisanal net-casting fishers have a strong sense of belonging and attachment to this activity (Machado et al., 2019).

The transmission of knowledge about the system (U7) and the socioeconomic attributes of fishers (U2) are associated with the fishing sites (U4). At the fishing sites inside the lagoon, vertical transmission and economic dependence on artisanal fishing remained unchanged over the years due to the importance of fishing for family economy and the cultural identity of the communities with artisanal fishing in general, as well as with fishing with the dolphins. At the most accessible fishing site, most fishers do not depend on artisanal fishing and the knowledge about the system is primarily acquired through social learning by watching other fishers, but also mediated by the use of new communication technologies such as social media or internet videos (U9). In this context, the transmission of local ecological knowledge adapts to changes in the social and environmental conditions of the system (Gómez-Baggethun et al., 2012, Gómez-Baggethun et al., 2013, Reyes-García, 2014), such as the increased access to smartphone technologies along this time span of 16 years. In the case of local ecological knowledge related to fishing with dolphins, we observed an increased use of diffuse/technology-mediated learning at the *Tesoura* beach over the years, which could explain the continuous arrival of more amateur and opportunistic fishers, which is also due to the easy access to the site.

In the long term, these changes in the transmission of local ecological knowledge over the years may result in changes in the characteristic of the artisanal fishing with dolphins. Fishing with dolphins used to be a subsistence activity, but nowadays it also serves as hobby and recreation. Although the local ecological knowledge may be adapting to match the realities and changes of a system, such changes may not be adaptive in the evolutionary sense (Fernández-Llamazares et al., 2015). It is important to understand the effectiveness of local ecological knowledge in social learning, since the fidelity of knowledge transmission from parents to children tends to be higher than among peers (Cavalli-Sforza; Feldman, 1981; Lozada, et al., 2006). Thus, it is possible that the transmission of the fishing skills with dolphins may not be significantly distorted when fishers learned from their fathers (da Rosa et al., 2019). Another factor is that a fisher's son (or daughter, although this activity is male-

dominated) may no longer be interested in artisanal fishing with the dolphins and refuse to learn the tactic from their father; otherwise, fishers may not see fishing as a successful profession and therefore do not want their children to follow this career. Several other studies point out that declining interest among younger generations of fishers, due to limited fishing opportunities, and low status of this activity (Mangi et al., 2007; Blythe et al., 2013; Power et al., 2014; Tzanatos et al., 2016). Also, this particular fishing activity with dolphins can also be recreative, attracting retired fishers or professionals of other areas, and therefore, is not so common to see young people in this activity.

Even with the presence of governmental (GS1), non-governmental (GS2) institutions, informal rules (GS6), and decisions implemented to protect artisanal fishing with dolphins (GS5), there are still various disconnections between the Governance System and the Users, as well as recurrent disagreements between them. As the *Tesoura* is a non-exclusive site where professional artisanal fishers and outsiders share fishing opportunities and resources, the increase in the number of individuals may create a more competitive environment. This site is also known for the cooperative groups of fishers who have been using the area for years, many of whom are recognized by their peers for having a high reputation as experienced, skilled fishers (Santos-Silva et al., submitted). The social capital of these fishers (U6) is characterized by trust and reciprocity between the members of each group, where tasks and outcomes (fish or cash) are shared (Peterson et al., 2008; Santos-Silva et al., submitted). In this context, social capital can be considered one of the main components to boost unity, mobility of ideas, mutual belief, and mutual benefit to achieve a joint goal (Wibowo et al., 2021). Also, government and non-government institutions reinforce the values associated with fishing with dolphins for tourism, education and research, that encourage the dissemination of this fishery, attracting more outsiders to *Tesoura*, or even locals who seek recreation in the activity.

Due to its recognition and easy access, fishers from *Tesoura* are those who lead actions associated with traditional fishing with dolphins, participating in interviews for newspapers, short movies, and scientific surveys. On the other hand, fishers who depend economically on artisanal fishing are excluded from these actions because they typically do not fish—or have quit fishing—at *Tesoura* to avoid competition with the several professional and amateur fishers there. As these fishers sell their fish to middlemen, they do not benefit from the selling of their fish directly to the final consumer, and consequently, they have less

possibilities to increase their own income (Lopes et al., 2015). The conservation of this artisanal fishery may depend, among other factors, on the ability of fishers to exclude outsiders and create institutions that assimilate local rules for the use of marine space in a way that minimizes overlap in the search for resources (Begossi, 2006). Thus, it is necessary to better understand the needs and motivations of amateurs and professional fishers, and then use appropriate approaches to avoid conflicts. Participatory processes that bring together different stakeholders at various levels can help reduce conflicts between users and build nested governance, increasing compliance with principles and socioecological sustainability (Begossi, 2006; Trimble & Berkes, 2015). Further, enhancing trust, a sense of belonging to the community, and communication between the local people and governmental institutions are important for effective community-based conservation (Ostrom, 1990). Actions involving local, amateur and opportunist fishers can reduce conflicts between them as well as strengthen the maintenance of this century-old tradition.

The lack of data on how much artisanal fishing with dolphins produces (RS5) for families that depend on this activity hinders understanding the importance of this system for the local economy. The artisanal fishers of Laguna reported informal observations about some resource units that are corroborated with published scientific data. The incidental bycatch of dolphins in the catfish fisheries practiced by a subset of the local fishing community within the lagoon is a major threat reported by the net-casting fishers who interact with dolphins at the interaction sites since the first survey in 2004, which is corroborated by evidence on stranded dolphins entangled in fishing gear (Bezamat et al., 2021). Artisanal net-casting fishers have also reported a decrease in the local availability of mullet nearshore (*Mugil liza*) (RU2), mirroring fisheries data that suggest that the mullet stock in southern Brazil is overfished, mainly due to the increased industrial fishing effort during the mullet reproductive migration period and throughout its migratory route (Gonzáles-Castro et al., 2015, Lemos et al., 2014, Sant' Ana et al., 2017). While much of the current scientific emphasis on global change and human response addresses large-scale patterns and processes, local ecological knowledge can be valuable in providing information at a precise scale and based on location (Hopping et al., 2016). The qualitative data suggest that some level of informal monitoring is taking place, with fishers being aware of the fish stock status (e.g., Martins et al., 2018). As the rate of global change accelerates, the fisher's ability to detect and respond to changes in the resource systems in which they are embedded is of critical importance (Lauer, Aswani,

2010). To build trust through adaptations in the systems, it is necessary to link traditional ecological knowledge with institutions of the governance system (Folke et al., 2005). This way, fishers who interact with the dolphins can help in the knowledge and monitoring of the resource system and resource units (fish and dolphins) and also changes related to this component.

In a socioecological system, it may not be possible to quantify the role of a particular variable in generating one outcome observed, but it may be possible to identify which combination of variables can be associated with the outcomes (Basurto et al., 2013). We can observe that the increase of opportunistic and amateur fishers at *Tesoura* fishing site is bringing social and economic impacts to professional fishers who depend economically on this activity. Some local artisanal fishers prefer not to compete for the resource on this site and thus make it available to others who do not necessarily depend economically on this resource. Also, users who interact with the dolphins seem to know the current threats to dolphins. They describe since 2004 that trammel-netting for catfish is a threat for the dolphin population, however, it was only in 2018 that a law was established to prohibit fishing gear that are risky for dolphins. Still, there are no data available about how these laws are being enforced and how efficient they are. If the local availability of mullets within the lagoon decreases, it could be necessary to give priority to artisanal fishers who depend economically on this resource, as reported by fishers in the last survey. Monitoring how much the dolphin-fisher interaction produces in terms of fishing resources would help to quantify, in monetary terms, the value of the system in monetary terms, as well as inform predictive models of its ecological resilience. It is possible that the increase of tourism may trigger a series of actions to protect this fishing tradition and more involvement from government institutions; however, the whole local fishing community should be included in these actions, especially those fishers who depend economically on these traditional fisheries.

CONCLUSION

The conceptual model of socioecological systems outlined the diversity and dynamism of the components of the artisanal fishing system with the dolphins. Fisher's fidelity to fishing sites is associated with changes in socioeconomic attributes and the transmission of knowledge about the socioecological system of fishing with dolphins over the last 16 years in Laguna, southern Brazil. The increase in social learning of local ecological knowledge

reflects the importance of observing and learning from other fishers, however, it is necessary to understand the effectiveness of this knowledge in the system. Even though the dependence on the fishing resource is decreasing among fishers, especially at the main site where this fishing occurs, the continuity of the historical use of the fishing system with the dolphin can be maintained due to the increase of fishers who use this socioecological system as a space for recreation, socialization, and leisure. However, it is necessary to include fishers who economically depend on this activity in governance decisions. Thus, it is important to promote safeguarding actions that reduce conflicts between users and reinforce the protection of this century-old artisanal fishing, which provides material and non-material benefits for fishers and dolphins. This research has the potential to contribute to other studies in the area of socio-ecological systems, especially those that focus on changes over the years in the characteristics of the system.

ACKNOWLEDGEMENTS

We are deeply grateful to the fishers for their collaboration over the years. We thank the researchers who carried out the interviews in the first three surveys (D. Peterson, DX da Rosa, AMS Machado), and who helped with data sampling and field logistics (FG Daura-Jorge, PV Castilho, PC Simões-Lopes).

DECLARATIONS

Funding

This study was supported by research grants from the Animal Behaviour Society, the National Geographic Society (Discovery Grant WW210R-17), the Max Planck Society, the Max Planck Digital Library; and it is part of the Brazil-Germany PROBRAL Research Program funded jointly by CAPES and the Deutscher Akademischer Austauschdienst (CAPES-DAAD 23038.002643/2018-01) and the SELA Long-Term Ecological Research Program (PELD CNPq, 445301/2020-1). B.S.S. received a MSc scholarship from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES-Brazil (Finance Code 01); N.H. received a research productivity scholarship from Conselho Nacional de Ciência e DesenvolvimentoCientífico e Tecnológico, CNPq-Brazil (304515/2019-1); F.G.D.J was supported by CNPq (308867/2019-0) and Fundação de Amparo à Pesquisa do Estado de Santa Catarina (FAPESC TR2012000295); M.C. was supported by CAPES

(88881.170254/2018-01) and the Department for the Ecology of Animal Societies, Max Planck Institute of Animal Behavior.

Conflicts of interest/Competing interests

The authors declare no competing interests and that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors' contributions

BSS: research idea conception, data sampling, writing. NH: study design, writing, editing, supervision. MC: study design, writing, editing, supervision. The manuscript was approved by all authors.

Ethics approval

This study was approved by the ethics committee at Universidade Federal de Santa Catarina, Brazil (CEPSH 06457419.6.0000.0121). All personal data were anonymized.

Consent to participate

All people interviewed signed a free informed consent to participate in this research, and were interviewed individually.

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4 CAPÍTULO 2 – SOCIAL FORAGING CAN BENEFIT ARTISANAL FISHERS WHO FISH WITH WILD DOLPHINS

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Abstract

Social foraging decisions depend on individual payoffs. However, it is unclear how individual variation in phenotypic and behavioural traits can influence these payoffs, thereby the individual decisions to forage in groups. Here we studied how individual traits influence social foraging in the traditional fishery between artisanal fishers and wild dolphins in Brazil. We carried out semi-structured interviews with fishers and found their social network to be structured by two foraging tactics: cooperative groups or solitary. We quantified how much individual traits explain the decisions to forage in groups or alone, and found that differences in peer reputation and similarities in perceived benefits of group foraging had a weak positive assortative effect on the fishers' foraging decisions. Finally, we quantified the fishers' catch and found that fishers in cooperative groups tend to catch more fish *per capita* than solitary fishers. Our findings indicate that individual traits play a small, but relevant, role in the fishers' decision to forage in groups and reveal the importance of both material (e.g. fish, income) and non-material benefits (e.g. social prestige) in this traditional fishery. Social foraging theory suggests that cooperative foraging can persist while beneficial for the individuals involved. Faced with local environmental changes and reduced availability of fishing resources, the payoffs of both fishers' foraging tactics may change, potentially making the persistence of this traditional fishery more reliant on the non-material benefits those fishers accrue from their social decisions than the direct, material benefits accrued from their foraging decisions.

Keywords: artisanal fishers, cooperation, ecological interaction, human forager, social foraging, social network

SIGNIFICANCE STATEMENT

Social foraging theory predicts that the decision to forage in groups is primarily driven by cost/benefit trade-offs individuals experience, but it remains unclear whether, and how much, individual foragers' characteristics influence these trade-offs and consequently the choice to forage in social groups. We study the social and foraging behaviour of artisanal fishers who engage in an unique interaction with wild dolphins and show that (i) peer reputation, foraging frequency and similarity in the perceived benefit of cooperating can influence the propensity to engage in social foraging; and that (ii) not only material gains (e.g. fish, income) but also non-material benefits (e.g. social prestige) contribute to the formation of foraging groups. These findings suggest that cooperation between social foragers can be influenced by both direct and indirect benefits, some of which can be related to trait similarity among individual foragers.

INTRODUCTION

Social foraging is a prominent strategy in both human (Apicella et al. 2012; Hill 2002) and non-human animals (Bednarz 1988; Benoit-Bird and Au 2009). Ecological theory predicts that the decision to partake in social foraging is primarily driven by the trade-offs in the foraging costs and benefits that individual foragers experience (Giraldeau and Caraco 2000; Beauchamp 2014). The direct benefits of foraging in cooperative groups include increased access to resources and information (e.g.Begossi 1992; Aplin et al. 2014) thus higher energy intake (e.g. Alvard et al. 2015; Creel 1997). However, such benefits can dissipate in large groups where the *per capita* share becomes prohibitively small (MacArthur and Pianka 1966; Clark and Mangel1986). Among human foragers such as artisanal fishers,

the social decisions during foraging are also driven by increased material returns—cooperating with peers can increase the capture success (Barnes et al. 2016; Turner et al. 2014) and monetary gains (Carpenter and Seki, 2011). However, social and foraging decision-making processes remain relatively understudied among fishers (e.g. Fulton et al. 2011; van Putten et al. 2012; Andrews et al. 2021) and may rely on more than the need for maximizing material benefits. Social interactions, for instance, play a role in the acquisition of local ecological knowledge and effective foraging techniques (e.g.Galef and Giraldeau 2001; Reyes-García et al. 2016), therefore choosing with which other individuals to form social bonds and forage cooperatively is also an important decision.

Social bonds, in general, tend to form among individuals who share similar traits—a process called homophily (McPherson et al. 2001) that typically assort social networks into cohesive clusters (e.g. Croft et al. 2005; Krause et al. 2007). There are many biological, ecological and behavioural traits whose similarity can influence individuals to interact socially and then to cooperate—e.g. kinship (Hamilton, 1964), age (e.g. Carter et al. 2013), foraging tactics (e.g. Machado et al. 2019a) and resource needs (Alexander et al. 2018; Conley and Udry, 2010). Differences in individual traits can also beget social attraction. An example is when low-rank individuals—in terms of reputation—aspire to build relationships of trust and reciprocity with high-status individuals, presumably because high reputation may imply privileged access to resources (Lyle and Smith 2014; von Rueden 2020). Thus, while foraging decisions of human social foragers are fundamentally driven by the direct and energetic benefits accrued by individuals (e.g. Carpenter and Seki 2011), there are more at stake than material gains. However, among artisanal fishers, the extent to which individual

traits—related to material (energetic) and non-material (reputation) benefits—influence social preferences that affect foraging decisions remains poorly understood.

In southern Brazil, a traditional fishing practice involving artisanal net-casting fishers and wild bottlenose dolphins (*Tursiops truncates gephyreus*) (Simões-Lopes et al. 1998; Daura-Jorge et al. 2012) provides an opportunity to investigate how individual traits may influence social foraging. Some fishers have learned how to interpret the dolphins' foraging behaviour of herding fish towards the coast and wait in line in shallow waters for the right moment to cast their nets (Simões-Lopes et al. 1998). Since the interaction area is restricted, these fishers self-organize their fishing activities with dolphins with an informal rule system (Peterson et al. 2008). There are specific spots in the water more suitable for throwing the cast nets, and fishers take turns to occupy them: when a fisher catches at least two fish, they must leave the line for the next fisher waiting on the beach for their turn (Peterson et al. 2008). Social interactions among these fishers seem correlated with their decision to cooperate or not with other fishers (Peterson et al. 2008). Fishers who cooperate with others can share their fishing spot in the line and share their turns, as well as the material fishing outcomes (fish or cash). By contrast, fishers who fish alone must wait for their turn to go into the water but can keep the whole catch for themselves (Peterson et al. 2008). While these decisions to cooperate may be influenced by the shared gains of fishing, human social relationships are multifaceted and shaped by several other factors and can yield indirect and non-material benefits (e.g.Hruschka 2010). Thus, we expect that similarity in other individual traits (such as kinship, behaviour, core values; McPherson et al. 2001; Christakis 2019), as well as non-material benefits of fishing with dolphins perceived by fishers (such as leisure, sense of

belonging; Machado et al. 2019b), to play a role in the individual decision of joining cooperative foraging groups.

Here, we study the social interactions among these artisanal fishers who fish with dolphins in Brazil to evaluate how individual traits and performance influence social foraging. We hypothesize that social preferences are correlated with their decisions to cooperate or not with each other, and that these decisions can be related to different material and/or non-material returns. First, we map the social and cooperative interactions among fishers and identify who engages in cooperative foraging or who only forages solitarily. Then, we evaluate if similarity among multiple traits of the individuals (e.g. age, kinship, fishing experience) and of their social environment (e.g. reputation, number of friends) can underlie these two foraging tactics. Finally, we count and measure the fish caught to compare the material benefits accrued by fishers who form cooperative foraging groups or forage alone.

MATERIAL AND METHODS

Data sampling

Study system

The study system is the artisanal fishing community from the complex lagoon system adjacent to Laguna, southern Brazil (28°20'S, 48°50'W). The traditional dolphin-fisher fisheries occurs across the lagoon system, but the main interaction site for this type of fisheries is the *Tesoura* beach, an easily accessible beach, where several fishers from Laguna and adjacent cities interact with the dolphins (Supplementary Fig. S1). We combined interviews with all-occurrence behavioural sampling to assess the socioeconomical, cooperative behaviour and foraging success of artisanal net-casting fishers at the *Tesoura*

beach. It was not possible to record data blind because our study involved focal individuals in the field.

Fishing behaviour and individual traits

We interviewed 49 artisanal fishers during 26 consecutive days between May and July 2019, when the dolphin-fisher interactions are intensified by the reproductive migration season of mullet fish (*Mugil liza*) (Simões-Lopes et al. 1998). This number of interviewees is a representative sample of resident fishers in this area (see Machado et al. 2019b; Peterson et al. 2008; Zappes et al. 2016 for studies with similar sample sizes). The potential interviewees were identified through participant observation (Schensul et al. 1999), following net-casting fishers at cooperative fishing spots (Supplementary Fig. S1), and conducting direct observations to identify those who interact with dolphins. The interviews were conducted at the beach when the fishers were waiting for their turn to go into the water to interact with dolphins. After agreeing and signing a free informed consent to participate in this research (ethical approval CEPSH 06457419.6.0000.0121), participants were interviewed individually. Only one approached fisher declined the invitation to participate in this research.

The interviews were based on a semi-structured questionnaire (Bernard 2006) with 14 questions defined after five pilot interviews carried out earlier in 2019 at the same location. The questionnaire (Supplementary Methods S2) contained questions on the fishers' individual traits (age, sex), social-economic aspects (place of residence, years of experience in fishing, frequency and economic dependence on fishing with dolphins), and social connection with the other artisanal fishers in the area. For the latter, we asked who among the local fishers are their relatives, close friends, and acquaintances (i.e. who else they knew); whom they perceive

as the most skilful, experienced or successful fisher; and with whom, if any fisher, they cooperate—share their spot in line and the fishing outcomes—when interacting with dolphins. Whenever the interviewee named a fisher with whom they fish in cooperative groups, we further asked why they cooperate, how the cooperation works, and what were their perceived benefits when cooperating with each other.

Fishing success

During all the 26 sampling days from 08:30 to 17:00h, we used an all-occurrence sampling protocol (Altmann 1974) to record the foraging behaviour of all fishers. For each foraging event—defined as when one or more fishers cast their nets independently or following the dolphins' behavioural cue (see Simões-Lopes et al. 1998)—we quantified the number of nets cast and counted and measured the resultant mullet caught, if any, for each individual fisher— an adaptation of a field method already used successfully in the same area (see Simões-Lopes et al. 1998.) We focused on the foraging of the 49 interviewed fishers but recorded the success of all fishers interacting with dolphins.

Data analyses

Fishers' social network and foraging tactics

We used network analysis to investigate how the fishing interactions among the artisanal fishers who forage with dolphins are structured. We built a social network of fishers based on their answers to the question on which fishers they cooperate with. The network was defined by a binary adjacency matrix **A**, where the element a_{ij}= 1 when fisher *i* declared to cooperate with *j* or fisher *j* declared to cooperate with *i*; and a_{ij} = 0 when neither *i* or *j* declared cooperation. In the network depiction, nodes representing fishers were connected by

undirected binary edges representing declarations of cooperation (the cooperative links); individuals who did not cooperate were then disconnected from the giant component of the network. Although disconnected, these fishers are still part of the social system of fishers who interact with dolphins, and thus we considered their nodes as part of the fishers' social network. The fishers who reported no cooperative interactions were then deemed as "solitary" fishers, whereas all fishers who reported cooperating with at least one other fisher were deemed "cooperative" fishers.

We then tested the existence of distinct groups of cooperative fishers by calculating the modularity, Q (Newman and Girvan 2004) of the giant component of the fishers' social network. A modular structure would contain subsets of individuals (modules) who are more connected with each other than with the rest of the network. We used a null model to test the significance of the observed modularity. We first created an ensemble of 2,000 theoretical networks using an algorithm that fills adjacency matrices based on the empirical columns and rows totals (number of interactions). Each cell had a probability of being filled that was proportional to the number of reported cooperative interactions (null model 2 in Bascompte et al. 2003 adapted for symmetric unipartite networks in Cantor et al. 2017). We then calculated modularity for all theoretical networks to build a benchmark distribution. The observed modularity was considered statistically significant when outside of the 95% confidence interval of the benchmark distribution. The significant modularity partition was then used to define membership to different cooperative groups (modules).

Influence of individual traits on fishers' behaviour

Next, we investigated whether fishers' individual traits could explain the foraging tactics. For all fishers in the network—either cooperative or solitary—we considered five continuous and three categorical individual traits. The continuous traits were: age (years), experience in fishing with dolphins (years of practice), frequency of fishing (number of months per year dedicated to fish with dolphins), peer reputation (or prestige, given by how many times each fisher was cited by their peers as the most successful in fishing with dolphins), and friendship (the total number of fishers in the area reported to be their friends). The categorical traits were: kinship (whether fishers were relatives or unrelated), the economic dependence of fishing (whether they were full-time or part-time fishers), and perceived benefits of cooperation with other fishers (described as none; shared spot in the fishers' line; shared fish caught; and shared money from fish sold).

To estimate the influence of each variable on the structure of the fishers's social network, while controlling for the effects of all the other variables, we used a generalized version of the Multiple Regression Quadratic Assignment Procedure (MRQAP), called GLMQAP (Franks et al. 2020), with the double-semi-partialling permutation method (Dekker et al. 2007). We considered the matrix **A** of binary cooperative links as a dependent variable, thus we fitted a Generalized Linear Model with Quadratic Assignment Procedure to consider a binomial error distribution (Franks et al. 2020).As independent variables, we considered all individual traits, which were organized into matrices of the same size as **A**, where the elements represent the similarity between pairs of fishers relative to these traits.

To calculate similarity among the traits, we computed a Euclidean distance matrix for each trait. Prior, the categorical variable perceived benefit of cooperation was coded into

five numerical categories (e.g. no benefit=0, shared spot=20, shared fish caught=30, shared money of fish sold =40, shared spot and money of fish sold=50) and the binary variables (kinship, economic dependence) were described as matrices where 1 indicated fishers of the same category, and 0 those of different categories. To make the individual traits more comparable, we rescaled each Euclidean matrix to range between 0 and 1, and subtract 1 from all rescaled distances to therefore consider the similarity among pairs of individuals. This way, each matrix describing the individual trait contained elements ranging from 0 (where pairs of fishers were completely different regarding that trait) to 1 (where pairs of fishers were completely similar).

We used a model selection procedure, starting with a full GLMQAP model containing all the nine predictors. To evaluate the significance of the regression coefficients of the model, we used 1,000 permutations to build randomized distributions to compare to the empirical coefficients. The P-values represent the proportion of times the empirical regression coefficients (β) were smaller or greater than the null expectancy. We then built simpler, nested models by removing non-significant variables, one by one. We used Akaike Information Criteria (AIC) to rank all candidate models and considered as the most parsimonious model the model with the lowest AIC (Burnhan and Anderson 2002). From the regression coefficients of the selected GLMQAP model, we evaluated the direction of the effect of each variable (negative or positive) on the fishers' social network structure, and used pairwise Mantel tests to double check the effect size of the significant variables.

Finally, we also checked for correlation among all individual traits, and estimated the assortment of the fishers' network around each individual trait independently. Here, we

calculated (continuous or discrete) assortativity indices (Farine 2014) to check for the tendency for similar nodes, in terms of the individual traits, to be connected (Newman 2006), calculating standard errors with a Jackknife resampling method.

Influence of fishers' behaviour on feeding success

Finally, we tested the hypothesis that the cooperative fishers outperform the solitary fishers. We first built a Generalized Linear Model (GLM) with negative binomial structure (to deal with overdispersion of the count data) and a log link function to evaluate the total mullet caught by each individual fisher as a function of their foraging tactic (cooperative, solitary). The unit of analysis was each interviewed fisher, combining all mullet caught by them through the study period. Second, we built a Generalized Linear Mixed Models (GLMM) to evaluate the total mullet caught in each net cast by each individual fisher as a function of their foraging tactic (cooperative or not) and social module size. We used a nested random effect structure to control for individual differences among fishers and module composition, as individuals from the same module can be more similar to one another, relative to the individual traits measured here. For both models, we created a corresponding null model with only the intercept as a benchmark. We used the lowest Akaike's information criterion corrected for small samples (AICc) and AIC weight to rank candidate models (Burnhan and Anderson 2002). The model selected was validated by a protocol for linear models (Bolker et al. 2009) and using simulated residuals (Hartig 2019). All modelling was performed in R 3.6.2 (R Development Core Team, 2019) using R packages 'glmmTMB' (Magnusson et al. 2017), 'MuMIn' (Bartoń 2018) and DHARMa (Hartig 2019).

RESULTS

Fishers' social network and foraging behaviour

All interviewed fishers were male, with ages between 24 and 72 years old (median = 44 ± 12.4 SD). Fishers had a minimum of less than a year and a maximum of 61 years of experience in cooperative fishing with dolphins (median = 24 ± 15.4 SD). From the 49 interviewed fishers, 24 reported that they cooperate with other fishers when fishing with dolphins, while the remaining 25 (solitary) fishers reported that they only fish solitarily (Fig. 1A). The connected component of the network was split into four modules, as shown by the modularity being significantly higher than the null expectancy (Q=0.37, 95% CI = 0.16-0.36, Supplementary Fig. S2).

Influence of individual traits on foraging behaviour

Among all individual traits, the perceived benefits of fishing in cooperative groups, the number of friends and the peer reputation were distinctive between the cooperative and solitary fishers (Fig. 1B-D). Cooperative fishers tended to be ranked higher than solitary fishers in all three traits, and reputation and number of friends were highly correlated (Spearman's r = 0.708, Supplementary Fig. S3). Cooperative fishers also tended to fish more frequently throughout the year and during the mullet season (Fig. 1E-F), but the differences relative to the solitary fishers were small. There was a moderate correlation between age and experience (r = 0.309; Supplementary Fig. S3), but individually these variables were not distinct between cooperative and solitary fishers (Fig. 1G-H). Finally, there was a tendency for solitary fishers to not depend economically on the fishery with dolphins, and to not fish with relatives, but these traits were less variable among cooperative fishers (Fig. 1I-J).

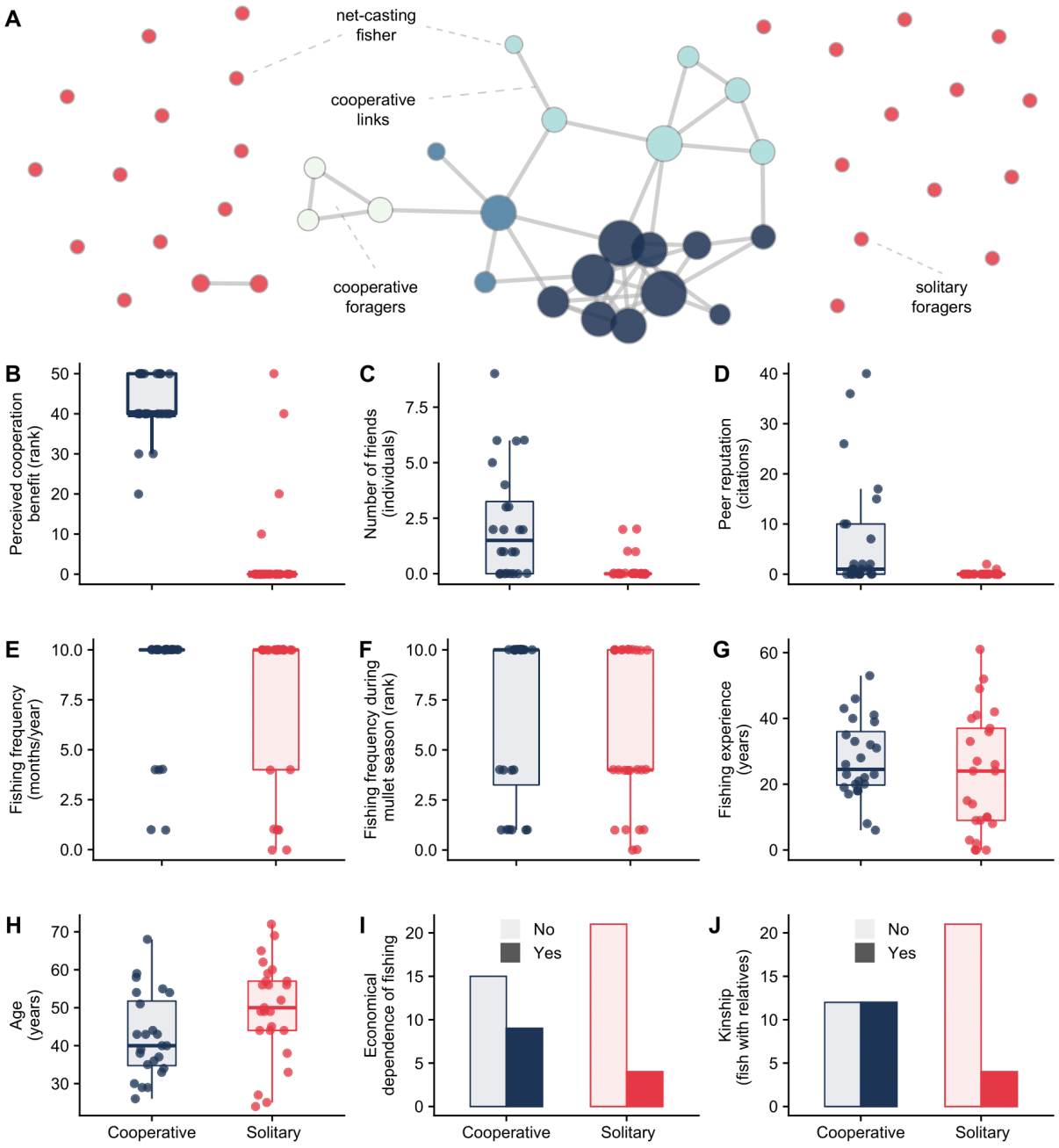

Fig. 1. Foraging tactics among artisanal net-casting fishers. (A) Fishers' social network of artisanal fishers suggesting two foraging tactics: cooperative and solitary.The network contains 49 individual fishers (nodes), out of which 22 for cooperative groups when fishing and are part of the giant component of the network containing 4 modules (blue-shaded nodes). Two individuals cooperate with each other and 25 others do not cooperate (red nodes) and only fish solitarily. The size of nodes is proportional to the number of cooperative ties. **(B-J)** Distribution of individual fisher traits between the foraging tactics.Cooperative (blue) and solitary (red) foraging. Each point (n = 49) is an interviewed fisher.

The fishers' social network was assorted by some of these individual traits (Supplementary Table S1). The assortativity indices of seasonal frequency of fishing with dolphins and number of friends suggested a moderate assortment effect on the cooperation links, while kinship and economic dependence of fishing were also positive, but smaller and more variable. There was a moderate disassortative effect of the perceived benefits of cooperating on the existence of cooperation links. The effects of the remaining traits were minor. When we evaluated the combined influence of these individual traits on the structure of the fishers' network, the most parsimonious GLMQAP models ($\Delta AIC<2$, Supplementary Table S2) suggested three significant individual traits. While the perceived benefits of foraging in cooperative groups and the frequency of fishing with dolphins during the mullet season had a positive, but small influence on the structure of the cooperative links, the peer reputation had negative effect (Tables 1, S3). The modules in the fishers' social network varied in these traits, but overall members of modules tended to perceive more benefits in foraging in groups, to fish frequently during the mullet season and to have variable reputation, while the solitary fishers were more variable in the seasonal fishing but showed consistently low reputation and perceived benefit of cooperating (Supplementary Fig. S4). The other six variables did not contribute significantly to the structure of the fishers' social network (Table 1).

Table 1. Generalized Linear Models with Quadratic Assignment Procedure. GLMQAP considering a binomial error distribution relates the structure of the cooperative ties among artisanal fishers as a function of nine individuals' traits: age, fishing experience, kinship, economic dependence on fishing, seasonal and annual frequency of fishing, peer reputation, number of friends, and perceived benefit of fishing in cooperative groups. Statistical significance is indicated by a single asterisk ($P < 0.05$). Both models support the data ($\Delta AIC<2$; see S2 Table)**.**

GLMQAP 1 **Traits**	**Regression Coefficient**	**Standard Error**	**Z-value**	**P-value**
Intercept	-5.63	0.75		
Peer reputation	2.72	0.54	5.02	0.0198*
Perceived benefit of cooperating	-2.81	0.46	-6.06	0.0198*
Seasonal frequency of fishing with dolphins	3.7	0.66	5.58	0.0198*
GLMQAP 2 **Traits**	**Regression Coefficient**	**Standard Error**	**Z-value**	**P-value**
Intercept	-8.62	1.3		
Age	0.82	0.91	0.9	0.42
Experience in fishing with dolphins	1.91	1.01	1.9	0.13
Kinship	0.25	0.35	0.73	0.458
Economic dependence of fishing with dolphins	-0.07	0.34	-0.22	0.855
Seasonal frequency of fishing with dolphins	2.67	0.56	4.79	0.002*
Annual frequency of fishing with dolphins	0.31	0.51	0.61	0.631
Peer reputation	-4.35	0.77	-5.65	0.002*
Number of friends	2.51	1.11	2.26	0.082
Perceived benefit of cooperating	3.57	0.68	5.24	0.002*

Influence of fishers' behaviour on foraging success

Among the 24 fishers who cooperate, 21 answered that they prefer to cooperate only with experienced and skilled fishers—those who were scored high by their peers in the reputation ranking. When the fishers were asked about the benefits of cooperating, the most frequent answer was the increased number of fish caught, as well the assistance in selling fish. On the other hand, fishers who do not cooperate had different perceptions about the benefits of this tactic. Among the 25 solitary fishers, only four reported that there are benefits of sharing the fishing spot and the catch with their peers, but most solitary fishers reported that any benefits in cooperating would be dampened by the uncertainty in the others' catch (Fig. 1B). Accordingly, the perceived benefits of cooperating were generally higher among cooperative fishers (Fig. 1B).

During 26 sampling days in the 2019 mullet season, a total of 1,186 mullets were caught and the foraging success of all fishers was 0.26 mullet per net cast (n=14,542 nets) and 0.44 mullet per foraging event (n=2,687 events including or not interaction with dolphins). The foraging success of cooperative fishers tended to be higher than of the solitary fishers. The total catch was, on average, higher for the cooperative (4.833 mullets ± 8.896 SD) than for the solitary fishers (1.408 ± 2.188 SD). There was an effect of higher collectively foraging effort among the cooperative fishers (Fig. 2A), as the number of net casts and the resulting number of mullets caught tended to increase with the cooperative module size (e.g. 3-fisher module: average 2.921 mullets ± 4.096 SD vs. 10-fisher module = 5.352 ± 9.919).

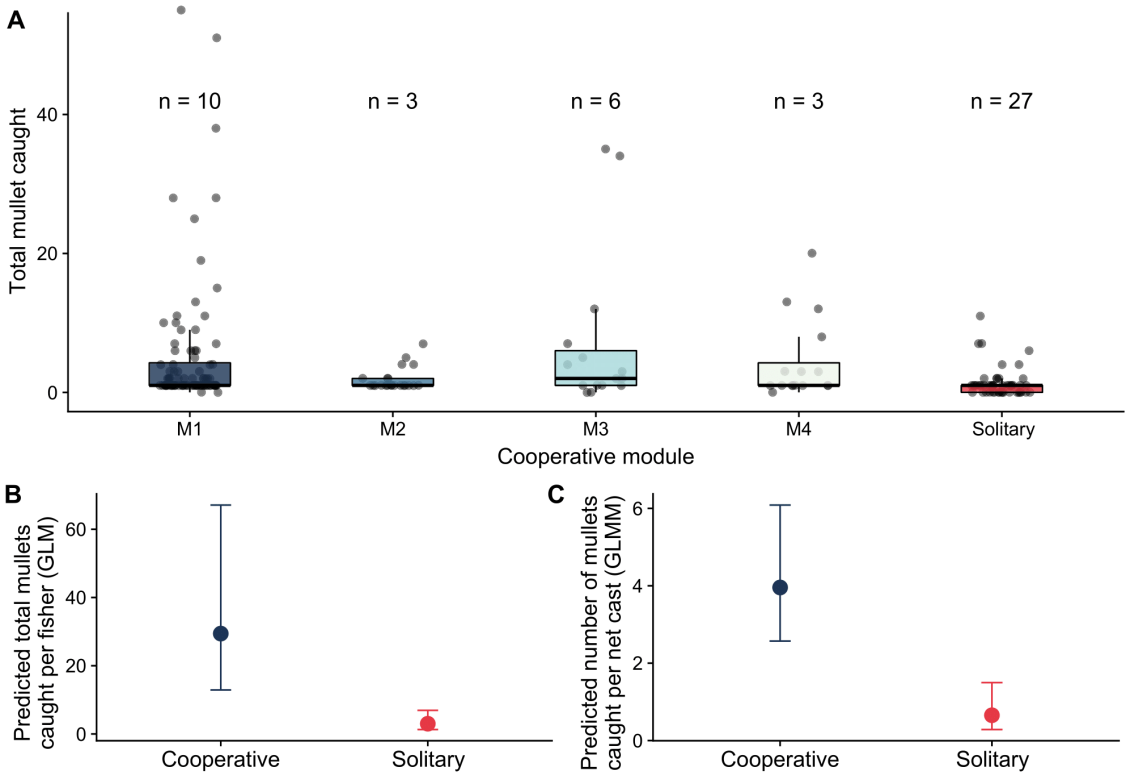

Fig. 2. Observed and predicted foraging success of artisanal fishers. (A) Observed total mullet caught by fishers of different foraging tactics (blue = cooperative; red = solitary), and fishers of different cooperative module sizes (n = number of individuals). **(B)** Number of total mullets caught during the study by fishers of different tactics, as predicted by the generalized linear model. **(C)** Number of mullets per net cast of fishers of different tactics, as predicted by the generalized linear mixed model. Whiskers represent 95% confidence intervals.

The negative binomial GLM of the total mullet caught by each interviewed fisher as a function of their foraging tactic reinforced that cooperative fishers tend to be more successful (Fig. 2B). The effect of solitary tactic was significantly negative and large (β= -2.28, SE = 0.60, 95% CI [-3.49, -1.08], $p < 0.001$). This model has considerable explanatory power (Nagelkerke R^2 = 0.32), more support (AICc weight = 0.986) than the null model (AICc = 8.45, AICc weight = 0.014), and it meets all the premises (uniformity: D = 0.125, p = 0.394; lack of overdispersion: ratio observed/simulated = 0.706, p = 0.614; no outliers: exact binomial test, p = 1.00). The GLMM relating the mullet caught by each net cast by each

fisher, but this time controlling for the size of the social module they belong, confirmed that the cooperative tactic also tended to be the most successful (Fig. 2C). The effect of cooperative tactic was significantly positive and large (β = 1.77, SE=0.43, p < 0.0001; intercept corresponding to the solitary tactic was at -0.423, SE=0.4203, p=0.314). The model had enough explanatory power when considering the fixed effect (marginal R^2 = 0.269) and even more when considering the random effects (conditional R^2 = 0.483) indicating the importance of individual variation. This model has more support (AICc weight = 0.961) than the null model (AICc = 6.39, AICc weight = 0.039), and it meets most premises (lack of overdispersion: ratio observed/simulated = 1.217, p = 0.412; no outliers: exact binomial test, p = 0.3509) except uniformity (D = 0.167, p <0.001).

DISCUSSION

In mapping the fine-scale social patterns of artisanal fishers who forage with wild dolphins, our study shows that some fishers engage in social foraging and some fish solitarily. Among individual traits that could influence the fishers' propensity to form cooperative foraging groups, we found a disassortative effect of peer reputation and a small assortative effect of the similarity in the perceived benefit of cooperating with other fishers, and frequency of fishing with dolphins. In addition, fishers who form cooperative foraging groups tend to, collectively, capture more fish *per capita* than those who fish alone. Our findings suggest that foraging and social interactions among these artisanal fishers are influenced by material benefits accrued from foraging as well as by non-material values perceived by fishers and accrued from socializing.

Individual traits and foraging behaviour

While the social network of the artisanal fishers is clearly structured into sets of individuals who forage or not in cooperative groups, it is not immediately clear whether individual traits contribute to such structure. We found that traits related to foraging (frequency of fishing with dolphins during the mullet season) and to socializing (peer reputation) explained part of the assortment in the fishers' social network.

Regarding the foraging traits, the social assortment among fishers who are more frequently at the interaction site can be related to the fact that they have had more opportunities to re-encounter, and to form social ties with each other, in comparison to the inexperienced fishers. In theory, the more frequent the individuals are at the fishing site, more interactions could take place. Some of the evidence for this process come from studies in primates, where repeated social interactions between the same individuals lead to the development of trust, and promote the emergence of reciprocity (Puga-González and Sueur 2017). Additional evidence comes from the aquatic partners of the Laguna fishers: among the dolphins, assortativity around the frequency at which individuals forage with fishers define socially-cohesive groups in their social network (Machado et al. 2019a). Is possible that fishers who are more frequently fishing with dolphins are also the most skilled, and so the most successful, fishers. Thus, the assortment around frequency of fishing may also represent, indirectly, an assortment around similar foraging success. Human foragers, in general, tend to search and share information with others with similar experiences (Alexander 2018; Conley; Udry 2010). This idea is in line with the evidence that fishers accumulate a rich knowledge about fishing techniques and the suitable ecological conditions for fishing over time (Johannes et al. 2008); and that being more experienced usually leads to higher fishing success (Branch et al. 2006). We speculate that a combination of active social preferences

around fishing experience and higher co-occurrence at the fishing site can contribute to the formation of more, or stronger, bonds among these artisanal fishers.

Regarding the social traits, we found that fishers who engage in cooperative groups are perceived by their peers as being more successful fishers, thus having higher social reputation. We found that reputation had a small, dissortative effect on the fishers' social network: the more different the reputation rank among cooperative fishers, the more likely they were to form cooperative foraging groups. We propose two potential explanations for this pattern. First, low-reputation fishers may seek to join cooperative foraging groups containing high-reputation fishers because associations with such high-status individuals can translate into greater access to information and resources (Henrich and Gil-White, 2001; von Rueden 2020). Second, the dissortativity of the social network could also reflect high-reputation fishers of different modules avoiding to form cooperative groups with each other. We speculate that the decision to cooperate may not only be an individual but also a collective decision, that is, while an individual fisher can opt to cooperate or not with others, some of their traits (e.g. high reputation and experience) may be considered key requirements for this individual to be accepted by the group. We acknowledge, however, that the overall low reputation of solitary fishers may have influenced this assortativity pattern, therefore our interpretations remain tentative. This is because low-reputation fishers may not be successful in developing cooperative ties or other relationships of trust with others, which could explain why solitary fishers have few or no friends, and were rarely perceived as successful fishers, in the context of fishing with dolphins.

Benefits of cooperative foraging

We found different foraging benefits, both perceived and accrued, among the artisanal fishers. When investigating their perceptions about the benefits, we found that those who cooperate perceive several benefits in forming such cooperative groups. They commonly reported having access to larger catches and assistance in selling the catch, both of which can be interpreted as a form of energy optimization. Theory suggests that foraging in cooperative groups can also imply in less energy expenditure (Dyble et al. 2016); in our case, we posit that when one fisher is in the water interacting with dolphins, the others may optimize the group's time by selling their catch or resting before their turn to go fish (Peterson et al. 2008). In line with the evidence that hunters and fishers tend to share resources with others who have previously helped and with those with whom they trust (Gurven 2000; Bliege Bird and Power 2015), another benefit of forming cooperative groups perceived by the artisanal fishers is the possibility of sharing the catch and/or the resultant cash. By fishing together, fishers can rely on their partners' success, which on average increases the *per capita* profit compared to when they fish alone. On the other hand, the fishers who fish solitarily reported that the main cost of cooperation is the risk of having to share their catch with inexperienced, usually unsuccessful fishers, thereby reducing their potential *per capita* gain.

Resource sharing implies that the group size (here, the modules in the fishers' social network) can also influence the decision about forming cooperative foraging groups. Being a member of large cooperative groups may reduce the individual payoff, especially when the resources are scarce. During our study, the net-casting fishers of Laguna experienced an atypically unproductive mullet season in 2019: there were only few catches compared to previous mullet seasons at the same beach, in line with the regional declining trends in the mullet stock in southern Brazil (Sant'Ana et al. 2017; Machado et al. 2021). We found that

cooperative fishers tend to catch more mullet than the solitary fishers, however, we also found a high variation in individual catches. It is possible that the perception about the cooperation benefits reported by the cooperative fishers was informed by previous, more productive years where the fishing success rate was higher. Should the years of low fish availability continue, it is possible that the payoffs of the foraging tactics change—fishers who do not cooperate may end up obtaining more fish *per capita,* since they do not share the catch with others. Changes in the material benefits of the cooperative foraging tactic may make it more reliant on their non-material benefits.

Conclusions

The human side of the dolphin-fisher interactions is characterized by a social network of artisanal fishers structured by cooperative and solitary foraging. We found that forming cooperative foraging groups can be beneficial, and that the formation of such groups is influenced by some individual traits of the fishers. These fishers who interact with dolphins are after material benefits (e.g. energetic and monetary gains) but also non-material benefits, such as recreation, social relationships, intrinsic values and a sense of belonging (Machado et al. 2019b). We expect that highly productive fishing years can guarantee their material returns, thereby supporting the persistence of both this traditional fishery and of the fishers' cooperative ties. Should the mullet availability tend to decline (Sant'Ana et al. 2017; Machado et al. 2021), the cooperative ties among fishers could be replaced by competitive ones in response to resource scarcity. In this case, the fishers' cooperative foraging is expected to continue only if the non-material values of these social relationships outweigh monetary or energetic returns. A possible outcome of this change is the traditional fisheries with dolphins in Laguna to become restricted to amateur and opportunistic fishers who do not

depend exclusively from fishing (Machado et al. 2019b), thereby excluding fishers who currently rely on this traditional fishing as their main source of income. Such changes in the composition of the fishing community that interact with wild dolphins could have implications for the persistence of this century-old local tradition in years to come, highlighting that understanding fishersbehaviour is an important component of fisheries management (see also Fulton et al. 2011; Andrews et al. 2021).

ACKNOWLEDGEMENTS

We are deeply grateful to the fishers for their collaboration. We thank all researchers and volunteers who helped with data sampling (JVS Valle-Pereira, AMS Machado, C Bezamat, B Romeu, E Erdhardt, DR Farine, PV Castilho, N da Silva, LF da Rosa, CF Alves), and field logistics (PV Castilho); and JVS Valle-Pereira, AMS Machado, S Zank for the insightful comments on the manuscript.

DECLARATIONS

Funding

This study was supported by research grants from the Animal Behaviour Society, the National Geographic Society (Discovery Grant WW210R-17), the Max Planck Society, the Max Planck Digital Library; and it is part of the Brazil-Germany PROBRAL Research Program funded jointly by CAPES and the DeutscherAkademischerAustauschdienst (CAPES-DAAD 23038.002643/2018-01) and the SELA Long-Term Ecological Research Program (PELD CNPq, 445301/2020-1). B.S.S. received a MSc scholarship from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES-Brazil (Finance Code 01); N.H. received a research productivity scholarship from Conselho Nacional de Ciência e

DesenvolvimentoCientífico e Tecnológico, CNPq-Brazil (304515/2019-1); F.G.D.J was supported by CNPq (308867/2019-0) and Fundação de Amparo a Pesquisa do Estado de Santa Catarina (FAPESC TR2012000295); M.C. was supported by CAPES (88881.170254/2018-01) and the Department for the Ecology of Animal Societies, Max Planck Institute of Animal Behavior.

Conflicts of interest/Competing interests

The authors declare no competing interests and that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Availability of data and material

For transparency, we provide all the (anonymized) data in the open-access repository: **https://bitbucket.org/maucantor/social_fishers/src/master/**

Code availability

For transparency, we provide all the (customized) R code to replicate the analyses and figures in the open-access repository:

https://bitbucket.org/maucantor/social_fishers/src/master/

Authors' contributions

BSS: data sampling, data analyses, writing. NH: study design, writing, editing, supervision. FGDJ: study design, editing. MC: study conception and design, data analyses, writing and editing, supervision. The manuscript was approved by all authors.

Ethics approval

This study was approved by the ethics committee at Universidade Federal de Santa Catarina, Brazil (CEPSH 06457419.6.0000.0121). All personal data were anonymized.

Consent to participate

All people interviewed signed a free informed consent to participate in this research, and were interviewed individually.

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SUPPLEMENTARY MATERIAL

Social foraging can benefit artisanal fishers who fish with wild dolphins

Bruna Santos-Silva, Natalia Hanazaki, Fábio G. Daura-Jorge, Mauricio Cantor*

Supplementary Methods

S1: Study area

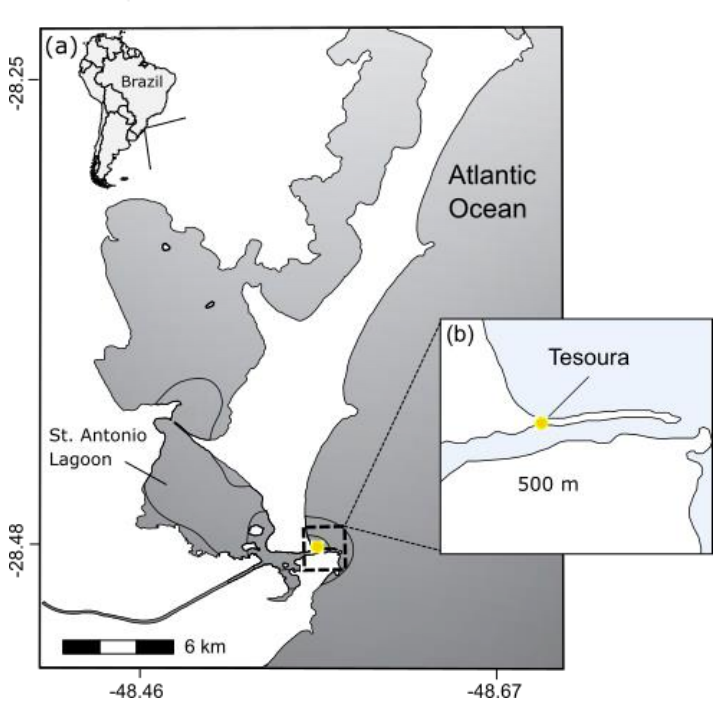

Fig. S1. (A) The complex lagoon system, Santo Antônio-Imaruí-Mirim in Laguna, southern Brazil. (B) The inlet channel, the yellow circle indicates where interviews were carried out.

S2: Questionnaire

Date:

Name:

Age: _____

Where you live (city / neighborhood):

Are you a native of Laguna? ( ) Yes ( ) No

Residence time: _____ (Years)

I) SOCIO-ECONOMIC ASPECTS

1) Is artisanal fishing your main economic activity?

( ) Yes ( ) No, which one?

2) Since when do you fish? _____ (Years)

3) Was your father a fisher?

( ) Yes ( ) in Laguna ( ) Other_____

( ) No

4) Do you have children; are them fishers?

( ) Yes ( ) in Laguna ( ) Another city: _____

( ) No ( ) Has no children

5) Do you have any relationship with another fisher who interact with dolphins?

( ) Yes, which one? _____ Name: _____

( ) No

II) FISHING DYNAMICS

1) How often do you fish with dolphins during the year?

( ) Always - 12 months / Year ( ) Sometimes - 6 months / Year ( ) Rarely - 3 months / Year

2) How often do you fish with dolphins during the mullet season?

( ) Always 5-7 days / week ( ) Sometimes 3-4 days / week ( ) Rarely 1-2 days / week

3) Since when do you fish with dolphins? _____(Years)

4) Who have taught you to fish with dolphins? How was the learning experience?

5) Do you fish (with dolphins or not) elsewhere? ( ) No; ( ) Yes, where/which other interaction sites?

6) Do you teach the technique of fishing with dolphins to new fishers or close relatives?

( ) Yes - New fishers ( ) Yes - Family members; how related are you to them? ( ) Yes - Both

( ) No If not, why you do not teach?

7) Are there fishers who are good at fishing with dolphins and others who are not?
( ) Yes ( ) No ( ) Don't know

8) Are there fishers who are known for their success/skills in fishing with dolphins?
( ) Yes, which one? _____ (Name / Surname)
( ) No ( ) Don't know

9) Are there better specific spots to fish with dolphins (at this interaction site)?
( ) No ( ) Don't know
( ) Yes - Do you dispute or share this spot?

10) Is there any kind of cooperation between you and any other fisher? If so, how does it occur?

11) Do you believe that cooperating will bring any benefits?
( ) Yes, which one?
( ) No ( ) Don't know

12) Do you prefer to cooperate with local and more experienced fisher than with new and inexperienced fisher?
( ) Yes, which one?
( ) No ( ) Does not cooperate

13) Do you prefer to cooperate with family members / relatives?
( ) Yes ( ) No ( ) No, there are family members who fish with dolphins

14) Who are your friends in this fishing site?

Supplementary Results

S3: Significance of the modularity

We use a null model to test the significance of the observed modularity of the giant component of cooperative fishers. We calculated modularity for all the 2,000 theoretical networks to build a

benchmark distribution. The modularity was considered significant when outside of the 95% confidence interval of the benchmark distribution (Fig. S2).

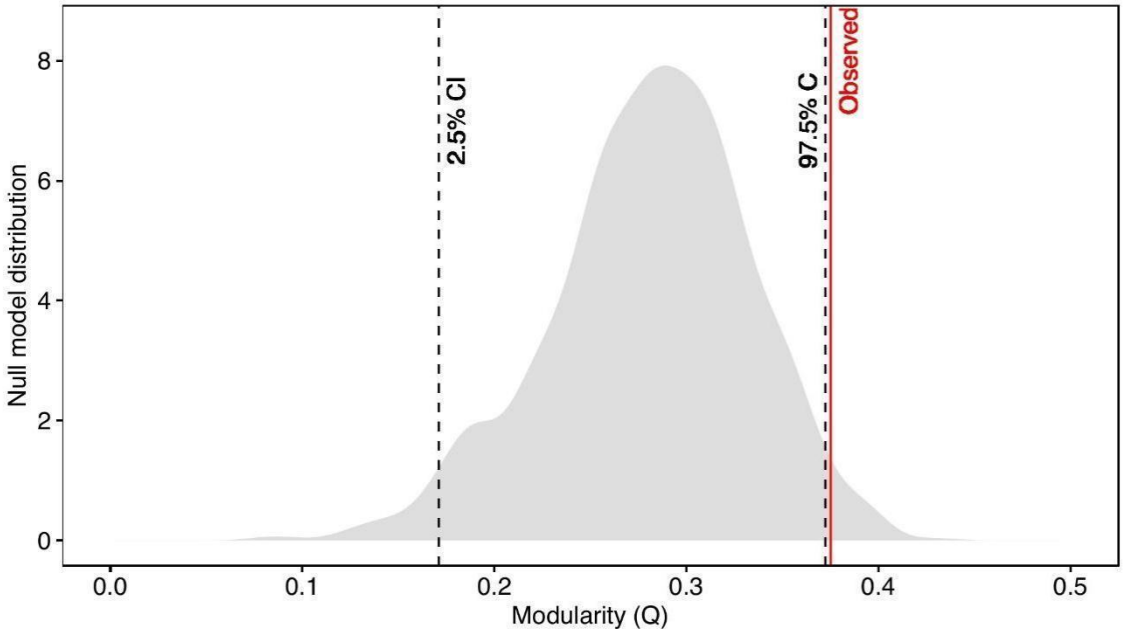

Figure S2. Benchmark distribution of the modularity of the giant component of the fishers' social network. The empirical modularity (red line) is outside of the 95% confidence interval (black lines) of the distribution generated by the null model (grey shade).

S4: Influence of individual traits on fishing strategies

a) Correlation

We investigated whether individual traits could explain the structure of the fishers' social network with individual traits of the fishers. For this, we analysed the correlations between the cooperative ties and the raw data on the individual traits (Fig. S3).

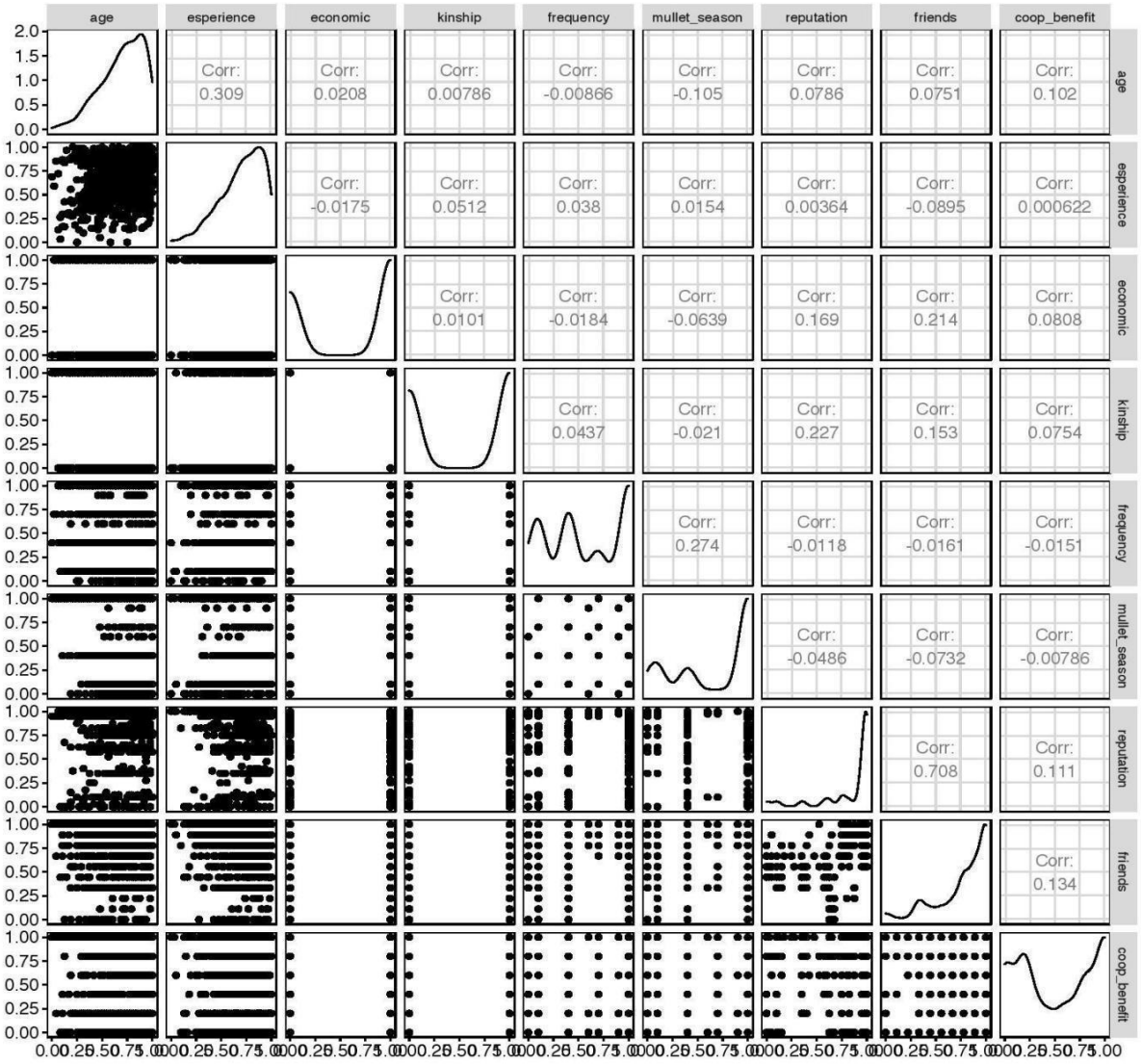

Figure S3. The correlation between the raw data of individual traits (age, experience, economic dependence, frequency of fishing with dolphins, reputation, number of friends and perceived benefits from the cooperation) and the cooperative ties. Reputation rank and the number of friends were highly correlated (r = 0.77) and a moderate correlation between age and experience (r= 0.54).

a) Assortativity

We calculated the continuous and discrete assortative indices (Farine, 2014) to test if there was a tendency for similar nodes to be connected (Newman, 2006). The indices vary from -1 for complete dissasortment to 1 for a perfect assortment.

Table S1. The assortment of the fishers' social network around each of the measured individual traits. Assortativity indices range from [-1, 1], where positive values indicate assortment, and negative values indicate disassortment of the network around a given trait. Standard errors were estimated using jackknife resampling.

Traits	Assortativity	Standard Error
Age	-0.043	0.106
Experience	-0.079	0.106
Kinship	0.130	0.104
Economic dependence	0.145	0.103
Annual frequency	-0.067	0.103
Seasonal frequency	0.498	0.110
Reputation	0.068	0.099
Friendship	0.404	0.074
Perceived benefits	-0.120	0.096

b) Generalized Linear Model with Quadratic Assignment Procedure (GLMQAP)

We used the generalized version of the multiple regression quadratic assignment procedure (Franks et al. 2020) with double-semi-partialling (Dekker et al., 2007) to estimate the influence of each individual trait on the structure of the fishers' social network while controlling for the effects of all the other traits. We selected the most parsimonious model by the lowest AIC (Burnhan; Anderson, 2002) (Table S2). We explored the significant traits individually with Mantel tests (Table S3).

Table S2. Candidate binomial Generalized Linear Models with Quadratic Assignment Procedure (GLMQAP) for the structure of the cooperative ties among artisanal fishers in function of similarity in nine individual traits, ranked by the lowest Akaike's information criterion (AIC). The difference (ΔAIC) and weight of AIC indicate relative support for the models.

GLMQAP	parameters	AIC	ΔAIC	AIC weight
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency	3	301.39	0.00	1.00
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency + annual fishing frequency + age + fishing experience + kinship + economic dependence + number of friends	9	301.42	0.03	0.99
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency + annual fishing frequency	4	303.39	2.00	0.37
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency + annual fishing frequency + economic dependence	5	305.39	4.00	0.14
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency + annual fishing frequency + age + fishing experience + kinship + economic dependence	8	305.48	4.09	0.13
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency + annual fishing frequency + age + kinship + economic dependence	7	306.17	4.78	0.09
Fishers' social network ~ peer reputation + perceive cooperation benefit + seasonal fishing frequency + annual fishing frequency + kinship + economic dependence	6	306.83	5.44	0.07

Table S3. Mantel tests for the correlation between the structure of the cooperative ties among artisanal fishers in function of the similarity of the three individual traits that were significant in the binomial Generalized Linear Models with Quadratic Assignment Procedure (GLMQAP).

	correlation	P-value	Standard Observation	Expectation	Variance
Peer reputation	-0.157	0.997	-2.951	0.001	0.003
Perceived benefit of cooperating	0.167	0.001	5.879	0.000	0.001
Seasonal frequency of fishing with dolphins	0.148	0.002	4.627	0.000	0.001

We explore the variation of the significant traits of the GLMQAP (peer reputation, frequency of fishing during the mullet season, and perceived benefit of cooperating) between the two foraging tactics: cooperative and non-cooperative. (Figure S4).

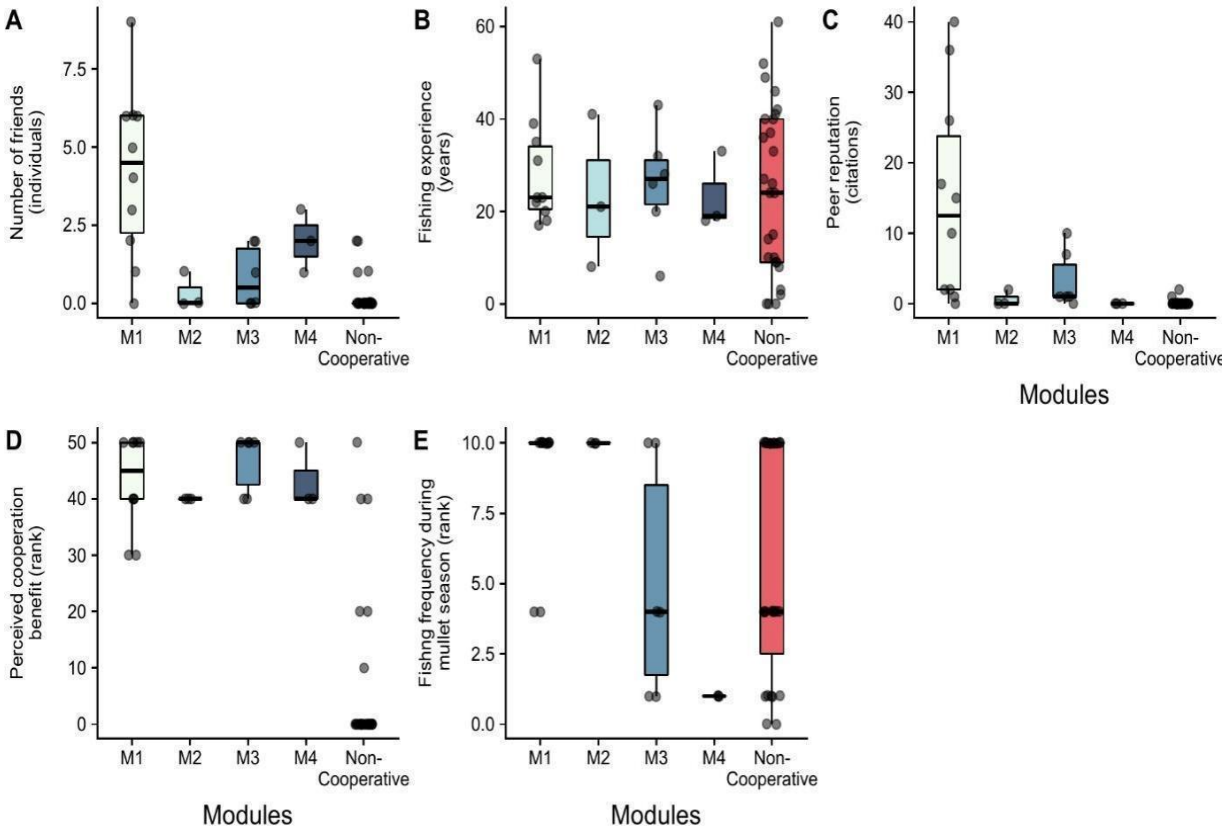

Fig. S4.Variation of the significant traits of the GLMQAP between cooperative and non-cooperative fishers. Each point (n = 49) is an interviewed fisher.

Supplementary References

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5 CONSIDERAÇÕES FINAIS

O modelo conceitual de sistemas socioecológicos mostrou-se útil para descrever a diversidade e dinamismo dos componentes do sistema de pesca artesanal com os botos. Este sistema provê benefícios materiais e não-materiais para os pescadores de Laguna e adjacências, mas processos participativos que reúnam os usuários do sistema (pescadores locais, amadores e oportunistas) parecem ser necessários para reduzir conflitos e promover um ambiente que mantenha tais benefícios. Dado que comportamento cooperativo pode gerar diferentes benefícios aos pescadores, torna-se importante compreender como a manutenção de tal comportamento influencia na manutenção deste sistema socioecológico.

No primeiro capítulo, observei que a dependência econômica da pesca artesanal vem diminuindo ao longo dos últimos 16 anos entre os pescadores e há aumento dos pescadores amadores e oportunistas nesta atividade nos últimos anos, principalmente no ponto de pesca mais acessível (Tesoura). Embora a dependência pelo recurso pescado pareça diminuir entre os pescadores, a continuidade do uso do sistema pesqueiro com botos pode ser mantida devido ao aumento de pescadores que utilizam esse sistema socioecológico como um espaço de recreação, socialização e lazer. Porém, esse aumento observado na Tesoura está relacionado ao seu fácil acesso e atrativo turístico, diferente dos outros pontos mais internos da lagoa onde não parece ocorrer um aumento no número de novos pescadores.

A fidelidade dos pescadores aos locais de pesca específicos pode estar associada com as mudanças nos atributos socioeconômicos e na transmissão do conhecimento ecológico sobre o sistema. Nos pontos mais internos da lagoa onde o acesso é mais restrito a pescadores profissionais, a transmissão oblíqua e vertical se manteve ao longo dos anos. Nesses locais, os pescadores mais novos tendem a aprender com os mais velhos, e a transmissão vertical do conhecimento técnico e ecológico desta prática de pesca (isto é, de pais para filhos) parece manter-se ativa. Já na Tesoura, a transmissão do conhecimento ecológico ocorre principalmente de forma horizontal e oblíqua, observando outros pescadores, aparentados ou não. Entender a eficácia desse conhecimento no sistema se faz necessário, já que o aprendizado social apenas por observação e cópia pode não ser tão eficiente quanto aprender as táticas com pescadores mais experientes de outras gerações ou familiares.

Devido ao seu reconhecimento e fácil acesso, os pescadores da Tesoura são aqueles que conduzem ações associadas à pesca tradicional com os botos (entrevistas a jornais,

participação em pesquisas, ações voltadas à educação ambiental etc.). Por outro lado, os pescadores que dependem da pesca artesanal, que não pescam ou pararam de pescar na Tesoura devido à competição e ao grande número de pescadores amadores e oportunistas na área, possuem menos oportunidades de serem incluídos nessas ações. Especulo que esse aumento de pescadores oportunistas e amadores no local de pesca da Tesoura poderia impactar social e economicamente os pescadores locais que dependem da atividade. É importante considerar que, para além das mudanças socioeconômicas e ambientais, este seja mais um processo que leve os pescadores locais a abandonarem a profissão, e consequentemente, diminuindo sua dependência ao recurso pescado. O aumento do turismo em Laguna pode ter contribuído para desencadear uma série de ações para proteger essa tradição pesqueira e mais envolvimento das instituições governamentais; porém, é necessário que a comunidade local de pescadores mais dependentes economicamente dessa atividade tenha seus espaços assegurados nessas ações.

No segundo capítulo, mostro que a rede social dos pescadores artesanais que interagem com os botos na Tesoura é estruturada tanto por forrageio cooperativo quanto solitário, e que a formação de grupos cooperativos pode ser benéfica em termos materiais e não-materiais. As características individuais desempenham um papel pequeno, mas relevante, na decisão dos pescadores de forragear em grupos. A maioria dos pescadores cooperativos não dependem exclusivamente desta atividade e, para além dos benefícios materiais, como ganhos energéticos e monetários, esses pescadores também buscam por benefícios não materiais, como recreação, relações sociais, valores intrínsecos e um sentimento de pertencimento. Em anos de pesca altamente produtivos podem garantir o retorno material (peixe ou dinheiro), mantendo assim a persistência desta pesca tradicional e dos laços cooperativos entre os pescadores. Caso a disponibilidade de tainha diminua ao longo dos próximos anos, os laços cooperativos entre os pescadores podem ser substituídos por interações competitivas devido à escassez de recurso pesqueiro. Porém, caso os valores não-materiais dessas relações sociais superarem os retornos monetários ou energético, espera-se que a cooperação entre os pescadores continue. Uma possível mudança neste cenário é a pesca tradicional com os botos ficar restrita aos pescadores amadores e oportunistas, excluindo assim os pescadores que dependem desta pesca. Essas mudanças na composição da comunidade pesqueira que interage com os botos podem ter implicações na transmissão deste conhecimento tradicional bem como para a persistência desta tradição nas próximas gerações de botos e pescadores.